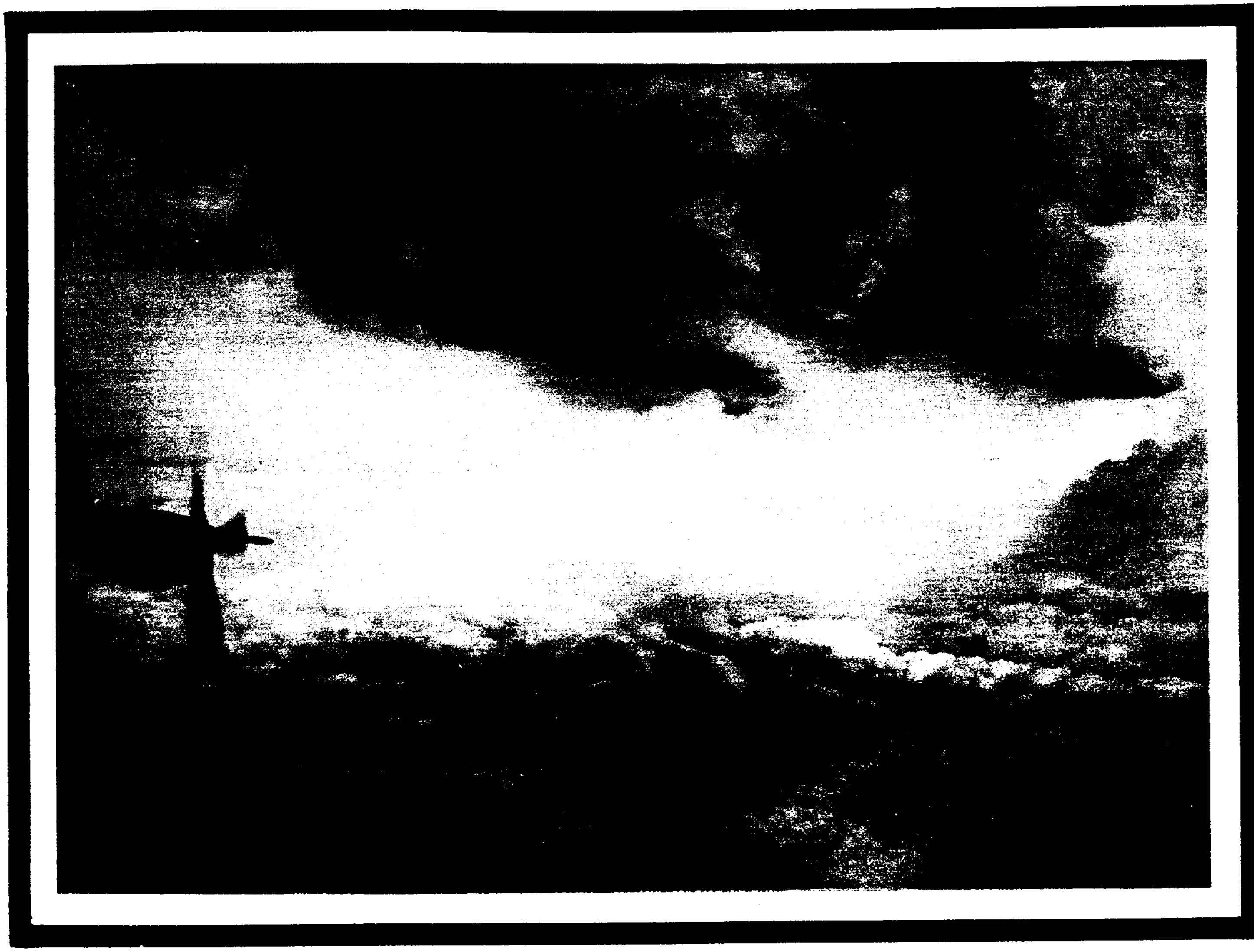
1986 ANNUAL TROPICAL CYCLONE REPORT



JOINT TYPHOON WARNING CENTER
GUAM, MARIANA ISLANDS

FRONT COVER: In the foreground gray cyclonic spirals of stratocumulus, as seen from the 54th Weather Reconnaissance Squadron WC-130 aircraft, define the eye of Typhoon Carmen (15W). The brighter patches in the mid-ground of the picture are more reflective water droplet clouds in the eye wall, which contrast with the other darker cloud debris and cirrus aloft. The previous day Carmen (15W) passed just 50 nm (93 km) north of the island of Guam. At picture time, 042355Z October 1986, the aircraft reconnaissance mission (AF966 0715 CARMEN) located the eye over the Philippine Sea 375 nm (695 km) northwest of Guam (Photo courtesy of Detachment 3, lst Weather Wing and photographer Susan K. Watters, Captain, USAF).

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FOREWORD

The Annual Tropical Cyclone Report is prepared by the staff of the Joint Typhoon Warning Center (JTWC), a combined USAF/USN organization operating under the command of the Commanding Officer, U.S. Naval Oceanography Command Center/Joint Typhoon Warning Center, Guam. JTWC was established in April 1959 when USCINCPAC directed USCINCPACFLT to provide a single tropical cyclone warning center for the western North Pacific region. The operations of JTWC are guided by CINCPACINST 3140.1 (series).

The mission of the Joint Typhoon Warning Center is multi-faceted and includes:

1. Continuous monitoring of all tropical weather activity in the northern and southern hemispheres, from 180 degrees longitude westward to the east coast of Africa, and the prompt issuance of appropriate advisories and alerts when tropical cyclone development is anticipated.

2. Issuing warnings on all significant tropical cyclones in the above area of responsibility.

3. Determination of reconnaissance requirements for tropical cyclone surveillance and assignment of appropriate priorities.

4. Post-storm analysis of all significant tropical cyclones occurring within the western North Pacific and North Indian Oceans, which includes an in-depth analysis of tropical cyclones of note and all typhoons.

5. Cooperation with the Naval Environmental Prediction Research Facility, Monterey, California, on the operational evaluation of tropical cyclone models and forecast aids, and the development of new techniques to support operational forecast scenarios.

Satellite imagery used throughout this report represents data obtained by the tropical cyclone satellite surveillance network. The personnel of Detachment 1, 1WW, collocated with JTWC at Nimitz Hill, Guam, coordinate the satellite acquisitions and tropical cyclone surveillance with the following units:

Det 4, 20WS, Hickam AFB, Hawaii

Det 5, 20WS, Clark AB, RP

Det 8, 20WS, Kadena AB, Japan

Det 15, 30WS, Osan AB, Korea

Air Force Global Weather Central, Offutt AFB, Nebraska

In addition, the Naval Oceanography Command Detachment, Diego Garcia, and DMSP equipped U.S. Navy aircraft carriers have been instrumental in providing vital satellite position fixes of tropical cyclones in the Indian Ocean.

Should JTWC become incapacitated, the Alternate Joint Typhoon Warning Center (AJTWC) located at the U.S. Naval Western Oceanography Center, Pearl Harbor, Hawaii, assumes warning responsibilities. Assistance in determining satellite reconnaissance requirements, and in obtaining the resultant data, is provided by Det 4, 20WS Hickam AFB, Hawaii.

Changes to this year's publication include: raw fix data files usually printed in Annex A, plus the raw warning, forecast and best track data, will be available, upon request (the requested data will be copied onto 5.25 inch "floppy" diskettes provided by the requestor); statistical verification for individual warnings for the North Indian Ocean and all warnings in the southern hemisphere are not provided; and, with reference to best track philosophy, a conscious effort has been made to extend the post-warning best tracks to provide better verification for the 48- and 72-hour forecasts (this has produced a larger sample and slightly higher errors for the extended forecasts).

A special thanks is extended to the men and women of: 27th Information Systems Squadron, Operating Location C, for their continuing support by providing high quality real-time satellite imagery; the Pacific Fleet Audio-Visual Center, Guam for their assistance in the reproduction of satellite and graphics data for this report; to the Navy Publications and Printing Service Branch Office, Guam; the Royal Observatory Hong Kong and Central Weather Bureau, Taiwan for radar scope photographs of tropical cyclones; Mr. Ron Miller of NEPRF, for his able assistance in data reduction, and Captain S. K. Watters (USAF) for the cover photograph.

Note: Appendix IV contains information on how to obtain past issues of the Annual Tropical Cyclone Report (titled Annual Typhoon Report prior to 1980).

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CONTRACTIONS

ABS MAG	Absolute Magnitude
ACCRY	Accuracy
ACFT	Aircraft
ADP	Automated Data Processing
AFGWC	Air Force Global Weather Central
AIREP	Aircraft Weather Report(s) (Commercial and Military)
ANT	Antenna
AOR	Area of Responsibility
APRNT	Apparent
APT	Automatic Picture Transmission
ARWO	Aerial Reconnaissance Weather Officer
ATT	Attenuated
AVG	Average
AWN	Automated Weather Network
BPAC	Blended Persistence and Climatology
BRG	Bearing
BT LAT	Best Track Latitude
BT LON	Best Track Longitude
BT WN	Best Track Wind
CDO	Central Dense Overcast
CI	Cirriform Cloud or Cirrus also Current Intensity (Dvorak)
CINCPAC	Commander-in-Chief Pacific AF - Air Force, FLT - Fleet (Navy)
CLD	Cloud
CLIM	Climatology
CLSD	Closed
CM	Centimeter
CNTR	Center
CPA	Closest Point to Approach
CSC	Cloud System Center
CYCLOPS	Tropical Cyclone Steering Program (HATTRACK and MOHATT)
DEG	Degree
DIAM	Diameter
DIR	Direction
DMSP	Defense Meterological Satellite Program
DST	Distance
DTG	Date Time Group
EL	Elongated
ELEV	Elevation
EXP	Exposed
FI	Forecast Intensity (Dvorak)
FLT	Flight
FNOC	Fleet Numerical Oceanography Center
FT	Feet
GMT	Greenwich Mean Time
GOES	Geostationary Operational Environmental Satellite
HATRACK	Hurricane and Typhoon Tracking Steering Program
HGT	Height
HPAC	Mean of XTRP and CLIM Techniques (Half Persistence and Climatology)
HR(S)	Hour(s)
HVY	Heavy
ICAO	International Civil Aviation Organization
INIT	Initial
INJAH	North Indian Ocean Component
INST	Instruction
IR	Infrared
KM	Kilometer(s)
KT	Knot(s)
LLCC	Low-Level Circulation Center
LVL	Level
M	Meter(s)
M/S	Meter(s) per Second
MAX	Maximum
MB	Millibar(s)
MET	Meteorological
MIN	Minimum
MOHATT	Modified HATTRACK
MOVG	Moving
MSLP	Minimum Sea-level Pressure
MSN	Mission
NAV	Navigational
NEDN	Naval Environmental Data Network
NEDS	Naval Environmental Display Station

NEPRF	Naval Environmental Prediction Research Facility
NESDIS	National Environmental Satellite, Data, and Information Service
NET	Near Equatorial Trough
NM	Nautical Mile(s)
N/O	Not Observed
NOAA	National Oceanic and Atmospheric Administration
NOCC	Naval Oceanography Command Center
NOGAPS	Navy Operational Global Atmospheric Prediction System
NTCM	Nested Tropical Cyclone Model
NWOC	Naval Western Oceanography Center
NR	Number
NRL	Naval Research Laboratory
OBS	Observations
OTCM	One Way (Interactive) Tropical Cyclone Model
PACOM	Pacific Command
PCN	Position Code Number
POS ER	Position Error
PSBL	Possible
PTLY	Partly
QUAD	Quadrant
RADOB	Radar Observation
RECON	Reconnaissance
RNG	Range
RT	Right
SAT	Satellite
SFC	Surface
SLP	Sea-Level Pressure
SRP	Selective Reconnaissance Program
STNRY	Stationary
SST	Sea Surface Temperature
ST	Subtropical
STR	Subtropical Ridge
STY	Super Typhoon
TAPT	Typhoon Acceleration Prediction Technique
TC	Tropical Cyclone
TCARC	Tropical Cyclone Aircraft Reconnaissance Coordinator
TCFA	Tropical Cyclone Formation Alert
TCM	Tropical Cyclone Model
TD	Tropical Depression
TDO	Typhoon Duty Officer
TIROS	Television Infrared Observational Satellite
TPAC	Extrapolation and Climatology Blend
TS	Tropical Storm
TY	Typhoon
TYAN	Typhoon Analog Program
TYFN	Western North Pacific Component (Revised) of TYAN
TUTT	Tropical Upper-Tropospheric Trough
ULAC	Upper-Level Anticyclone
ULCC	Upper-Level Circulation Center
VEL	Velocity
VIS	Visual
VMNT	Vector Movement (ddff)
WESTPAC	Western (North) Pacific
WMO	World Meteorology Organization
WND	Wind
WRNG(S)	Warning(s)
WRS	Weather Reconnaissance Squadron
WW ER	Wind Warning Error
W#	Warning Number
XTRP	Extrapolation
Z	Zulu Time (Greenwich Mean Time)
24 ER	24-Hour (Position) Error
48 ER	48-Hour (Position) Error
72 ER	72-Hour (Position) Error
24 WE	24-Hour Wind (Warning) Error
48 WE	48-Hour Wind (Warning) Error
72 WE	72-Hour Wind (warning) Error

CHAPTER I - OPERATIONAL PROCEDURES

1. GENERAL

The Joint Typhoon Warning Center (JTWC) provides a variety of routine services to the organizations within its area of responsibility, including:

a. Significant Tropical Weather Advisories: issued daily, these products describe all tropical disturbances and assess their potential for further development during the advisory period;

b. Tropical Cyclone Formation Alerts: issued when synoptic, satellite and/or aircraft reconnaissance data indicate development of a significant tropical cyclone in a specified area is likely;

c. Tropical Cyclone Warnings: issued periodically throughout each day for significant tropical cyclones, giving forecasts of position and intensity of the system; and

d. Prognostic Reasoning Messages: issued twice daily for tropical storms and typhoons in the western North Pacific; these messages discuss the rationale behind the most recent JTWC warnings.

The recipients of the services of JTWC essentially determine the content of JTWC's products according to their ever changing requirements. Therefore, the spectrum of routine services is subject to change from year to year. Such changes are usually the result of deliberations held at the Annual Tropical Cyclone Conference.

2. DATA SOURCES

a. COMPUTER PRODUCTS:

A standard array of synoptic-scale computer analyses and prognostic charts are available from the Fleet Numerical Oceanography Center (FLENUMOCEANCEN) at Monterey, California. These products are provided to JTWC via the Naval Environmental Data Network (NEDN).

b. CONVENTIONAL DATA:

This data set is comprised of land-based and shipboard surface and upper-air observations taken at, or near, synoptic times, cloud-motion winds derived twice daily from satellite data, and enroute meteorological observations from commercial and military aircraft (AIREPS) within six hours of synoptic times. Conventional data charts are prepared daily at 0000Z and 1200Z using computer- and hand-plotted data for the surface/gradient and 200 mb (upper-tropospheric) levels. In addition to these analyses, charts at the 925, 850, 700, 500 and 400 mb levels are computer-plotted from rawinsonde/pibal observations at the 12-hour synoptic times.

c. AIRCRAFT RECONNAISSANCE:

Data provided by aircraft weather reconnaissance are invaluable for locating the position of the center of developing systems and essential for the accurate determination of:

- maximum surface and flight-level wind
- minimum sea-level pressure
- horizontal surface and flight-level wind distribution
- eye/center temperature and dew point

In addition, wind and pressure-height data at the 500 and/or 400 mb levels, provided by the aircraft while enroute to, or from fix missions, or during dedicated synoptic-scale flights, provide a valuable supplement to the all too sparse data fields of JTWC's area of responsibility. A more detailed discussion of aircraft weather reconnaissance is presented in Chapter II.

d. SATELLITE RECONNAISSANCE:

Meteorological satellite data obtained from the Defense Meteorological Satellite Program (DMSP) and National Oceanic and Atmospheric Administration (NOAA) spacecraft played a major role in the early detection and tracking of tropical cyclones in 1986. A discussion of the role of these programs is presented in Chapter II.

e. RADAR RECONNAISSANCE:

During 1986, as in previous years, land-based radar coverage was utilized extensively when available. Once a tropical cyclone moved within the range of land-based radar sites, their reports were essential for determination of small-scale movement. Use of radar reports during 1986 is discussed in Chapter II.

3. COMMUNICATIONS

a. JTWC currently has access to three primary communications circuits.

(1) The Automated Digital Network (AUTODIN) is used for dissemination of warnings, alerts and other related bulletins to Department of Defense installations. These messages are relayed for further transmission over U.S. Navy Fleet Broadcasts, and U.S. Coast Guard CW (continuous wave Morse Code) and voice broadcasts. Inbound message traffic for JTWC is received via AUTODIN addressed to NAVOCEANCOMCEN GQ or DET 1 1WW NIMITZ HILL GQ.

(2) The Air Force Automated Weather Network (AWN) provides weather data to JTWC through a dedicated circuit from the Automated Digital Weather Switch (ADWS) at Hickam AFB, Hawaii. The ADWS selects and routes the large volume meteorological reports necessary to satisfy JTWC requirements for the right data at the right time. Weather bulletins prepared by JTWC are inserted into the AWN circuit via the Naval Environmental Display Station (NEDS) through the Nimitz Hill Naval Telecommunications Center (NTCC) of the Naval Communications Area Master Station Western Pacific.

(3) The Naval Environmental Data Network (NEDN) is the communications link with the computers at FLENUMOCEANCEN. JTWC is able to receive environmental data from FLENUMOCEANCEN and provide data directly to the computers to execute numerical techniques.

b. NEDS has been the backbone of the JTWC communications system for several years. Currently, JTWC is undergoing an upgrade that will make use of microcomputer technology and automate much of the work that goes into message preparation and transmission. This will decrease the workload on the NEDS and allow JTWC to interface directly with NTCC for AWN and AUTODIN messages.

4. ANALYSES

A composite surface/gradient level (3000 ft (914 m)) manual analysis of the JTWC area of responsibility is accomplished on the 0000Z and 1200Z conventional data. Analysis of the wind field using streamlines is stressed for tropical and subtropical regions. Analysis of the pressure field outside the tropics is accomplished routinely by the Naval Oceanography Command Center Operations watch team and is used by JTWC in conjunction with their analysis of the tropical wind fields.

A composite upper-tropospheric manual streamline analysis is accomplished daily utilizing rawinsonde data from 300 mb through 100 mb, winds obtained from satellite-derived cloud motion analysis, and AIREPS (taken plus or minus six hours of chart valid time) at or above 29,000 feet (8,839m). Wind and height data are used to generate a representative analysis of tropical cyclone outflow patterns, mid-latitude steering currents, and features that may influence tropical cyclone intensity. All charts are hand-plotted in the tropics to provide all available data as soon as possible to the Typhoon Duty Officer (TDO). These charts are augmented by computer-plotted charts for the final analysis.

Computer-plotted charts for the 925, 850, 700, 500 and 400 mb levels are available for streamline and/or height-change analysis from the 0000Z and 1200Z data base. Additional sectional charts at intermediate synoptic times and auxiliary charts, such as station-time plot diagrams and pressure-change charts, are also analyzed during periods of significant tropical cyclone activity.

5. FORECAST AIDS

The following objective techniques were employed in tropical cyclone forecasting during 1986 (a description of these techniques is presented in Chapter V):

a. MOVEMENT

(1) 12-HOUR EXTRAPOLATION

(2) CLIMATOLOGY

(3) COSMOS (Model Output Statistics)

(4) NTCM (Nested Grid Dynamic Model)

(5) OTCM (Dynamic Model)

(6) TAPT (Empirical)

(7) TPAC (Extrapolation and Climatology Blend)

(8) TYAN78 (Analog)

b. INTENSITY

(1) CLIMATOLOGY

(2) DVORAK (Empirical)

(3) THETA E (Empirical)

c. WIND RADIUS

6. FORECAST PROCEDURES

a. INITIAL POSITIONING

The warning position is the best estimate of the center of the surface circulation at synoptic time. It is estimated from an analysis of all fix information received up to one and one-half hours after synoptic time. This analysis is based on a semi-objective weighting of fix information based on the historical accuracy of the fix platform and the meteorological features used for the fix. The interpolated warning position reduces the weighting of any single fix and results in a more consistent movement and a warning position that is more representative of the larger-scale circulation. If the fix data are not available due to reconnaissance platform malfunction or communication problems, synoptic data or extrapolation from previous fixes are used.

b. TRACK FORECASTING

A preliminary forecast track is developed based on an evaluation of the rationale behind the previous warning and the guidance given by the most recent set of objective techniques and numerical prognoses. This preliminary track is then subjectively modified based on the following considerations:

(1) The prospects for recurvature or erratic movement are evaluated. This determination is based primarily on the present and forecast positions and amplitudes of the middle-tropospheric, mid-latitude troughs and ridges as depicted on the latest upper-air analysis and numerical forecasts.

(2) Determination of the best steering level is partly influenced by the maturity and vertical extent of the tropical cyclone. For mature tropical cyclones located south of the subtropical ridge axis, forecast changes in speed of movement are closely correlated with anticipated changes in the intensity or relative position of the ridge. When steering currents are relatively weak, the tendency for tropical cyclones to move northward due to internal forces is an important consideration.

(3) Over the 12- to 72-hour (12- to 48-hour in the southern hemisphere) forecast period, speed of movement during the early forecast period is usually biased towards persistence, while the later forecast periods are biased towards objective techniques. When a tropical cyclone moves poleward, and toward the mid-latitude steering currents, speed of movement becomes increasingly more biased toward a selective group of objective techniques capable of estimating acceleration.

(4) The proximity of the tropical cyclone to other tropical cyclones is closely evaluated to determine if there is a possibility of binary interaction.

A final check is made against climatology to determine whether the forecast track is reasonable. If the forecast deviates greatly from one of the climatological tracks, the forecast rationale may be reappraised.

c. INTENSITY FORECASTING

For this parameter, heavy reliance is placed on intensity trends from aircraft reconnaissance reports, wind and pressure data from ships and land stations in the vicinity of the tropical cyclone, the Dvorak satellite empirical model and climatology. An evaluation of the entire synoptic situation is made, including the location of major troughs and ridges, the position and intensity of any nearby tropical upper-tropospheric troughs (TUTTs), the vertical and horizontal extent of the tropical cyclone's circulation and the extent of the associated upper-level outflow pattern. An essential element affecting each intensity forecast is the accompanying forecast track and the environmental influences along that track, such as terrain, vertical wind shear, and the existence of an extratropical environment.

Once the forecast intensities have been derived, the horizontal distribution of surface winds (winds greater than 30-, 50-, and 100-knots) is determined. The most recent wind radii and associated asymmetrics are deduced from all available surface wind observations and reconnaissance aircraft reports. Based on the current surface wind distribution, preliminary estimates of future wind radii are provided by an empirically derived objective technique. These estimates may be subjectively modified based upon the anticipated interaction of the tropical cyclone's circulation with forecast locations of large-scale wind regimes and significant land masses. Other factors including the tropical cyclone's speed of movement and possible extratropical transition are also considered.

7. WARNINGS

Tropical cyclone warnings are issued when a closed circulation is evident and maximum sustained winds are forecast to increase to 34 knots (18 meters per second) within 48 hours, or if the tropical cyclone is in such a position that life or property may be endangered within 72 hours. Warnings may also be issued in other situations if it is determined that there is a need to alert military or civil interests to threatening tropical weather conditions.

Each tropical cyclone warning is numbered sequentially and includes the following information: the position of the surface center; estimate of the position accuracy and the supporting reconnaissance (fix) platforms; the direction and speed of movement during the past six hours (past 12-hours in the southern hemisphere); the intensity and radial extent of over 30-, 50-, and 100-knot surface winds, when applicable. At forecast intervals of 12-, 24-, 48-, and 72-hours (12-, 24-, and 48-hours in the southern hemisphere), information on the tropical cyclone's anticipated position, intensity and wind radii are also provided. Vectors indicating the mean direction and mean speed between forecast positions are also included in all warnings.

Warnings in the western North Pacific and North Indian Oceans are issued every six hours valid at standard times; 0000Z, 0600Z, 1200Z and 1800Z (every 12-hours; 0000Z, 1200Z or 0600Z, 1800Z in the southern hemisphere). All warnings are released to the communications network no earlier than synoptic time and no later than synoptic time plus two and one-half hours so that recipients will have a reasonable expectation of having all warnings "in hand" by synoptic time plus three hours (0300Z, 0900Z, 1500Z and 2100Z).

Warning forecast positions are later verified against the corresponding "best track" positions (obtained during detailed post-storm analysis to determine the actual path and intensity of the cyclone). A summary of the verification results for 1986 for the North Indian and western North Pacific Ocean is present in Chapter V.

8. PROGNOSTIC REASONING MESSAGES

For tropical storms and typhoons in the western North Pacific Ocean, prognostic reasoning messages are transmitted following the 0000Z and 1200Z warnings, or whenever the previous forecast reasoning is no longer valid. This plain language message is intended to provide meteorologists with the reasoning behind the latest forecast.

In addition to this message, prognostic reasoning information applicable to all customers is provided in the remarks section of warnings when significant forecast changes are made or when deemed appropriate by the TDO.

9. TROPICAL CYCLONE FORMATION ALERT

Tropical Cyclone Formation Alerts (TCFAs) are issued whenever interpretation of satellite imagery and other meteorological data indicate that the formation of a significant tropical cyclone is likely. These formation alerts will specify a valid period not to exceed twenty-four hours and must either be cancelled, reissued, or superseded by a tropical cyclone warning prior to the expiration of the valid time.

10. SIGNIFICANT TROPICAL WEATHER ADVISORY

This product contains a general, non-technical description of all tropical disturbances in JTWC's area of responsibility (AOR) and an assessment of their potential for further (tropical cyclone) development. In addition, all tropical cyclones in warning status are briefly discussed. Two separate messages are issued daily and are valid for a 24-hour period. The Significant Tropical Weather Advisory for the western Pacific Ocean (ABPW PGTW) covers the area east of 100 degrees East Longitude to the dateline and is issued by 0600Z. The Significant Tropical Weather Advisory for the Indian Ocean (ABIO PGTW) covers the area west of 100 degrees East Longitude to the coast of Africa and is issued by 1800Z. It is reissued whenever the situation warrants. For each suspect area, the words "poor", "fair", and "good" are used to describe the potential for further development. "Poor" is used to describe a tropical disturbance that is not expected to require a TCFA during the advisory period; "fair" is used to describe a tropical disturbance that is currently not covered by a TCFA, but for which it is likely that a TCFA will be issued during the advisory period; and "good" is used when the tropical disturbance is covered by a TCFA.

CHAPTER II - RECONNAISSANCE AND FIXES

1. GENERAL

The Joint Typhoon Warning Center depends on reconnaissance to provide necessary, accurate, and timely meteorological information in support of each warning. JTWC relies primarily on three reconnaissance platforms: aircraft, satellite, and radar. In data rich areas, synoptic data are also used to supplement the above. Optimum utilization of all available reconnaissance resources is obtained through the Selective Reconnaissance Program (SRP); various factors are considered in selecting a specific reconnaissance platform including capabilities and limitations, and the tropical cyclone's threat to life and property both afloat and ashore. A summary of reconnaissance fixes received during 1985 is included in Section 6 of this chapter.

2. RECONNAISSANCE AVAILABILITY

a. Aircraft

Aircraft weather reconnaissance for the JTWC is performed by the 54th Weather Reconnaissance Squadron (54th WRS) located at Andersen Air Force Base, Guam. The 54th WRS only averaged three to four storm-capable aircraft (six assigned) throughout the entire year. On April 8th, five of the 54th WRS's six WC-130 aircraft were grounded for cracked wings (the sixth was previously grounded for major maintenance repairs). This left the unit with no storm-capable aircraft for a short period of time until replacements began arriving from the 53rd WRS, Keesler Air Force Base, Mississippi. During the period 1 August - 5 October, two 53rd WRS WC-130 aircraft and crews were in place to augment 54th WRS resources. But during this period, Joint Chiefs of Staff tasking took away two WC-130 aircraft from the 54th WRS, resulting in no net aircraft augmentation for the season. The JTWC aircraft reconnaissance requirements are provided daily to the Reconnaissance Coordinator (TCARC). The TCARC then marries the tasking from JTWC with the available airframes from the 54th WRS.

As in previous years, aircraft reconnaissance provides direct measurements of standard pressure-level height, temperature, flight-level winds, sea-level pressure, estimated surface winds (when observable), and numerous additional parameters. The meteorological data are gathered by the Aerial Reconnaissance Weather Officer (ARWO) and dropsonde operators of Detachment 3, 1st Weather Wing who fly with the 54th WRS. These data provide the Typhoon Duty Officer (TDO) with indications of tropical cyclone position and intensity. Another important aspect is the availability of the data for technique development and tropical cyclone research.

b. Satellite

Satellite fixes from USAF/USN ground sites and USN ships provide day and night coverage in JTWC's area of responsibility. Interpretation of this satellite imagery provides tropical cyclone positions and estimates of current and forecast intensities through the Dvorak technique.

c. Radar

Land-based radar provides positioning data on well-developed tropical cyclones when in the proximity (usually within 175 nm (324 km)) of the radar sites in the Philippines, Taiwan, Hong Kong, Japan, South Korea, Kwajalein, and Guam.

d. Synoptic

JTWC also determines tropical cyclone positions based on the analysis of the surface/gradient-level synoptic data. These positions were helpful in situations where the vertical structure of the tropical cyclone was weak or accurate surface positions from aircraft or satellite were not available.

3. AIRCRAFT RECONNAISSANCE SUMMARY

During 1986, JTWC levied requirements for 250 vortex fixes and 73 investigative missions of which 9 were flown into disturbances that did not develop. In addition to the levied fixes, 206 intermediate fixes were also obtained. Thirty-six synoptic missions were requested and flown to provide mid-level steering information. The average distance error for all aircraft fixes received at JTWC during 1986 was 13 nm (24 km).

Aircraft reconnaissance effectiveness is summarized in Table 2-1. The manner in which the aerial reconnaissance mission is graded changed during 1986. A new Mission Effectiveness Grading (MEG) system was tested operationally. No longer is the early, late or on-time criteria being used. The new system graded the performance of the mission as satisfactory, degraded but satisfactory, unsatisfactory or missed. A mission could be degraded if certain critical weather parameters were not obtained such as temperature, dew point, minimum sea-level pressure, flight-level height in meters, etc. Also if too much time or too little time elapsed between the primary and intermediate fixes, the mission could be degraded and yet be satisfactory.

TABLE 2-1. AIRCRAFT RECONNAISSANCE EFFECTIVENESS

MISSIONS	TASKED	COMPLETED	MISSED	PERCENT
FIXES	250	240	10	96.0%
INVESTS	73	70	3	95.9%
SYNOPTIC TRACKS	36	30	6	83.3%

MISSION EFFECTIVENESS GRADING

	TOTAL	PERCENT
FIX MISSIONS TASKED	250	——
SATISFACTORY	210	84.0%
DEGRADED (BUT SATISFACTORY)	57	22.8%
UNSATISFACTORY	40	16.0%

LEVIED VS. MISSED FIXES

	LEVIED	MISSED	PERCENT
AVERAGE 1965-1970	507	10	2.0%
1971	802	61	2.0%
1972	624	126	20.2%
1973	227	13	5.7%
1974	358	30	8.4%
1975	217	7	3.2%
1976	317	11	3.5%
1977	203	3	1.5%
1978	290	2	0.7%
1979	289	14	4.8%
1980	213	4	1.9%
1981	201	3	1.5%
1982	276	17	6.2%
1983	157	3	1.9%
1984	210	2	1.0%
* 1985	210	14	6.7%
1986	250	10	4.0%

* CORRECTED DATA FOR 1985.

4. SATELLITE RECONNAISSANCE SUMMARY

The Air Force provides satellite reconnaissance support to JTWC through a tropical cyclone satellite surveillance network consisting of both tactical and centralized facilities. Tactical DMSP sites monitoring DMSP, NOAA and geostationary satellite data are located at Nimitz Hill, Guam; Clark AB, Republic of the Philippines; Kadena AB, Okinawa, Japan; Osan AB, Republic of Korea; and Hickam AFB, Hawaii. These sites provide a combined coverage that includes most of JTWC's area of responsibility in the western North Pacific from near the dateline westward to the Malay Peninsula. For the remainder of its AOR, JTWC relies on the Air Force Global Weather Central (AFGWC) to provide coverage using stored satellite data. The Naval Oceanography Command Detachment, Diego Garcia, provides NOAA polar orbiting coverage in the central Indian Ocean as a supplement to this support. U.S. Navy ships equipped for direct readout also provide supplementary support.

AFGWC, located at Offutt AFB, Nebraska, is the centralized member of the tropical cyclone satellite surveillance network. In support of JTWC, AFGWC processes stored imagery from DMSP and NOAA spacecraft. Imagery recorded onboard the spacecraft as they pass over the earth is later downlinked to AFGWC via a network of command readout sites and communication satellites. This enables AFGWC to obtain the coverage necessary to fix all tropical systems of interest to JTWC. AFGWC has the primary responsibility to provide tropical cyclone surveillance over the entire Indian Ocean, southwest Pacific, and the area near the dateline. Additionally, AFGWC can be tasked to provide tropical cyclone positions in the entire western North Pacific as backup to coverage routinely available in that region.

The hub of the network is Detachment 1, First Weather Wing (Det 1, 1WW), colocated with JTWC on Nimitz Hill, Guam. Based on available satellite coverage, Det 1, 1WW is responsible for coordinating satellite reconnaissance requirements with JTWC and tasking the individual network sites for the necessary tropical cyclone fixes and intensity estimates. When a particular fix is important to the development of JTWC's next tropical cyclone warning, two sites are tasked to fix the tropical cyclone from the same satellite pass. This "dual-site" concept provides the necessary redundancy to virtually guarantee JTWC an accurate satellite fix on the tropical cyclone.

The network provides JTWC with several products and services. The main service is one of monitoring its AOR for indications of tropical cyclone development. If an area exhibits the potential for development, JTWC is notified. Once JTWC issues either a Tropical Cyclone Formation Alert or warning, the network is tasked to provide three products: tropical cyclone positions, intensity estimates and forecast intensities. Each satellite tropical cyclone position is assigned a Position Code Number (PCN) to indicate the accuracy of the fix position. This is determined by the availability of visible landmarks in the image for precise gridding, and the degree of organization of the tropical cyclone's cloud system (Table 2-2).

TABLE 2-2. POSITION CODE NUMBERS

PCN	METHOD OF CENTER DETERMINATION/GRIDDING
1	EYE/GEOGRAPHY
2	EYE/EPHEMERIS
3	WELL-DEFINED CIRCULATION CENTER/GEOGRAPHY
4	WELL-DEFINED CIRCULATION CENTER/EPHEMERIS
5	POORLY DEFINED CIRCULATION CENTER/GEOGRAPHY
6	POORLY DEFINED CIRCULATION CENTER/EPHEMERIS

During 1986, the network provided JTWC with a total of 2693 satellite fixes on tropical systems in the western North Pacific. This is a record number of fixes for the year. Another 57 fixes were made for tropical systems in the North Indian Ocean. A comparison of those fixes of numbered tropical cyclones in the western North Pacific with their corresponding JTWC best track positions is shown in Table 2-3a (Comparison of fixes with the corresponding best track for the South Pacific and Indian Oceans are presented in Table 2-3b).

TABLE 2-3A. MEAN DEVIATION (NM) OF ALL SATELLITE DERIVED TROPICAL CYCLONE POSITIONS FROM THE JTWC BEST TRACK POSITIONS IN THE WESTERN NORTH PACIFIC AND NORTH INDIAN OCEANS. NUMBER OF CASES IN PARENTHESES.

	WESTERN NORTH PACIFIC OCEAN				NORTH INDIAN OCEAN			
	1976-1985 AVERAGE		1986		1980-1985 AVERAGE		1986	
PCN	(ALL SITES)		(ALL SITES)		(ALL SITES)		(ALL SITES)	
1	13.6	(1632)	17.7	(188)	16.7	(40)	------	(0)
2	16.6	(1792)	16.0	(450)	18.9	(7)	------	(0)
3	20.9	(2367)	26.6	(204)	17.6	(21)	161.6	(1)
4	22.9	(1300)	29.4	(398)	58.3	(10)	------	(0)
5	37.4	(4381)	45.1	(322)	33.5	(220)	87.4	(12)
6	39.5	(3250)	40.8	(1125)	37.5	(203)	106.1	(22)
1&2	15.2	(3424)	16.5	(638)	17.2	(47)	------	(0)
3&4	21.6	(3667)	28.5	(602)	33.0	(31)	161.6	(1)
5&6	38.3	(7631)	41.8	(1447)	34.7	(423)	99.5	(34)
TOTALS		(14722)		(2687)		(501)		(35)

TABLE 2-3B. MEAN DEVIATION (NM) OF ALL SATELLITE DERIVED TROPICAL CYCLONE POSITIONS IN THE SOUTH PACIFIC AND SOUTH INDIAN OCEANS. NUMBER OF CASES IN PARENTHESES.

PCN	1986 (ALL SITES)	
1	18.3	(48)
2	15.6	(144)
3	39.5	(55)
4	23.9	(111)
5	46.7	(158)
6	36.1	(1012)
1&2	16.3	(192)
3&4	29.1	(166)
5&6	37.5	(1170)
TOTALS		(1528)

Estimates of the tropical cyclone's current intensity and 24-hour intensity forecast are made every 12 hours by applying the Dvorak technique (NOAA Technical Report NESDIS 11) to visual and enhanced infrared imagery (Figure 2-1 and Table 2-4).

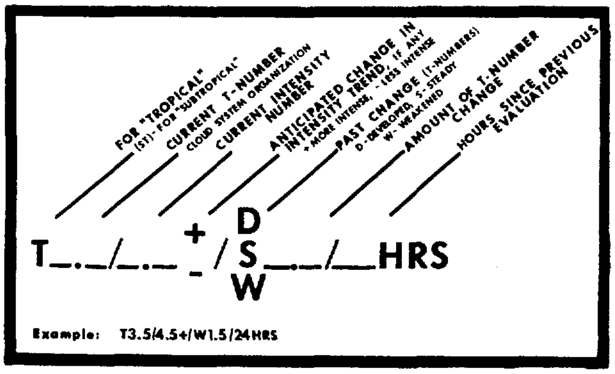
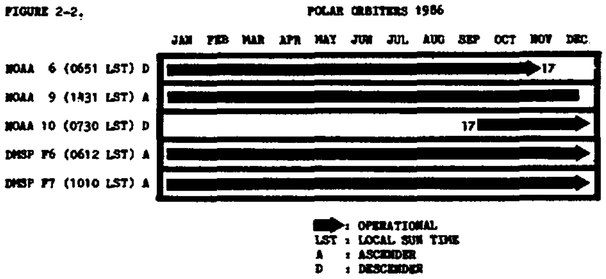


Figure 2-1. Dvorak code for communicating estimates of current and forecast intensity derived from satellite data. In the example, the current T-number is 3.5, but the current intensity estimate is 4.5 (equivalent to 77 kt (40 m/sec)). The cloud system has weakened by 1.5 T-numbers since the previous evaluation conducted 24 hours earlier. The plus (+) symbol indicates an expected reversal of the weakening trend or very little further weakening of the tropical cyclone during the next 24-hour period.

Figure 2-2 shows the status of operational polar orbiting spacecraft. Four were available, on the average, throughout the year. The two DMSP satellites, 17540 (F6) and 18541 (F7), operated reliably through the year with only occasional minor imagery loss due to seasonal repositioning of a glare obstructor (GLOB) on the F6 spacecraft. NOAA spacecraft did not fare as well. On January 1st,

FIGURE 2-2.



NOAA 6 was returned to service from standby mode to replace an ailing NOAA 8. Only partially operational, NOAA 6 served as the primary morning spacecraft for most of 1986. Its most serious limitation (for Det 1, 1WW's operations) was the appearance of "railroad track-like" lines through the center of its High Resolution Picture Transmissions (HRPT) imagery. But by 17 November, it had again been placed on standby (with HRPT and Automatic Picture Transmission (APT) turned off), and was replaced by the newly-launched NOAA 10. NOAA 10 and NOAA 9 have had no major problems providing high-quality imagery through the remainder of the year.

5. RADAR RECONNAISSANCE SUMMARY

Eighteen of the 27 significant tropical cyclones in the western North Pacific during 1986 passed within range of land-based radar with sufficient cloud pattern organization to be fixed. The land-based radar fixes that were obtained and transmitted to JTWC totaled 899. Only one radar fix was obtained by reconnaissance aircraft.

The WMO radar code defines three categories of accuracy: good (within 10 km (5 nm)), fair (within 10-30 km (5-16 nm)), and poor (within 30-50 km (16-27 nm)). Of the 900 radar fixes coded in this manner; 243 were good, 257 were fair, and 400 were poor. Compared to JTWC's best track, the mean vector deviation for land-based radar sites was 16 nm (29 km). Excellent support through timely and accurate radar fix positioning allowed JTWC to track and forecast tropical cyclone movement through even the most difficult erratic tracks.

As in previous years, no radar reports were received on North Indian Ocean tropical cyclones.

6. TROPICAL CYCLONE FIX DATA

A total of 3868 fixes on 27 western North Pacific tropical cyclones and 59 fixes on 3 North Indian Ocean tropical cyclones were received at JTWC. Table 2-5A, Fix Platform Summary, delineates the number of fixes per platform for each individual tropical cyclone. Season totals and percentages are also indicated. (Table 2-5B provides the same information for the South Pacific and South Indian Oceans.)

TABLE 2-4. MAXIMUM SUSTAINED WIND SPEED (KT) AS A FUNCTION OF DVORAK CI & FI (CURRENT AND FORECAST INTENSITY) NUMBER AND MINIMUM SEA-LEVEL PRESSURE (MSLP)

TROPICAL CYCLONE INTENSITY NUMBER	WIND SPEED	MSLP (NW PACIFIC)
0.0	<25	----
0.5	25	----
1.0	25	----
1.5	25	----
2.0	30	1000
2.5	35	997
3.0	45	991
3.5	55	984
4.0	65	976
4.5	77	966
5.0	90	953
5.5	102	941
6.0	115	927
6.5	127	914
7.0	140	898
7.5	155	879
8.0	170	858

TABLE 2-5A. FIX PLATFORM SUMMARY FOR 1986

WESTERN NORTH PACIFIC		AIRCRAFT	SATELLITE	RADAR	SYNOPTIC	TOTAL
TY JUDY	(01W)	9	84	0	0	93
TY KEN	(02W)	8	97	0	0	105
STY LOLA	(03W)	10	92	0	0	102
TS MAC	(04W)	4	104	27	0	135
TY NANCY	(05W)	4	60	26	0	90
TS OWEN	(06W)	8	49	0	0	57
STY PEGGY	(07W)	16	179	40	0	235
TY ROGER	(08W)	10	98	82	0	190
TS SARAH	(09W)	8	112	2	0	122
TY GEORGETTE	(11E)	9	93	0	0	102
TY TIP	(10W)	10	91	0	0	101
TY VERA	(11W)	20	190	70	0	280
TY WAYNE	(12W)	18	257	374	3	652
TY ABBY	(13W)	10	93	79	1	183
TY BEN	(14W)	21	147	0	0	168
TY CARMEN	(15W)	11	99	7	0	117
TS DOM	(16W)	1	56	13	0	70
TY ELLEN	(17W)	8	174	74	0	256
TY FORREST	(18W)	8	91	0	0	99
TS GEORGIA	(19W)	4	76	5	0	85
TS HERBERT	(20W)	4	90	1	0	95
TS IDA	(21W)	6	90	10	1	107
TY JOE	(22W)	13	153	64	0	230
STY KIM	(23W)	23	263	21	0	307
TS LEX	(24W)	2	48	0	0	50
TY MARGE	(25W)	9	144	6	0	159
TY NORRIS	(26W)	16	149	29	0	194
TOTALS		270	3179	930	5	4384
% OF TOTAL NR OF FIXES		6.2%	72.5%	21.2%	0.1%	100.0%

NORTH INDIAN OCEAN	SATELLITE	SYNOPTIC	TOTAL
TC 01B	25	2	27
TC 02B	15	0	15
TC 03A	17	0	17
TOTALS	57	2	59
% OF TOTAL NR OF FIXES	96.6%	3.4%	100.0%

TABLE 2-5B. FIX PLATFORM SUMMARY FOR 1986

THE SOUTH PACIFIC AND SOUTH INDIAN OCEANS	SATELLITE	RADAR	SYNOPTIC	TOTAL
TC 01S ----------	54	0	0	54
TC 02S NICHOLAS	156	0	0	156
TC 03P ----------	48	0	0	48
TC 04S DELIFININA	58	0	1	59
TC 05S COSTA	57	0	5	62
TC 06S ----------	16	0	0	16
TC 07S OPHELIA	46	0	0	46
TC 08S ----------	36	0	0	36
TC 09S HECTOR	60	0	2	62
TC 10S PANCHO	21	0	0	21
TC 11P VERNON	42	0	0	42
TC 12P WINIFRED	58	0	0	58
TC 13S ERINESTA	74	0	0	74
TC 14S FILOMENA	40	0	0	40
TC 15P IMA	14	0	0	14
TC 16P JUNE	8	0	0	8
TC 17P KELI	48	0	0	48
TC 18S RHONDA	17	0	0	17
TC 19S GISTA	42	0	0	42
TC 20S SELWYN	43	0	0	43
TC 21S TIFFANY	32	0	0	32
TC 22S VICTOR	90	3	0	93
TC 23P LUSI	81	0	3	84
TC 24P ALFRED	54	0	0	54
TC 25S HONORININA	75	0	0	75
TC 26S IARIMA	19	0	0	19
TC 27S JEFOTRA	56	0	0	56
TC 28S KRISOSTOMA^	73	0	1	74
TC 29P MARTIN	43	0	0	43
TC 30P ----------	33	0	0	33
TC 31P MANU	52	0	0	52
TC 32S BILLY#	91	0	0	91
TC 33P NAMU	82	0	0	82
TOTALS	1719	3	12	1734
% OF TOTAL NR OF FIXES	99.1%	0.2%	0.7%	100.0%

^ TC 28S (KRISOSTOMA) WAS ALSO NAMED ALISON.
# TC 32S (BILLY) WAS ALSO NAMED LILA.

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

1. GENERAL

During 1986, JTWC issued warnings for twenty-seven tropical cyclones in the western North Pacific. This included three super typhoons, sixteen typhoons, eight tropical storms and no tropical depressions. This also included one typhoon, Georgette (11E), which initially developed in the eastern North Pacific. For the second year in a row the total number of western North Pacific tropical cyclones was four lower than the climatological mean of thirty-one. The total for the North Indian Ocean was three tropical cyclones (of tropical storm intensity), which is also less than the climatological mean of 4.5 and three less than the preceding year. In summary, warnings were issued on a total of thirty tropical cyclones in the northern hemisphere.

In WESTPAC there were 163 "warning days". (A "warning day" is defined as a day during which JTWC was issuing warnings on at least one tropical cyclone. A "two-cyclone" day refers to a day when two different tropical cyclones were warned on simultaneously, a "three-cyclone" day - three tropical cyclones at one time, and so on...). In WESTPAC, there were thirty-two two-cyclone days, four three-cyclone days and no four- or five-cyclone days. When North Indian Ocean tropical cyclones are included, there were 168 warning days, thirty-two two-cyclone days, seven three-cyclone days and no four- or five-cyclone days.

JTWC issued 743 warnings on the twenty-seven western North Pacific tropical cyclones and twenty-nine warnings on the three North Indian Ocean tropical cyclones, for a total of 772 northern hemisphere warnings. There were thirty-eight initial Tropical Cyclone Formation Alerts (TCFAs) issued for the western North Pacific and seven for the North Indian Ocean, for a total of forty-five. All WESTPAC and North Indian Ocean tropical cyclones (100 percent) developed after the issuance of a TCFA. For the western North Pacific, the false alarm rate was twenty-six percent (a ten percent improvement over last year) and the mean lead time (to issuance of first warning) was twenty-five hours. For the North Indian Ocean, the false alarm rate was 57.0 percent; the mean lead time was 5.7 hours.

2. WESTERN NORTH PACIFIC TROPICAL CYCLONES

Several factors made 1986 an unusual, and therefore difficult, tropical cyclone season for JTWC. There were only four classic "straight runners" (which normally have the lowest forecast errors) in 1986, as compared to the seven of 1985. The number of "recurvers" was the same, but there were three more tropical cyclones in the "other" category in 1986 than in 1985. "Other" tropical cyclones are those whose tracks do not easily fit into the straight runner or recurver categories, i.e., the erratic systems. The tropical cyclones in this last category were the most difficult to forecast. The major forecast problems arose with those tropical cyclones that formed in the active monsoon trough and during the extremely active winter period. For discussion purposes the tropical cyclone year is divided into three periods.

JANUARY THROUGH AUGUST

The season began in late January with Typhoon Judy (01W), a "classic" recurving system which passed between Guam and the Philippine Islands. Although JTWC did a good job forecasting the track, difficulties with the speed of movement caused forecast errors to be larger than average. Typhoon Ken (02W) was a short-lived tropical cyclone which formed southwest of Guam and dissipated over water. Super Typhoon Lola (03W) developed very slowly in the vicinity of Pohnpei in the Caroline Islands. The enhanced southwest monsoon flow associated with Lola's formation was significant, as indicated by damaging 60 kt 31 (m/sec) winds which were reported on Pohnpei. At the same time, and of particular meteorological interest, was the development of a "twin" tropical cyclone, Namu (33P), in the western South Pacific. This situation occurs periodically in the Western Pacific and Indian Oceans when strong low-latitude westerlies enhance the development of tropical cyclones in both hemispheres. This is usually observed during the spring and fall transition periods. Tropical Cyclone Namu (33P), incidentally, was the most intense tropical cyclone to strike the Solomon Islands this century. Tropical Storm Mac (04W) developed near the island of Hainan in the South China Sea and passed between Luzon and Taiwan at the end of May. As a monsoon depression, it struggled against strong vertical wind shear most of its life. Typhoon Nancy (05W) developed in June in the central Philippine Sea, struck the east coast Taiwan and recurved into the Korea Strait. JTWC forecast Nancy's recurvature track quite well until near the end, when it began to accelerate toward the northeast and central convection sheared away. Tropical Storm Owen (06W) was another relatively weak system which had difficulty developing due to strong vertical shear. The second super typhoon of the year, Peggy (07W), developed east of Guam and followed a west-northwest track into northern Luzon, where 93 deaths resulted. It continued onward until it made a second landfall on the China coast northeast of Hong Kong. Typhoon Roger (08W) was another one of the several early season recurving tropical cyclones. The recurvature near the island of Okinawa was accurately forecast 48-hours in advance. Tropical Storm Sarah (09W) was the first of a series of tropical cyclones which caused serious forecast problems for JTWC. Sarah (09W) developed in an active monsoon trough east of Luzon and appeared, from satellite imagery, to track west-northwestward across Luzon into the South China Sea. Post-analysis of aircraft reconnaissance data, however, indicated that the low-level center never made landfall on Luzon, but recurved northeastward instead. Typhoon Tip (10W) and Typhoon Georgette (11E) engaged in a classic binary interaction (Fujiwhara, 1921 and 1923; Brand, 1970; Dong and Neumann, 1983) northeast of Guam which resulted in larger than average forecast errors for both systems. Typhoon Georgette (11E), incidentally had one of the longest tracks on record. It initially developed in the eastern North Pacific, dissipated as a significant tropical cyclone in the central North Pacific, and then regenerated from the pre-existing disturbance in the western North Pacific. Typhoon Vera (11W) caused more forecast problems than any tropical cyclone in 1986. It generated in the active monsoon trough as a "classic" monsoon depression - difficult to position and forecast. Typhoon Wayne (12W) was probably the most interesting tropical cyclone in 1986. During its exceptionally long life (twenty days), it struck Luzon (once) and Taiwan (twice), threatened Hong Kong (twice), dissipated and reformed (once), before finally dissipating over North Vietnam near Hanoi. Many multiple-storm days occurred during the later part of this first period. As a result, reconnaissance (both satellite and aircraft) assets were working overtime to keep up with the requirements for the latest data.

SEPTEMBER THROUGH OCTOBER

The tropics quieted down somewhat during this second period. Typhoon Abby (13W) developed just to the southeast of Guam and moved northwestward before recurving near Taiwan. Typhoon Ben (14W) developed rapidly southeast of Guam and drifted northward before recurving through a break in the subtropical ridge. Typhoon Carmen (15W) was the third tropical cyclone in a row to develop southeast of Guam. It followed a recurvature track, passing north of Guam and east of Japan. The forecast statistics for Carmen (15W) were excellent.

During the rest of October and into early November, the major tropical cyclone generation area shifted, for the most part, from southeast of Guam to the Philippine Islands. Although Tropical Storm Dom (16W) did not become a "significant" tropical cyclone until it was approaching the coast of Vietnam, the Republic of the Philippines suffered extensive flooding when Dom (16W), at tropical depression intensity, passed by. Typhoon Ellen (17W) intensified east of the central Philippine Islands and passed about 90 nm (167 km) south of Subic Bay. Initially, it appeared that recurvature toward Taiwan would take place, but a surge in the low-level northeasterlies from the China mainland resulted in a more westerly track towards the island of Hainan. Further to the east, Typhoon Forrest (18W), which attained 100 kt (185 m/sec) intensity, developed northeast of Guam and recurved. Tropical Storm Georgia (19W) spawned just east of the central Philippine Islands, passed south of Subic Bay and made landfall over Vietnam after following a nearly straight track.

NOVEMBER AND DECEMBER

The combined months of November and December 1986 proved to be one of the most active winters in WESTPAC history with seven tropical cyclones (compared to an average of four). The three typhoons in December is an all-time record. Tropical Storm Herbert (20W) developed in the wake of Tropical Storm Georgia (19W) and followed an almost identical track westward across the South China Sea with landfall on the coast of central Vietnam. Tropical Storm Ida (21W) was hindered by the frictional effects during its passage through the central Philippine Islands and strong vertical wind shear over the South China Sea. Typhoon Joe (22W) formed east of Luzon and recurved to the northeast without making landfall. Its associated convective bands, however, produced significant rainfall over the northern Luzon. The tropical cyclone activity then shifted eastward. Super Typnoon Kim (23W) was the first in a series of four difficult late season tropical cyclones. It formed to the southeast of Guam and initially followed a northwestward track. Although Kim (23W) appeared to change to a recurvature track before reaching Guam, it abruptly turned toward the west and passed 15 nm (28 km) north of the island of Saipan in the Marianas at near super typhoon intensity, causing extensive damage. Tropical Storm Lex (24W) developed in the wake of Kim (23W) but was unable to mature due to the strong upper-level shear caused by the intense outflow from Kim (23W). Typhoon Marge (25W) also developed southeast of Guam, but very slowly. It turned westward, passed south of Guam, then crossed the central Philippine Islands and dissipated in the South China Sea. Typhoon Norris (26W) continued the late season trend by developing to the southeast of Guam. It oscillated about a westward track and crossed the central Philippine Islands before dissipating over the South China Sea.

The last three typhoons of the year - Kim (23W), Marge (25W) and Norris (26W) were similar in that they followed a "step-like" track. It appeared that the basic steering flow south of the subtropical ridge axis changed the tracks from a westward to more northwestward, as mid-latitude troughs moved off China. Once these troughs had passed to the north, the tracks reverted back to westward. The mid-latitude troughs never penetrated far enough to the south to break through the subtropical ridge and allow the tropical cyclones to recurve. Later, as the tropical cyclones approached the Philippine Islands, southwestward movement was observed due to surges in the northeast monsoon, which had fully established itself across the Philippine Islands and South China Sea. During wintertime synoptic regimes, forecast difficulties were also compounded by the instability of the One-Way Interactive Tropical Cyclone Model (OTCM), JTWC's primary dynamic forecast aid, due to kinetic energy conversion problems.

Tables 3-1 through 3-6 provide information on the monthly and annual distribution of tropical cyclones, warnings and tropical cyclone formation alerts.

TABLE 3-1. WESTERN NORTH PACIFIC
1986 SIGNIFICANT TROPICAL CYCLONES

TROPICAL CYCLONE	PERIOD OF WARNING	CALENDAR DAYS OF WARNING	NUMBER OF WARNINGS ISSUED	MAXIMUM SURFACE WINDS-KT (M/S)	ESTIMATED MSLP - MB
01W TY JUDY	01 FEB - 06 FEB	5	21	85 (44)	974
02W TY KEN	26 APR - 01 MAY	5	18	90 (46)	960
03W STY LOLA	17 MAY - 23 MAY	7	26	150 (77)	910
04W TS MAC	26 MAY - 29 MAY	4	15	45 (23)	992
05W TY NANCY	21 JUN - 25 JUN	4	15	80 (41)	955
06W TS OWEN	28 JUN - 02 JUL	5	17	50 (26)	987
07W STY PEGGY	03 JUL - 11 JUL	9	35	140 (72)	900
08W TY ROGER	13 JUL - 17 JUL	5	19	85 (44)	955
09W TS SARAH	30 JUL - 04 AUG	6	22	55 (28)	986
11E TY GEORGETTE	09 AUG - 15 AUG	7	26	65 (33)	973
10W TY TIP	13 AUG - 19 AUG	7	25	80 (41)	965
11W TS VERA #1	15 AUG - 17 AUG	3	7	40 (21)	995
11W TY VERA #2	17 AUG - 29 AUG	13	48	110 (57)	923
12W TY WAYNE	18 AUG - 25 AUG	8	29	85 (44)	956
12W TY WAYNE*	28 AUG - 06 SEP	10	38	90 (46)	951
13W TY ABBY	13 SEP - 20 SEP	8	30	95 (49)	943
14W TY BEN	19 SEP - 30 SEP	12	46	120 (62)	917
15W TY CARMEN	02 OCT - 08 OCT	7	27	100 (51)	939
16W TS DOM	09 OCT - 11 OCT	3	11	45 (23)	990
17W TY ELLEN	11 OCT - 19 OCT	8	33	80 (41)	970
18W TY FORREST	15 OCT - 20 OCT	6	19	110 (57)	932
19W TS GEORGIA	18 OCT - 21 OCT	4	15	55 (28)	983
20W TS HERBERT	08 NOV - 11 NOV	4	16	60 (31)	986
21W TS IDA	10 NOV - 16 NOV	6	22	55 (28)	986
22W TY JOE	18 NOV - 24 NOV	7	24	100 (51)	940
23W STY KIM	28 NOV - 11 DEC	13	52	140 (72)	905
24W TS LEX	03 DEC - 05 DEC	3	8	40 (21)	994
25W TY MARGE	14 DEC - 23 DEC	10	38	95 (49)	947
26W TY NORRIS	21 DEC - 01 JAN	11	43	90 (46)	953
	1986 TOTALS:	163 **	743 ***		

* REGENERATED
** OVERLAPPING DAYS INCLUDED ONLY ONCE IN SUM.
*** YEAR-END TOTAL DOES NOT INCLUDE TWO WARNINGS ON TY NORRIS ON 01 JAN 87.

NOTE: DISTANCE TRAVELED HAS NOT BEEN PROVIDED, BUT CAN BE COMPUTED FROM RAW DATA - SEE ANNEX A.

TABLE 3-2

WESTERN NORTH PACIFIC TROPICAL CYCLONE DISTRIBUTION

Year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTALS
1959	0	1	1	1	0	1	3	8	9	3	2	2	31
	000	010	010	100	000	001	111	512	423	210	200	200	17 7 7
1960	1	0	1	1	1	3	3	9	5	4	1	1	30
	001	000	001	100	010	210	210	810	041	400	100	100	19 8 3
1961	1	1	1	1	4	6	5	7	6	7	2	1	42
	010	010	100	010	211	114	320	313	510	322	101	100	20 11 11
1962	0	1	0	1	3	0	8	8	7	5	4	2	39
	000	010	000	100	201	000	512	701	313	311	301	020	24 6 9
1963	0	0	1	1	0	4	5	4	4	6	0	3	28
	000	000	001	100	000	310	311	301	220	510	000	210	19 6 3
1964	0	0	0	0	3	2	8	8	8	7	6	2	44
	000	000	000	000	201	200	611	350	521	331	420	101	26 13 5
1965	2	2	1	1	2	4	6	7	9	3	2	1	40
	110	020	010	100	101	310	411	322	531	201	110	010	21 13 6
1966	0	0	0	1	2	1	4	9	10	4	5	2	38
	000	000	000	100	200	100	310	531	532	112	122	101	20 10 8
1967	1	0	2	1	1	1	8	10	8	4	4	1	41
	010	000	110	100	010	100	332	343	530	211	400	010	20 15 6
1968	0	1	0	1	0	4	3	8	4	6	4	0	31
	000	001	000	100	000	202	120	341	400	510	400	000	20 7 4
1969	1	0	1	1	0	0	3	3	6	5	2	1	23
	100	000	010	100	000	000	210	210	204	410	110	010	13 6 4
1970	0	1	0	0	0	2	3	7	4	6	4	0	27
	000	100	000	000	000	110	021	421	220	321	130	000	12 12 3
1971	1	0	1	2	5	2	8	5	7	4	2	0	37
	010	000	010	200	230	200	620	311	511	310	110	000	24 11 2
1972	1	0	1	0	0	4	5	5	6	5	2	3	32
	100	000	001	000	000	220	410	320	411	410	200	210	22 8 2
1973	0	0	0	0	0	0	7	6	3	4	3	0	23
	000	000	000	000	000	000	430	231	201	400	030	000	12 9 2
1974	1	0	1	1	1	4	5	7	5	4	4	2	35
	010	000	010	010	100	121	230	232	320	400	220	020	15 17 3
1975	1	0	0	1	0	0	1	6	5	6	3	2	25
	100	000	000	001	000	000	010	411	410	321	210	002	14 6 5
1976	1	1	0	2	2	2	4	4	5	0	2	2	25
	100	010	000	110	200	200	220	130	410	000	110	020	14 11 0
1977	0	0	1	0	1	1	4	2	5	4	2	1	21
	000	000	010	000	001	010	301	020	230	310	200	100	11 8 2
1978	1	0	0	1	0	3	4	8	4	7	4	0	32
	010	000	000	100	000	030	310	341	310	412	121	000	15 13 4
1979	1	0	1	1	2	0	5	4	6	3	2	3	28
	100	000	100	100	011	000	221	202	330	210	110	111	14 9 5
1980	0	0	1	1	4	1	5	3	7	4	1	1	28
	000	000	001	010	220	010	311	201	511	220	100	010	15 9 4
1981	0	0	1	1	1	2	5	8	4	2	3	2	29
	000	000	100	010	010	200	230	251	400	110	210	200	16 12 1
1982	0	0	3	0	1	3	4	5	6	4	1	1	28
	000	000	210	000	100	120	220	500	321	301	100	100	19 7 2
1983	0	0	0	0	0	1	3	6	3	5	5	2	25
	000	000	000	000	000	010	300	231	111	320	320	020	12 11 2
1984	0	0	0	0	0	2	5	7	4	8	3	1	30
	000	000	000	000	000	020	410	232	130	521	300	100	16 11 3
1985	2	0	0	0	1	3	1	7	5	5	1	2	27
	020	000	000	000	100	201	100	520	320	410	010	110	17 9 1
1986	0	1	0	1	2	2	2	5	2	5	4	3	27
	000	100	000	100	110	110	200	410	200	320	220	210	19 8 0
(1959-1986)													
AVG	0.5	0.3	0.6	0.8	1.3	2.1	4.6	6.3	5.6	4.6	2.8	1.5	30.9
CASES	15	9	18	21	36	58	128	175	157	130	78	41	866

Legend: Total for the month —— 6

Typhoons —— 3 1 2
Tropical Storms —— (1)
Tropical Depressions —— (2)

NOTE: This new compilation of 1959 through 1986 data was done after establishing a standard for the times when a tropical cyclone existed in two separate months. The criterion used follows:

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

2. If a tropical cyclone was warned on prior to the last two days of a month, it was attributed to the first month - no matter how long the system lasted.

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

TABLE 3-3

WESTERN NORTH PACIFIC SUMMARY

TYPHOONS

(1945-1958)

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

(1959-1986)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTALS
AVG	0.2	0.1	0.2	0.5	0.7	1.0	2.7	3.3	3.3	3.0	1.7	0.7	17.4
CASES	6	2	6	15	19	29	76	91	91	85	47	19	486

TROPICAL STORMS AND TYPHOONS

(1945-1958)

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

(1959-1986)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTALS
AVG	0.5	0.3	0.5	0.7	1.1	1.8	4.1	5.3	4.9	4.1	2.6	1.3	27.1
CASES	14	8	14	20	30	49	116	147	136	116	73	36	759

(1986)

FORMATION ALERTS: 27 of 38 Formation Alerts developed into significant tropical cyclones. Tropical Cyclone Formation Alerts were issued for all of the significant tropical cyclones that developed in 1986.

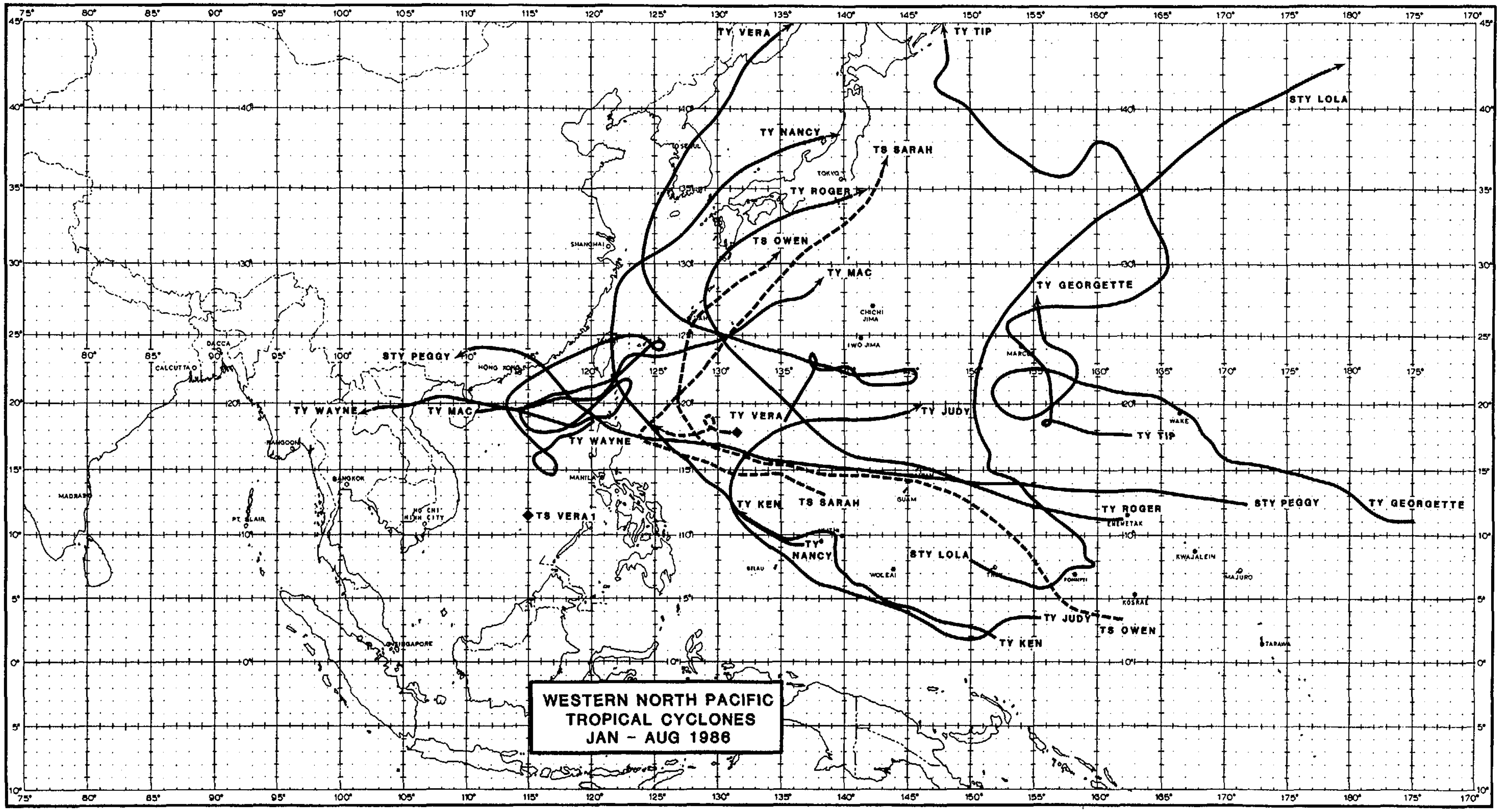
WARNINGS:

Number of calendar warning days:	163
Number of calendar warning days with two tropical cyclones:	32
Number of calendar warning days with three tropical cyclones:	4

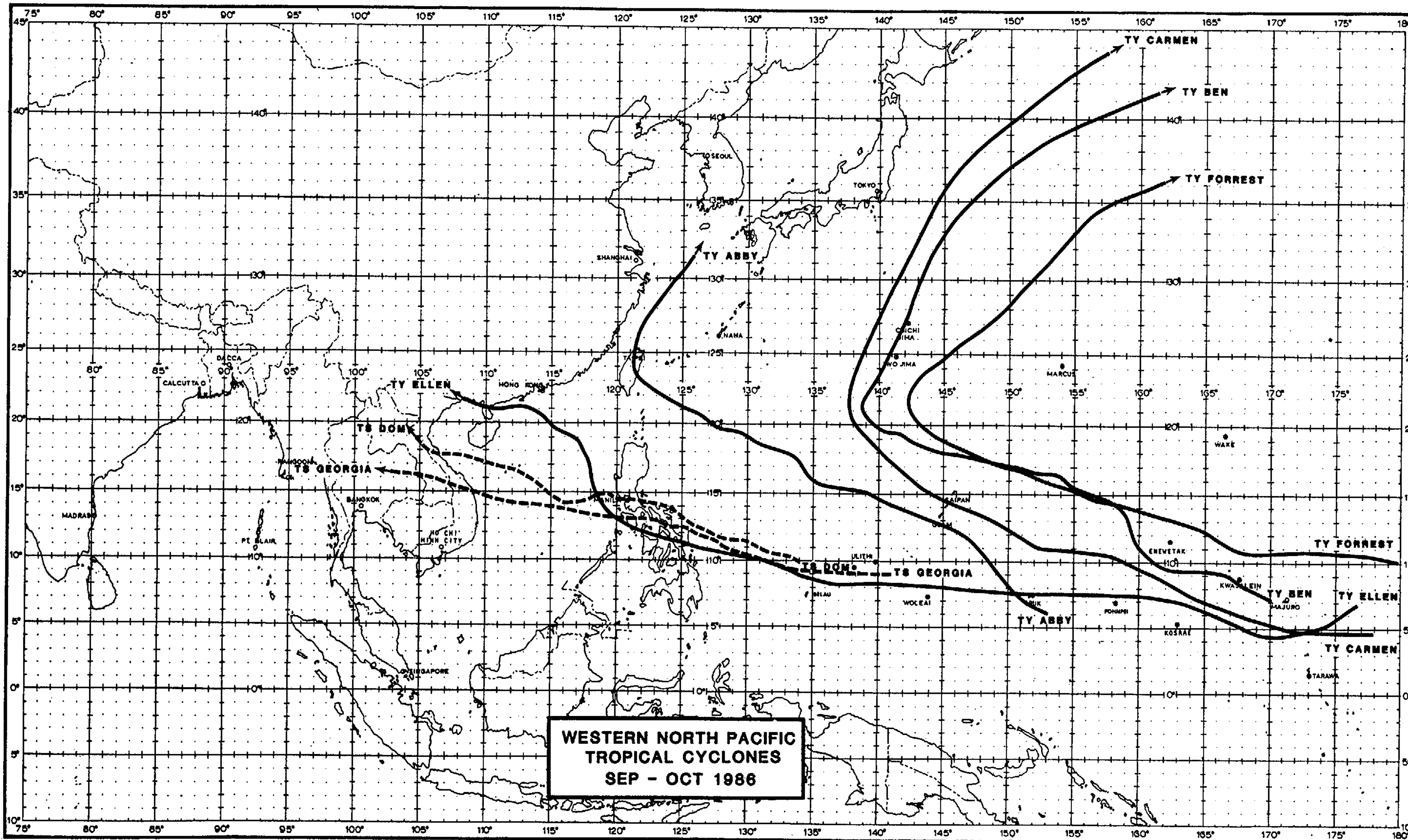
TABLE 3-4.

FORMATION ALERT SUMMARY WESTERN NORTH PACIFIC

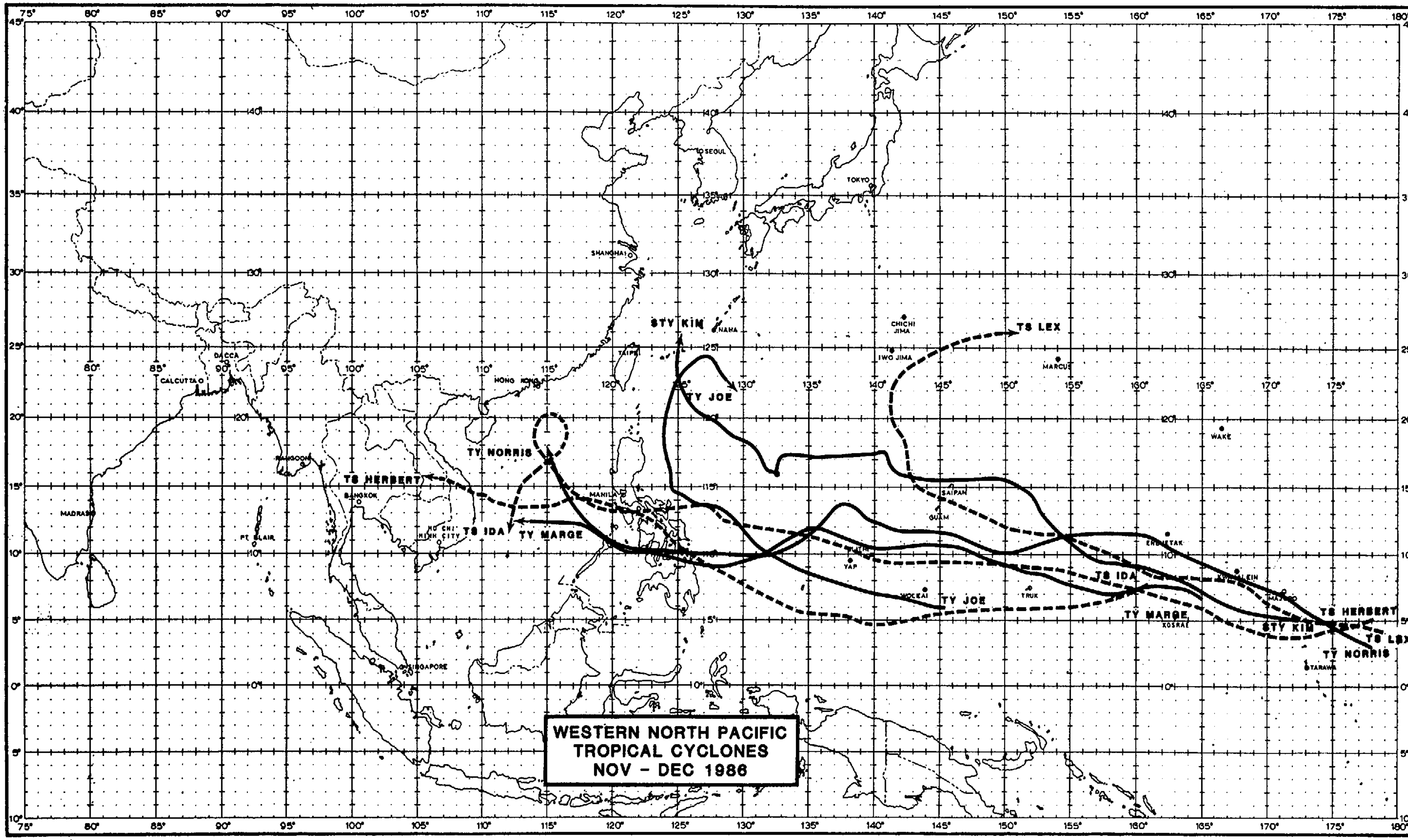
YEAR	NUMBER OF ALERT SYSTEMS	ALERT SYSTEMS WHICH BECAME NUMBERED TROPICAL CYCLONES	TOTAL NUMBERED TROPICAL CYCLONES	FALSE ALARM RATE
1975	34	25	25	26%
1976	34	25	25	26%
1977	26	20	21	23%
1978	32	27	32	16%
1979	27	23	28	15%
1980	37	28	28	24%
1981	29	28	29	3%
1982	36	26	28	28%
1983	31	25	25	19%
1984	37	30	30	19%
1985	39	26	27	33%
1986	38	27	27	29%
(1975-1986) AVERAGE	33.3	25.8	27.1	21.9%
CASES	400	310	325	



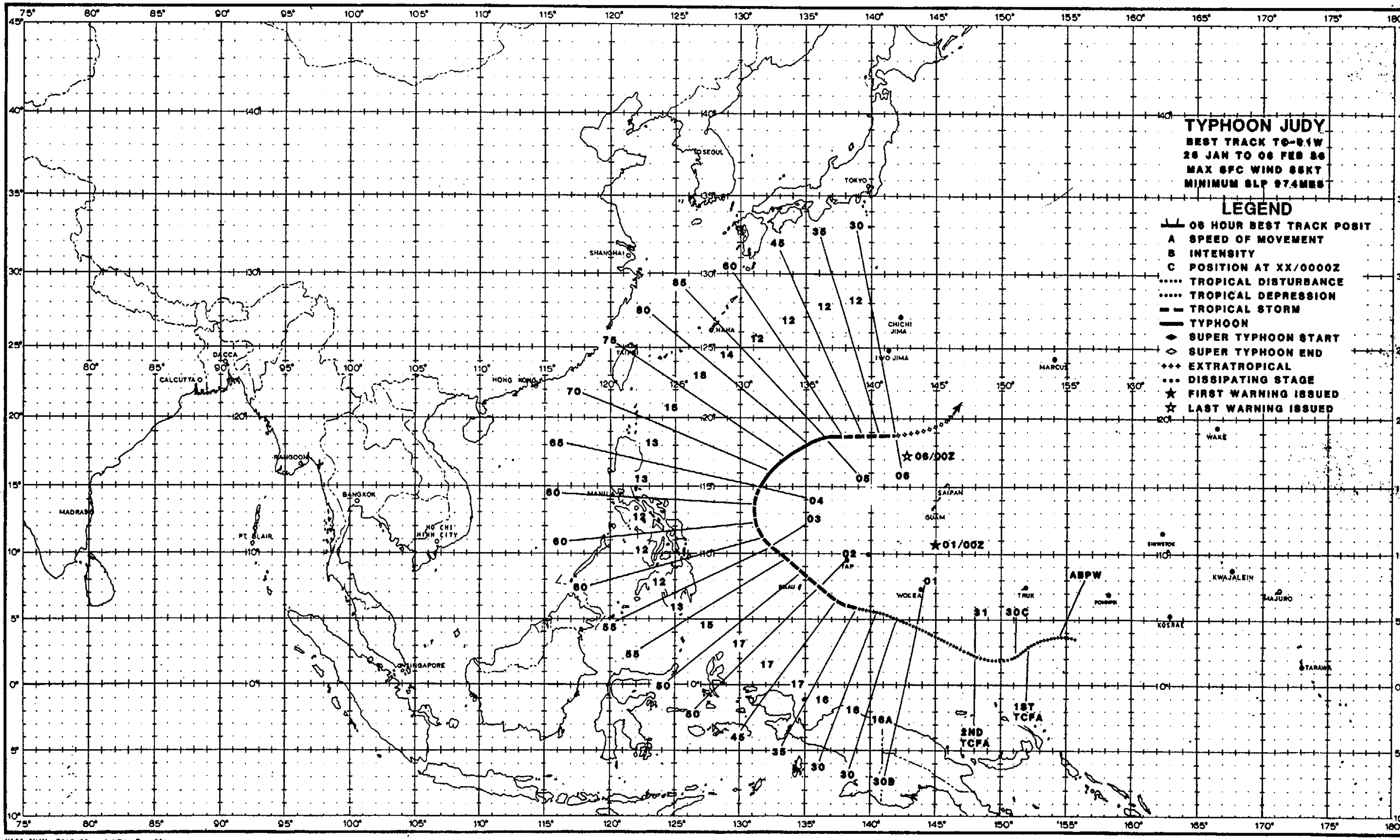
NOCC GUAM 3142/20 (NEW 5 - 80)



NOCC GUAM 3142/20 (NEW 5 - 80)



NOCC GUAM 3142/20 (NEW 5 - 80)



NOCC GUAM 3142/20 (NEW 5 - 80)

The formation of Typhoon Judy marked the start of the western North Pacific tropical cyclones for 1986. Judy originated near two degrees North Latitude in the near-equatorial trough. It was aided in its initial development by brisk northeasterly trade flow associated with a shear line situated to the north and the low latitude monsoonal westerlies in the southern hemisphere. Judy was also the season's first tropical cyclone to enter the mid-latitude westerlies and recurve.

During most of January, a winter weather pattern dominated the tropical western North Pacific area. Convective activity was confined to low latitudes on the periphery of the near-equatorial trough (NET). In the last week of January, the NET extended from the southern Philippines east-southeast to the equator 420 nm (778 km) south-southeast of the island of Pohnpei.

The cloud system first appeared late on 25 January as an area of disorganized convection 300 nm (556 km) in diameter. With unrestricted upper-level outflow to the north and west, the convection persisted through the diurnal minimum period (around 0400Z) on the 26th and was first noted on the Significant Tropical Weather Advisory (ABPW PGTW) at 260600Z.

During the next three days, the convection continued a gradual increase in areal extent, but remained poorly organized. Early on 29 January, an aircraft reconnaissance investigative mission flown into the disturbance was unable to locate a low-level circulation center. However, the Aerial Reconnaissance Weather Officer (ARWO) estimated a minimum sea-level pressure (MSLP) in the area at 1001 mb. Since this pressure was approximately 6 mb below the surrounding environmental MSLP to the north and the disturbance was expected to track westward into an upper-level environment with less vertical wind shear, a Tropical Cyclone Formation Alert (TCFA) was issued at 290630Z.

A second investigative mission flown early on the 30th also failed to locate a definite low-level circulation. The ARWO estimated maximum surface winds of 25 kt (13 m/sec) to 35 kt (18 m/sec) to the north in the easterly flow. Satellite imagery and synoptic data indicated this enhanced flow was a result of a shear line to the north of the disturbed area. Because of a decrease in both convection (diurnal) and low-level inflow, the TCFA for the disturbance was cancelled at 300600Z.

Post analysis indicates this cancellation was premature. Satellite imagery, over the next forty-eight hours, detected a dramatic increase in convection associated with this slowly, westward moving disturbance. Analysis of satellite imagery (Figure 3-01-1) prompted the issuance of a second

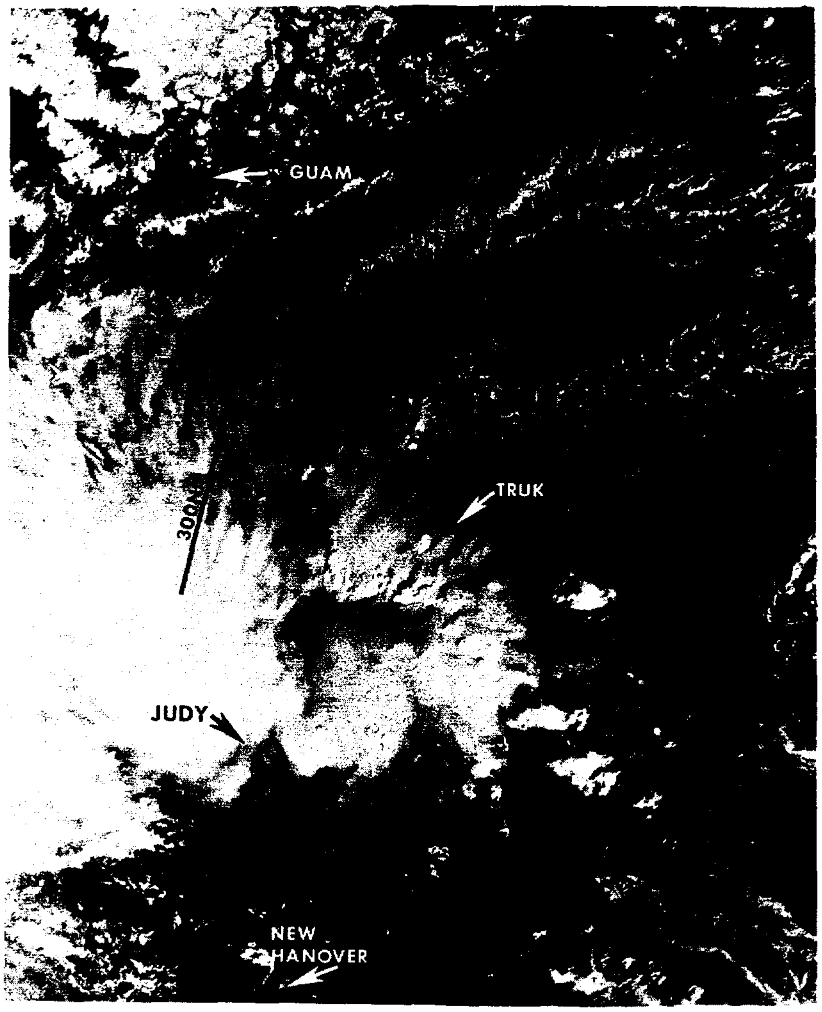


Figure 3-01-1. Judy just prior to issuance of second TCFA (302349Z January DMSP visual imagery).

TCFA at 310130Z. Twenty-four hours later, infrared satellite imagery indicated a upper-level anticyclone was developing over the disturbance and (Dvorak) satellite intensity analysis estimated surface winds of 30 kt (15 m/sec). This prompted the initial warning at 010000Z on Judy, as a 30 kt (15 m/sec) tropical depression. Within twenty-four hours, Judy was upgraded to tropical storm intensity based on the aircraft reconnaissance data.

The initial forecasts called for Judy to track west-northwestward. Due to the uncertainty of the position of the ridge axis and its strength over the data sparse Philippine Sea, 400 mb synoptic tracks were flown on the 2nd and 3rd of February to help define the mid-level flow north of Judy. Data from these flights confirmed the presence of the east-west orientation of the ridge axis and indicated a weakness in the ridge along 130 degrees East Longitude with strong westerly mid-level flow north of 16 degrees North Latitude. With the above information and mindful of a similar synoptic pattern associated with Typhoon Hope in December 1985, JTWC altered the forecast to reflect initial northward movement followed by recurvature toward the northeast. As with Typhoon Hope (1985), Judy was expected to undergo a rapid extratropical transition with a drastic decrease in intensity and no significant eastward movement. The dynamic forecast guidance proved of no assistance in this regard apparently due to the strongly sheared/baroclinic environment.

Judy slowed slightly as it approached the ridge near 131 degrees East Longitude early on 3 February. Continuing to intensify, the system tracked north briefly before turning northeast. Judy reached its maximum intensity of 85 kt (44 m/s) with a MSLP of 974 mb at 050000Z (see Figure 3-01-2). As it reached maximum intensity, Judy also came under the influence of strong mid-latitude westerlies. By 060000Z, Judy's convection had been sheared away and extratropical transition was complete. The nearly convective free low-level circulation drifted slowly east-northeast and dissipated. No deaths, injuries or property damage were attributed to Typhoon Judy.

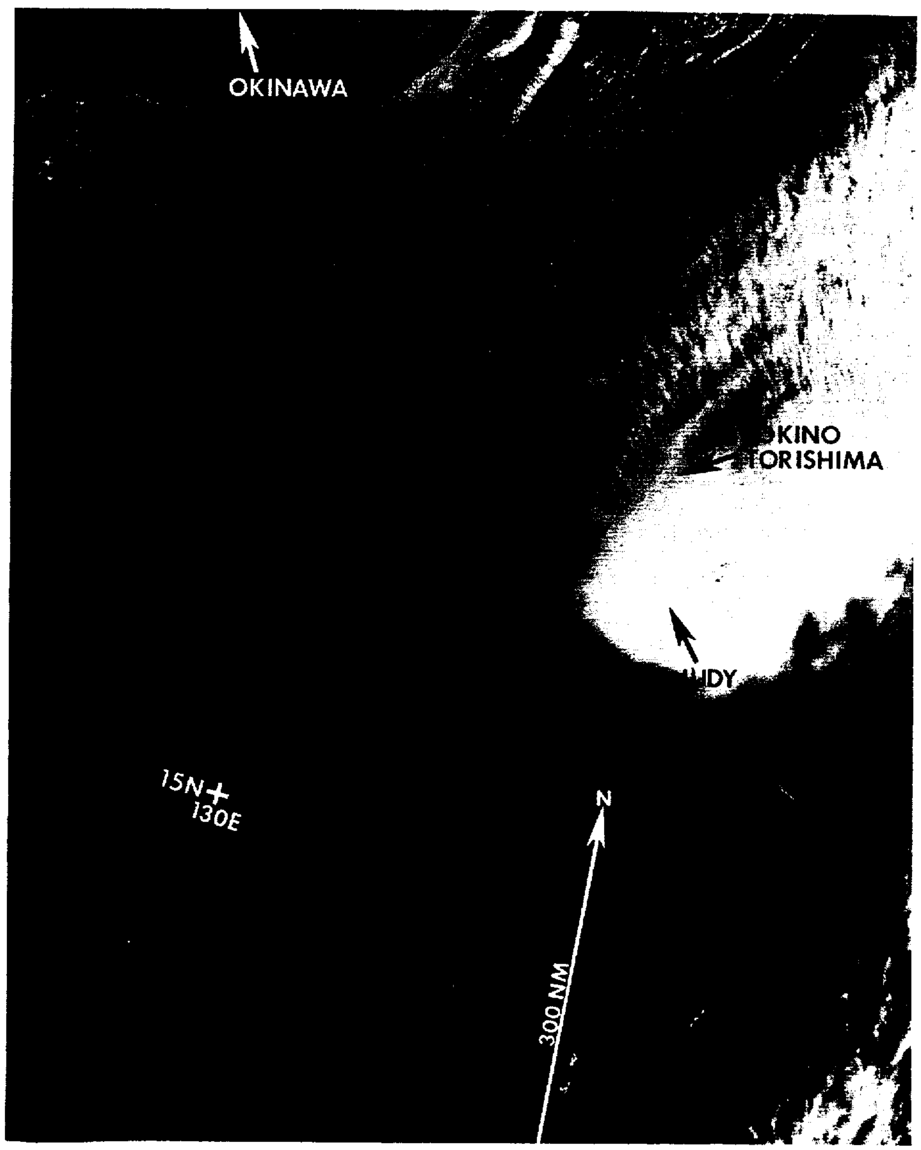
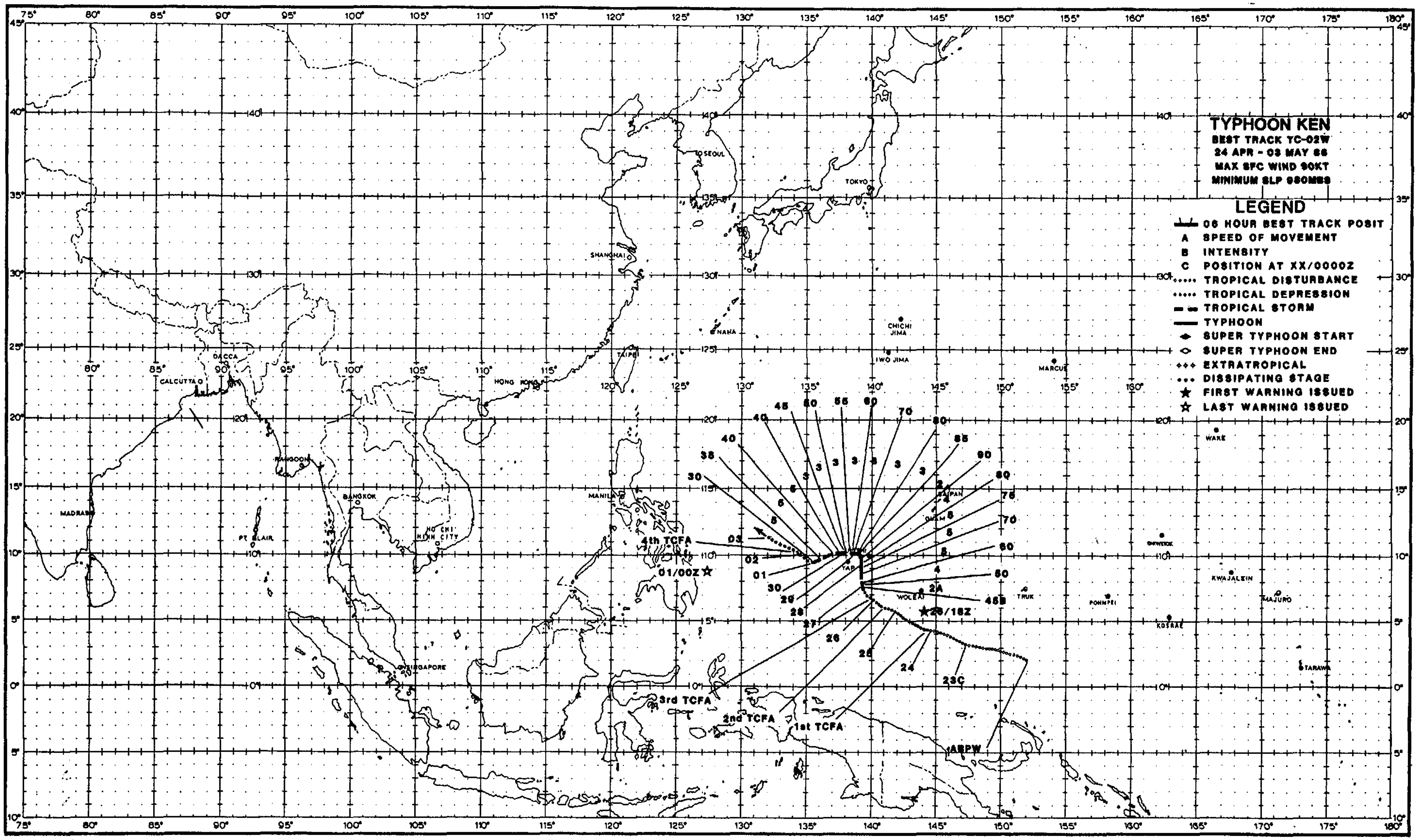


Figure 3-01-2. Typhoon Judy near maximum intensity (050120Z February DMSP visual imagery).



NOCC GUAM 3142/20 (NEW 5 - 80)

Typhoon Ken, the second tropical cyclone of 1986, was also the first tropical cyclone to develop in the western North Pacific in April during the past five years. After the formation of Ken, two tropical systems quickly followed in May.

During late April, the near-equatorial trough was quite active with enhanced convective activity from the southern Philippine Islands to the region south of Truk near the equator. Embedded within this trough was the tropical disturbance that eventually intensified into Typhoon Ken. At 200600Z, it was mentioned on the Significant Tropical Weather Advisory (ABPW PGTW) for the first time. No surface circulation was present, only convergent flow at the low levels. Synoptic data on 21 April indicated a weak surface circulation 540 nm (1000 km) south of Guam. The associated convection increased in amount and organization through the 23rd. Analysis of satellite imagery showed continued development and winds were estimated at 20 kt (10 m/sec). As a result, JTWC issued a Tropical Cyclone Formation Alert (TCFA) at 240730Z.

The first aircraft reconnaissance investigative mission was conducted the following day. It located a weak circulation center at 5000 ft (1524 m) 250 nm (463 km) southeast of Yap. Estimated surface winds were 10 to 25 kt (5 to 13 m/sec). These data, plus satellite imagery, prompted JTWC to reissue the TCFA at 250730Z.

A second aircraft reconnaissance investigative mission was conducted on the morning of the 26th and was again unable to locate a surface circulation. Instead, a broad area of troughing was observed at the surface with the maximum low-level winds of 25 to 30 kt (13 to 15 m/sec) within the convection banding in the northeast quadrant of the disturbance. Satellite data indicated the upper-level circulation center existed 90 nm (167 km) to the east-southeast of Yap (Figure 3-02-1). Based on that information, the third TCFA was issued at 260730Z.

The first warning on Ken was issued at 261900Z after satellite imagery showed a significant increase in the central convection and the development of a comma-shaped cloud pattern. Surface winds were

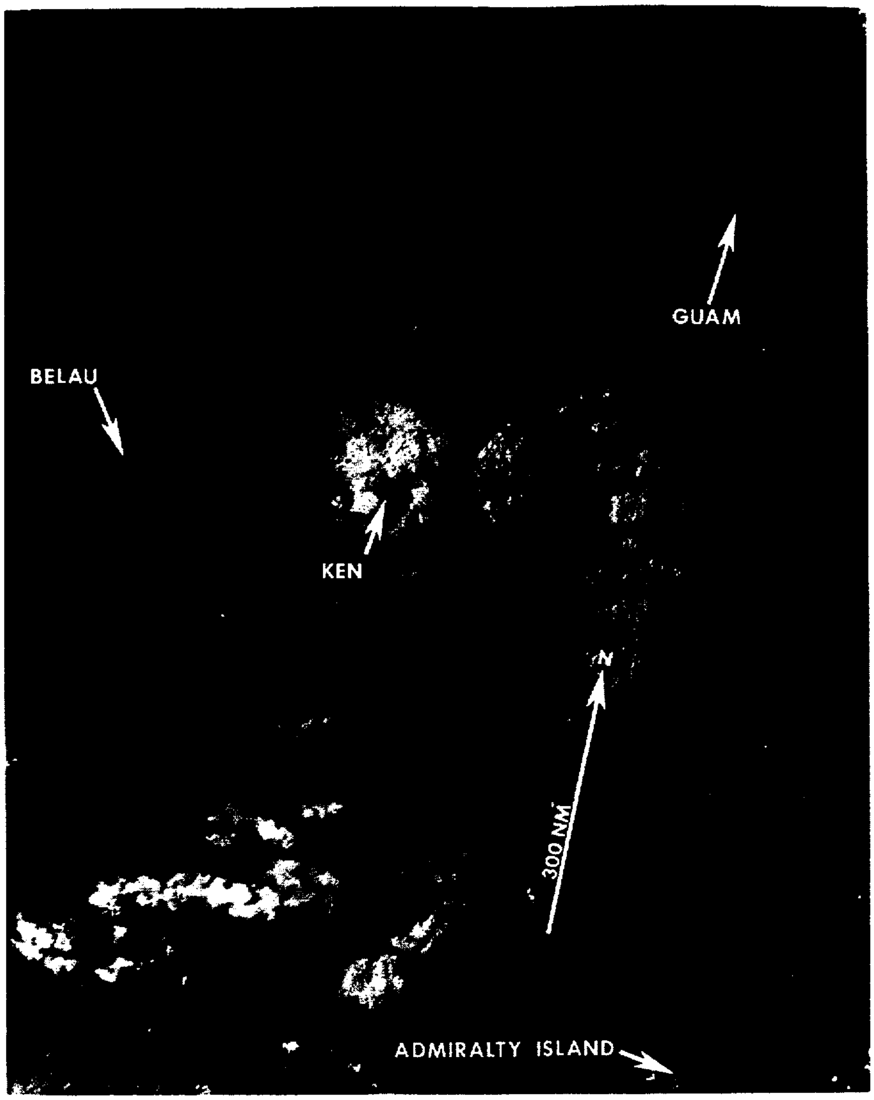


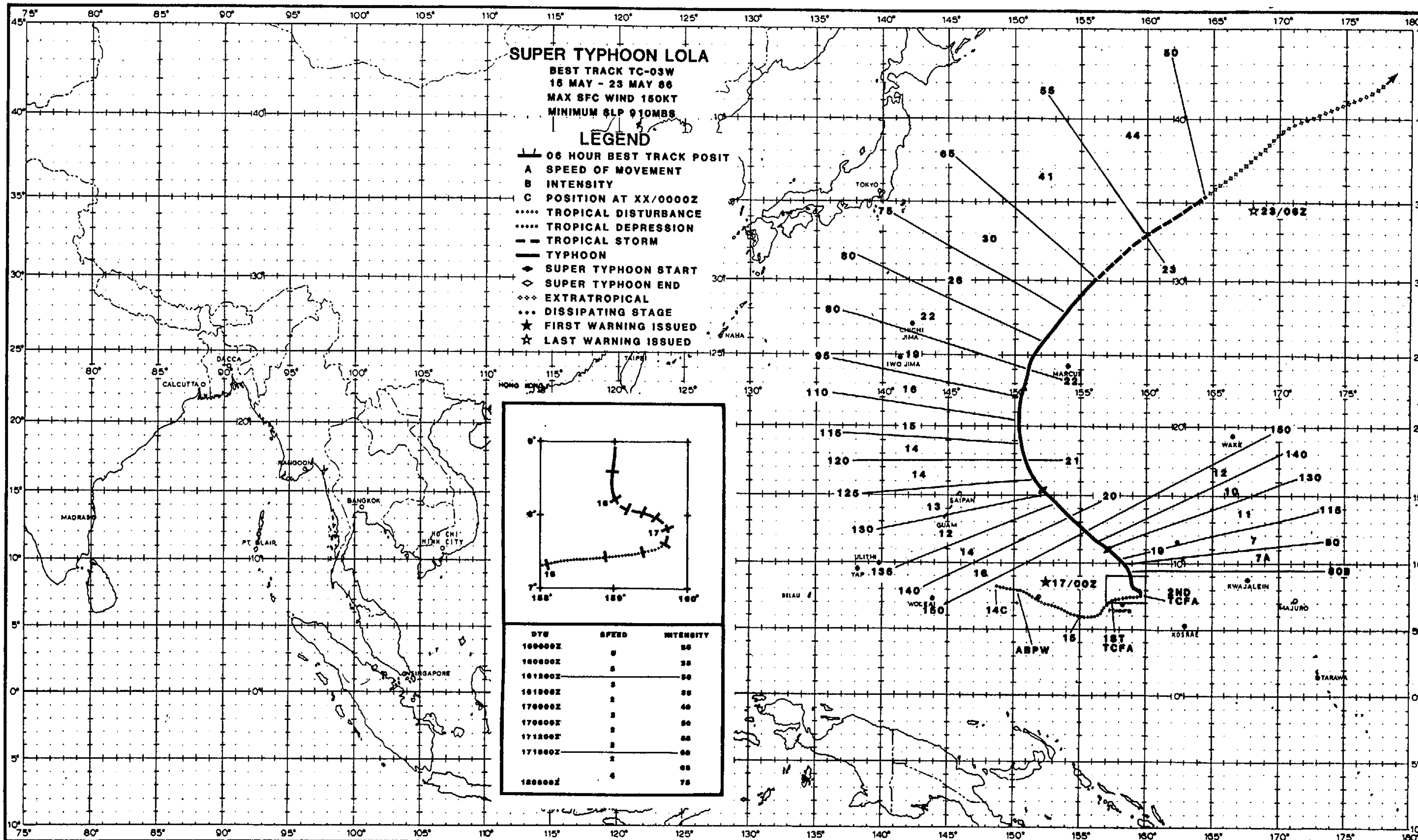
Figure 3-02-1. Typhoon Ken at the time the third TCFA was issued. The aircraft reconnaissance investigative mission into the disturbance two hours earlier was unable to find a surface circulation (260500Z April NOAA visual imagery).

estimated at 35 kt (18 m/sec). Ken reached typhoon intensity on the 27th. Aircraft reconnaissance penetration of the system revealed a compact surface circulation, a minimum sea-level pressure (MSLP) of 980 mb, and an elliptical eye (oriented east-west). Peripheral aircraft data showed the stronger surface winds of 30 to 50 kt (15 to 26 m/sec) in the northern semicircle in contrast to 15 to 20 kt (8 to 10 m/sec) in the southern semicircle. This resulted from the higher pressure gradient between Ken's low pressure center and the subtropical ridge. As gradual intensification took place, the forecast track for Ken became more northerly based on the expected influence of the mid-latitude trough on the mid-level subtropical ridge and the general tendency of intensifying tropical cyclones to move into higher latitudes. By 281800Z, after the trough passed eastward from Japan, the subtropical ridge reintensified across the northern Philippine Sea, forcing Ken to move westward.

Ken's intensity peaked at 90 kt (46 m/sec) on the 28th. Satellite imagery showed the system remained compact with a slight east-west elongation of the central dense overcast and an eye which was obscured by high cirrus. On the 29th, Ken began to weaken significantly. Aircraft reconnaissance reports indicated that the 700 mb center was displaced 20 nm (37 km) northeast of the surface center due to increased shearing flow aloft from the southwest. Throughout the next day, both aircraft and satellite reconnaissance found an exposed low-level circulation center. Since the upper-level circulation center was now displaced 170 nm (315 km) to the northeast of the low-level circulation (Figure 3-02-2), the last warning, valid at 0300Z on the first of May, was issued. Stripped of its deep central convection, the residual low-level cyclonic vorticity drifted westward and dissipated over water by the 3rd.

No reports of damage or injuries were attributed to Ken. Of interest, Ken's proximity to Guam and slow movement caused official concern because of the scheduled refueling stop of Air Force One at Andersen AFB. Once the tropical cyclone's track changed to west late on 28 April, serious worries were removed. In summary, forecasting direction changes for slow moving tropical cyclones is usually difficult - Ken was no exception. JTWC's ability to correctly forecast slow movement along the track resulted in a good product and excellent statistics.

Figure 3-02-2. Typhoon Ken during its final stage. Note the large (170 nm (315 km)) displacement between the exposed low-level circulation and the upper-level circulation (302133Z April DMSP visual imagery).



NOCC GUAM 3142/20 (NEW 5 - 80)

Super Typhoon Lola was the first of three super typhoons (tropical cyclones with 130 kt (67 m/sec) or greater intensity) to occur during 1986. Lola's appearance coincided with a very destructive tropical cyclone in the southern hemisphere, Tropical Cyclone 33P (Namu) (see Figure 3-03-1). Namu, an unusual "twin" cyclone with Lola, was the worst tropical cyclone to strike the Solomon Islands this century. Over 90,000 people were left homeless on the island of Guadalcanal and nearly 100 people died as a result of the fury of Namu. From a historical perspective, Lola was of particular interest to residents of Guam since its appearance coincided with the ten year anniversary of Super Typhoon Pamela's devastating visit to the island on May 21, 1976. Super Typhoon Pamela (1976) destroyed 40 percent of the homes on Guam and caused extensive damage with torrential rains and maximum sustained winds of 120 kt (63 m/sec) and gusts to 145 kt (70 m/sec).

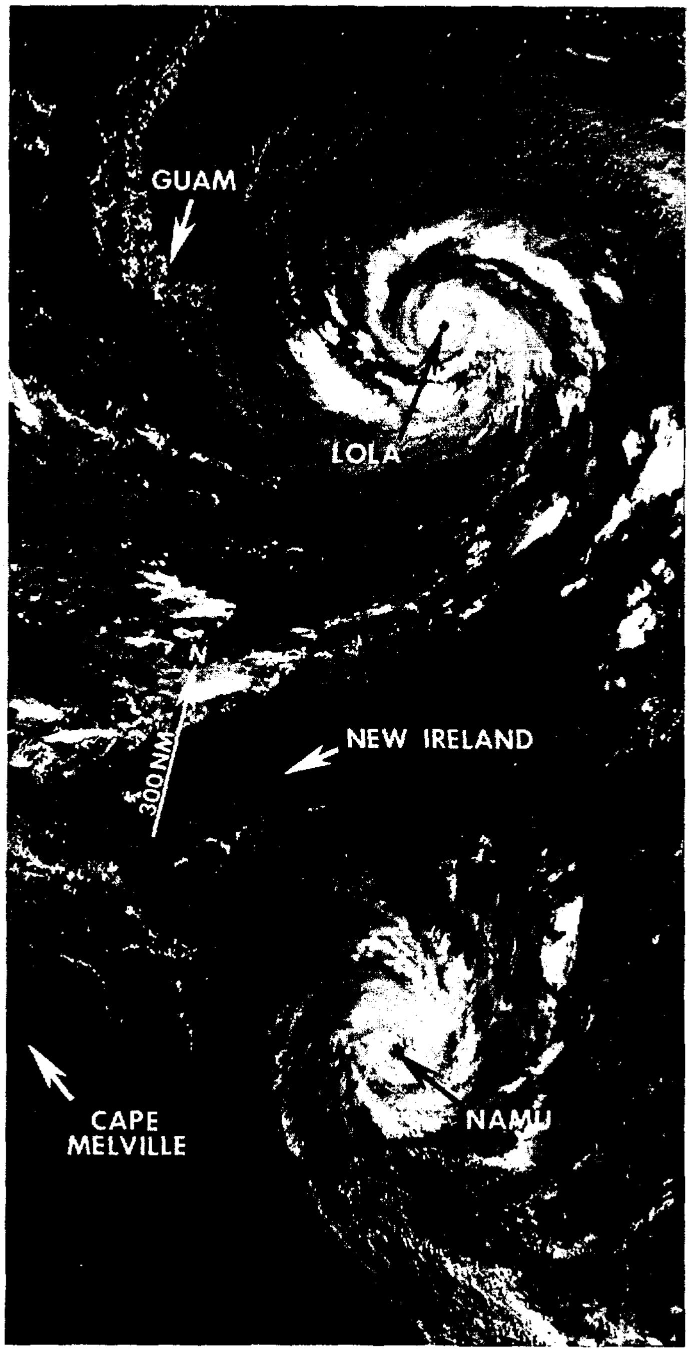


Figure 3-03-1. Super Typhoon Lola and Tropical Cyclone 33P (Namu). This is an unusual case of "twin" tropical cyclones occurring in opposite hemispheres (192349Z May DMSP visual imagery).

Lola began as a tropical disturbance in a very active monsoon trough extending from south of Guam eastward to the Marshall Islands. This area of disturbed weather was enhanced by two opposing wind flows - cross-equatorial winds provided strong southwesterly flow and the tradewinds provided northeasterly flow. For several days prior to Lola's inception, destructive winds and torrential rains battered the Caroline Islands. The island atoll of Nukuoro 285 nm (528 km) southeast of Truk, for example, experienced damage from winds of 40 kt (21 m/sec) with gusts to 60 kt (31 m/sec) on 14 May associated with severe thunderstorms.

At that time Lola was just a tropical disturbance 50 nm (93 km) northwest of Truk and received mention on the Significant Tropical Weather Advisory (ABPW PGTW) because of its persistent cloudiness. Within 24-hours, sea-level pressures dropped throughout the monsoon trough as Lola increased in organization (see Figure 3-03-2). These

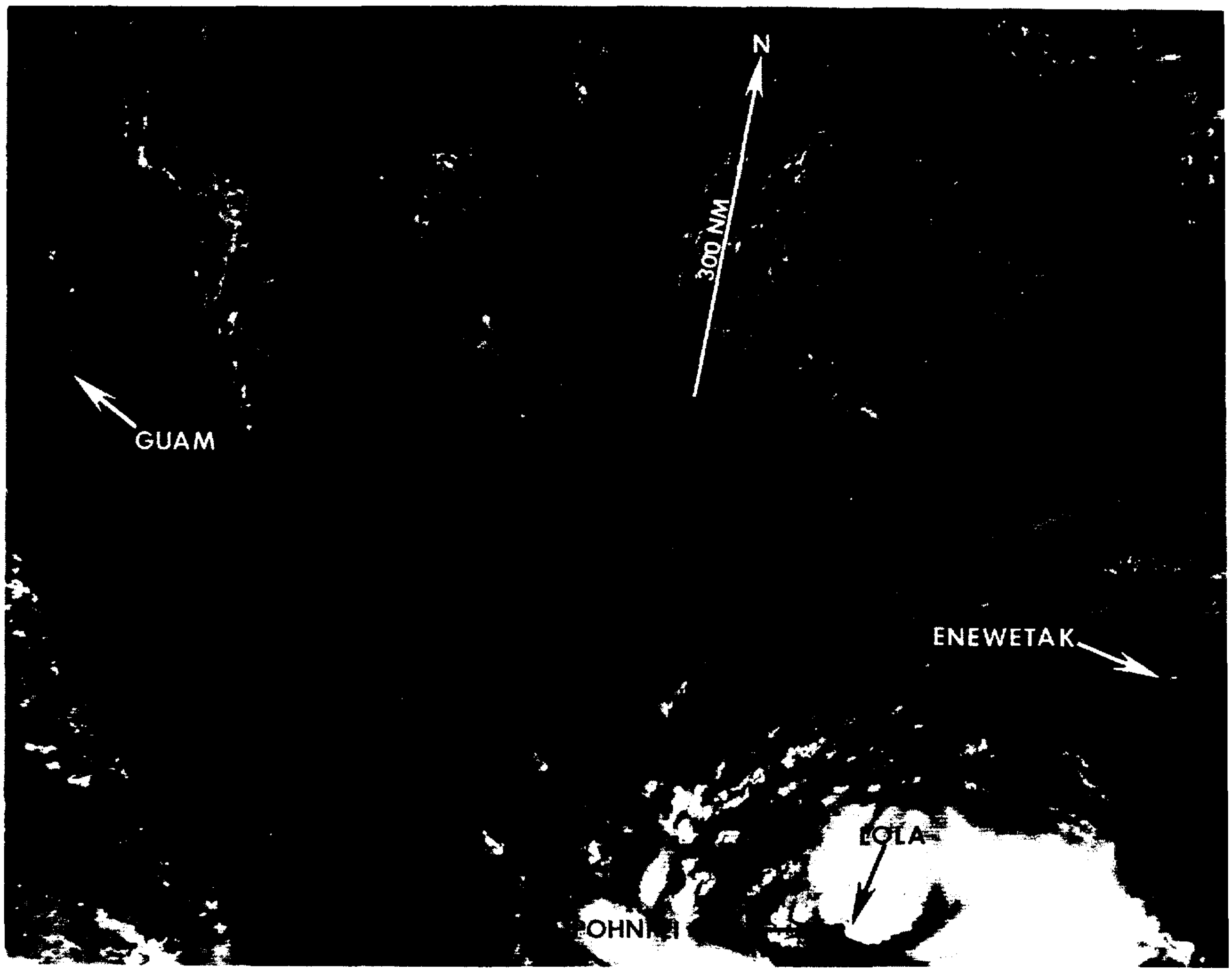


Figure 3-03-2. Lola showing increased organization at low latitudes (152330Z May DMSP visual imagery).

events prompted the issuance of a Tropical Cyclone Formation Alert (TCFA) valid at 152330Z. Aircraft reconnaissance scheduled to investigate the disturbance at that time turned back to Guam due to the loss of hydraulic fluid. A second TCFA was issued at 161530Z when Lola moved outside of the alert area. The first warning on Tropical Depression 03W followed at 170000Z based on analysis of satellite imagery (Figure 3-03-3) and synoptic data that clearly indicated a closed circulation. An aerial reconnaissance investigative mission later that day discovered winds of 40 kt (21 m/sec) at the surface and an estimated minimum sea-level pressure (MSLP) of 981 mb. Lola was subsequently upgraded to a tropical storm with the second warning, valid at 170600Z. Due to its proximity to Pohnpei, Lola caused extensive damage to the island; mostly due to flooding and high winds. Authorities there claimed it was the worst battering Pohnpei had suffered in the past 28 years since Typhoon Ophelia (1958).

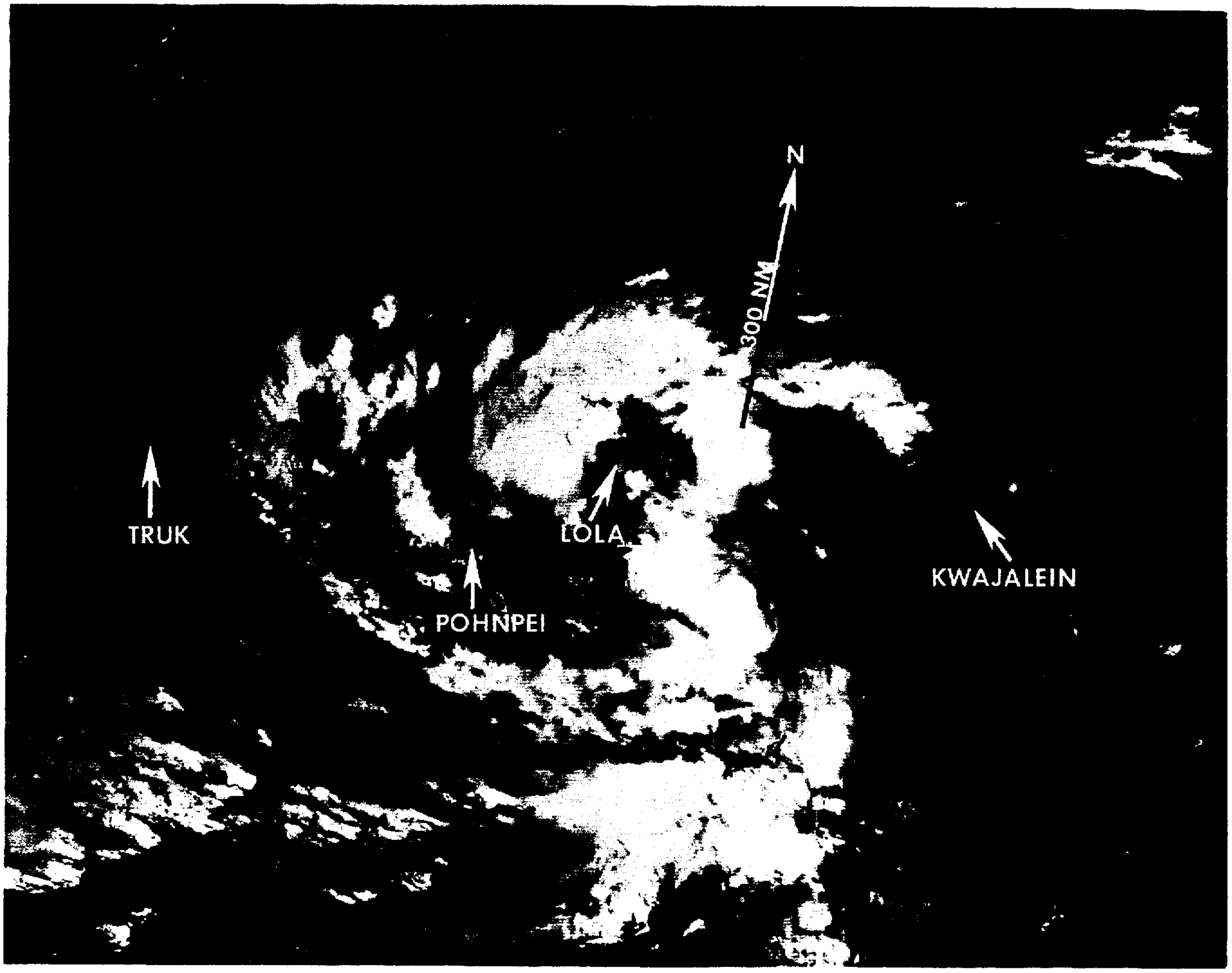


Figure 3-03-3. Lola a day later showing more convective activity and curvature (162309Z May DMSP visual imagery).

By early morning on the 18th, Lola was already at typhoon intensity (see Figure 3-03-4). Initial interpretation of data from the second synoptic track mission flown along 18 degrees North Latitude determined there were no obvious breaks in the ridge north of Lola (Figure 3-03-5), thus the forecast took Lola northward initially, and then westward under the ridge. (Upon closer inspection of the 500 mb data, there is cyclonic turning at the western portion of the track. This implies a weakness in the subtropical ridge slightly north of the track and near 150 degrees East Longitude.) By late afternoon, Lola's intensity had increased to 75 kt (40 m/sec) and an eye became clearly visible on satellite imagery. A third synoptic track, flown the next day (19 May), again along 18 degrees North Latitude, still did not find any breaks in the subtropical ridge and the forecast appeared to be right on track. However, Lola was only two days away and all of Guam worried that this might be a repeat of Super Typhoon Pamela (1976). JTWC's warning on the morning of the 19th indicated Lola would become a super typhoon (see Figure 3-03-6). A three fix mission was flown into Typhoon Lola that morning to determine the rate at which it was intensifying. The results confirmed the worst - explosive deepening.

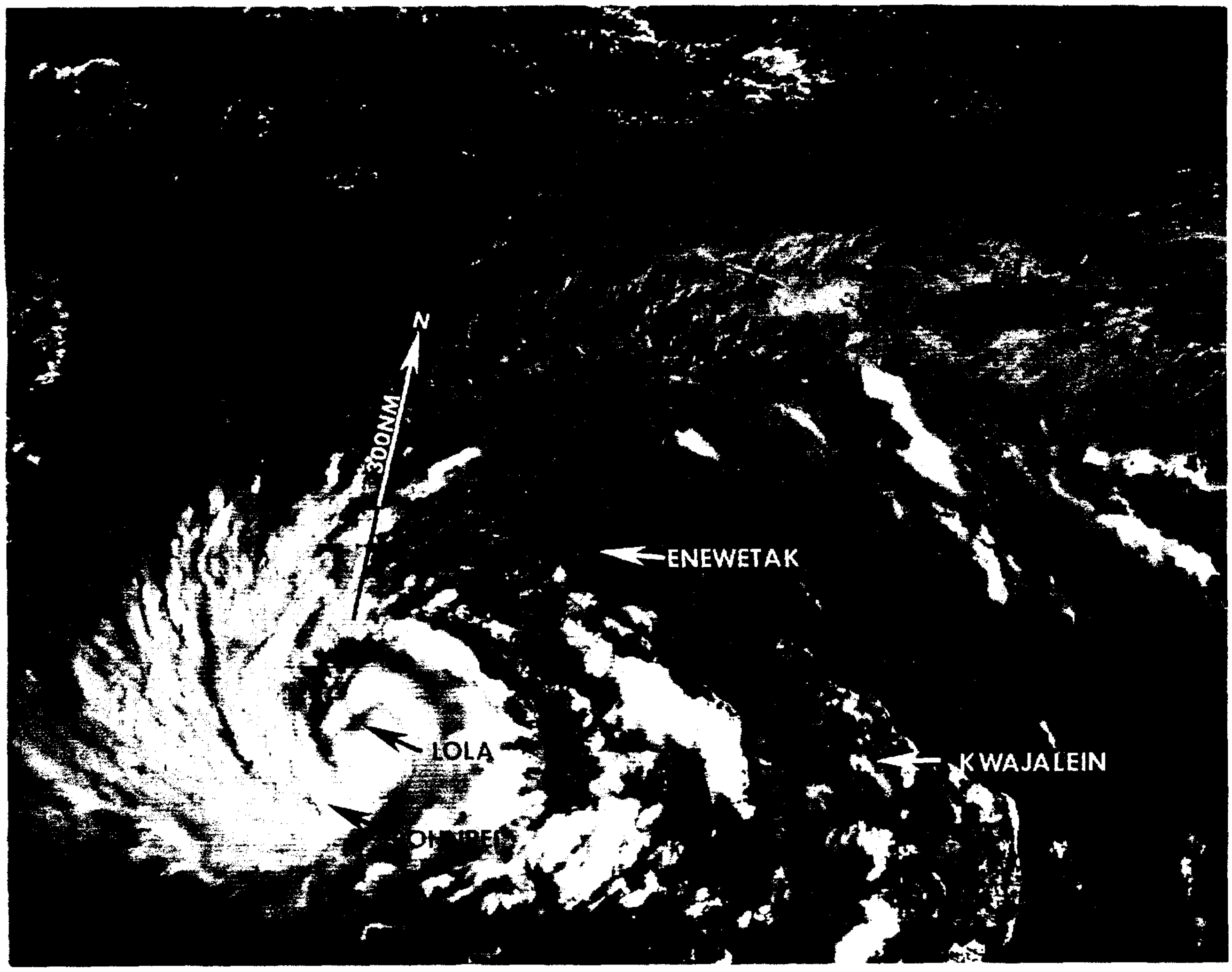


Figure 3-03-4. Lola on the third day reached typhoon intensity (172249Z May DMSP visual imagery).

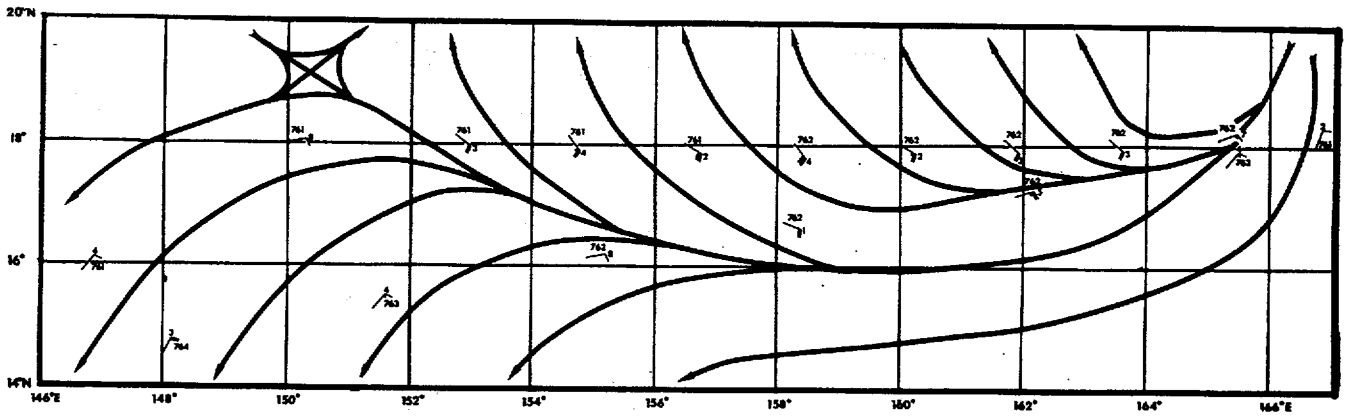


Figure 3-03-5. Data from the second synoptic track (172300Z through 180700Z) shows no obvious break in the subtropical ridge. (Upon closer inspection the streamlines imply a neutral point in the flow slightly north of the track and along 150 degrees East Longitude.)

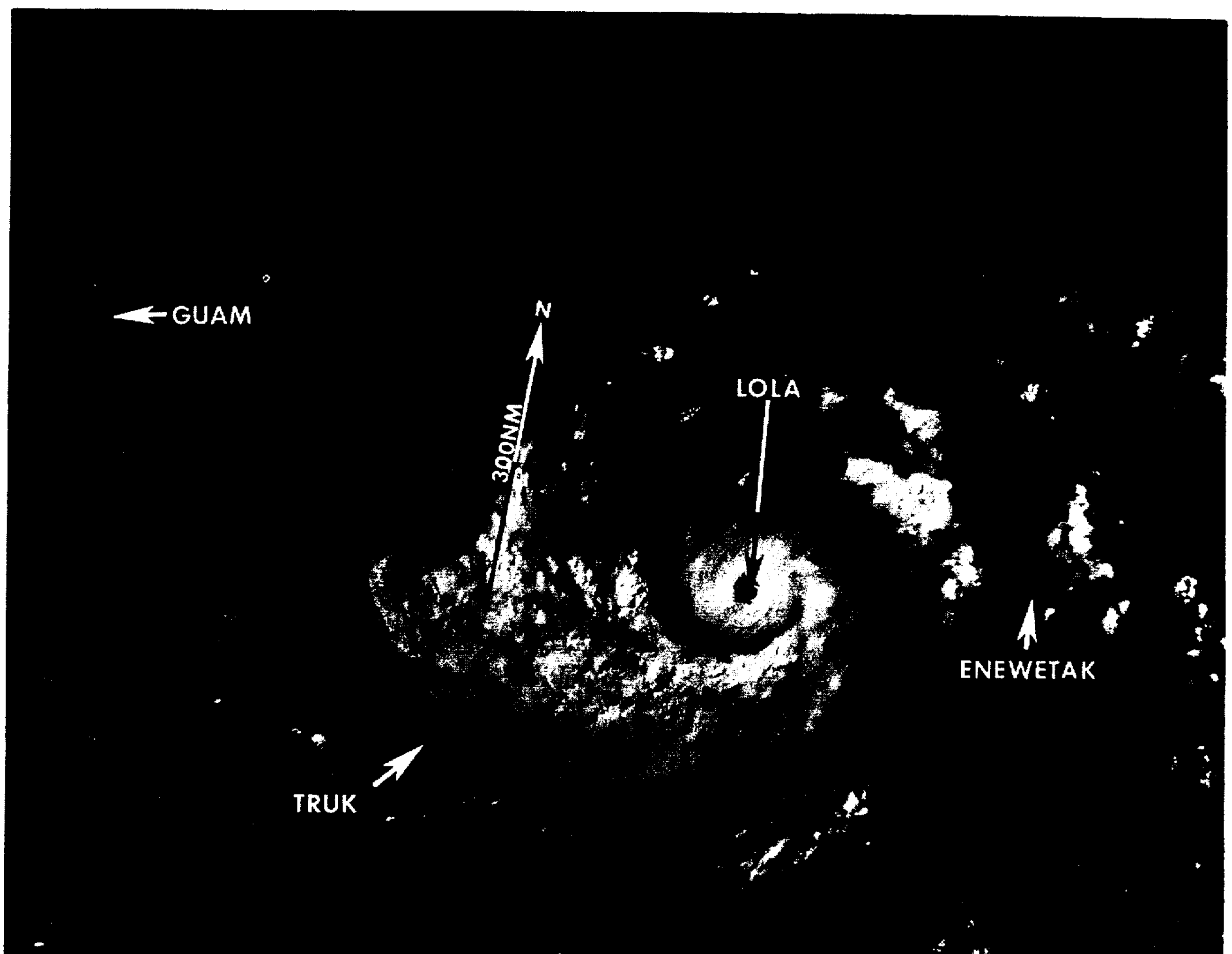


Figure 3-03-6. Lola near maximum intensity of 150 kt (77 m/sec) (190414Z May NOAA visual imagery).

Lola became a super typhoon at 130 kt (67 m/sec) and was forecast to intensify even more as it neared Guam. A fourth synoptic track mission was sent out on 20 May to locate any weakness in the subtropical ridge. The data showed the ridge at 400 mb displaced south and west across the path of Lola with a strong zone of mid-level divergence stretching from Guam through the northern Marianas (Figure 3-03-7). The forecast philosophy changed to a recurvature track rather than keeping the track toward the west-northwest. The intensity estimates indicated Lola had peaked at 191800Z at 150 kt (77 m/sec) and was now decreasing (see Figure 3-03-8). Aircraft reconnaissance that night (20 May) confirmed this

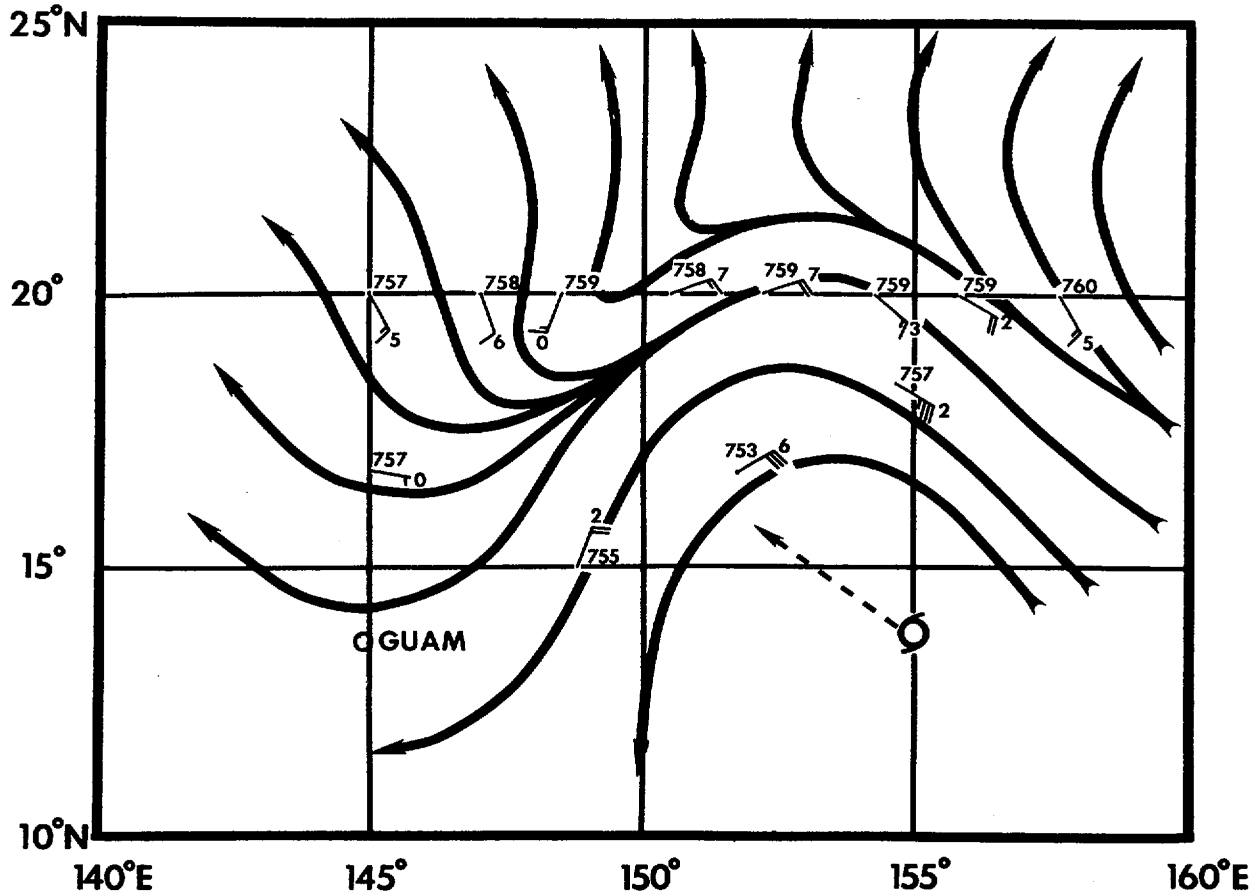


Figure 3-03-7. Data from the fourth synoptic track (192200Z through 200400Z May) shows the mid-level ridging displaced south and west across Guam.

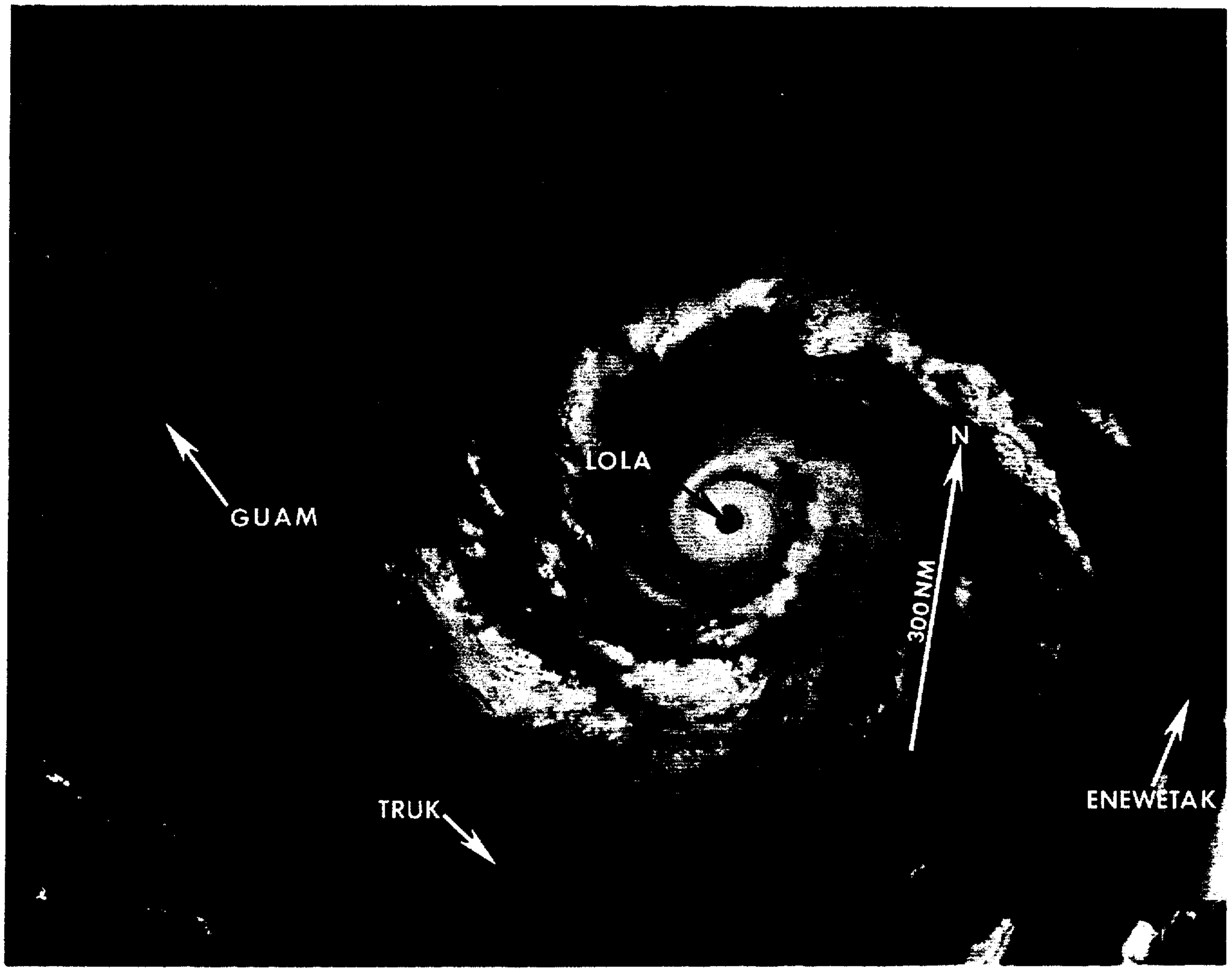


Figure 3-03-8. Lola shortly after it peaked at 150 kt (77 m/sec) (192350Z May DMSP visual imagery).

fact as the 700 mb heights also increased dramatically. Figures 3-03-9 and 3-03-10 show Lola weakening and becoming extratropical. Extratropical transition was completed on 23 May.

In retrospect, the early forecasts followed the Nested Tropical Cyclone Model (NTCM) too long during Lola's development and took the system toward the Marianas. Fortunately, JTWC made the right decision later to follow the One-way Interactive Tropical Cyclone Model (OTCM) and curved Lola toward the northeast before any major efforts had to be made to sortie ships and evacuate aircraft from the military bases on Guam (closest point of approach to Guam was 405 nm (750 km) to the northeast). However, the statistical damage had already been done and the overall forecast performance was only fair.

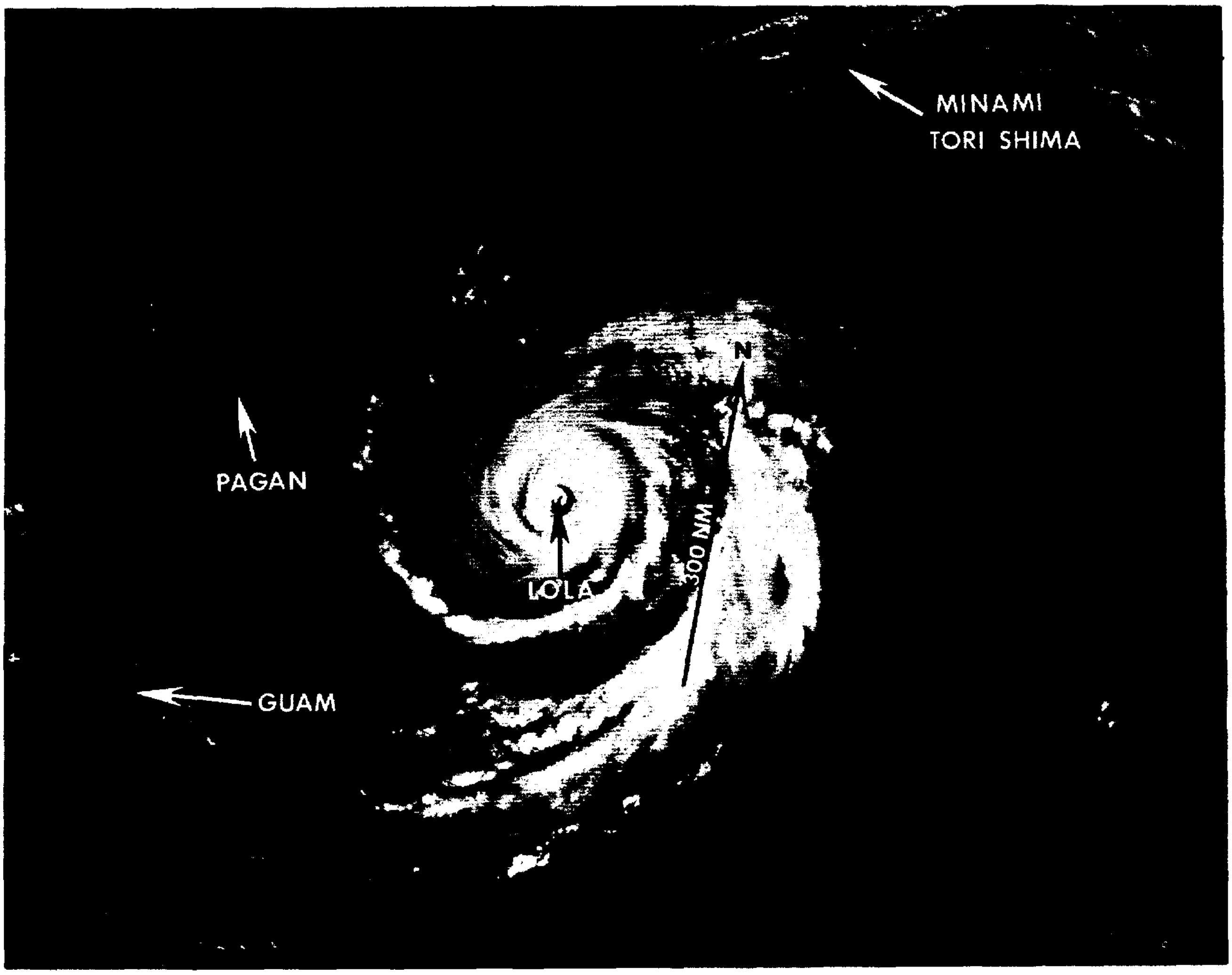


Figure 3-03-9. Lola decreasing in intensity (202329Z May DMSP visual imagery).

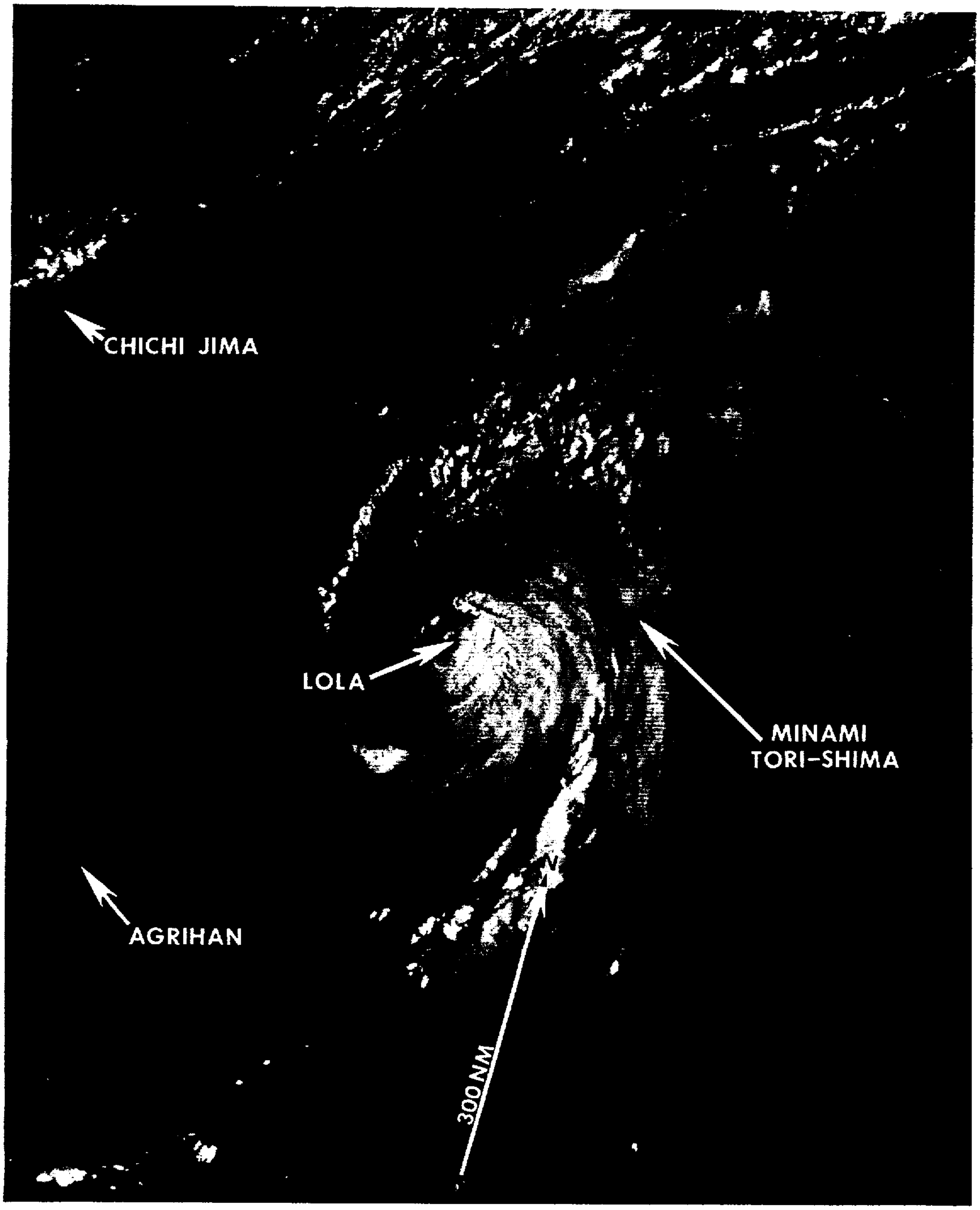
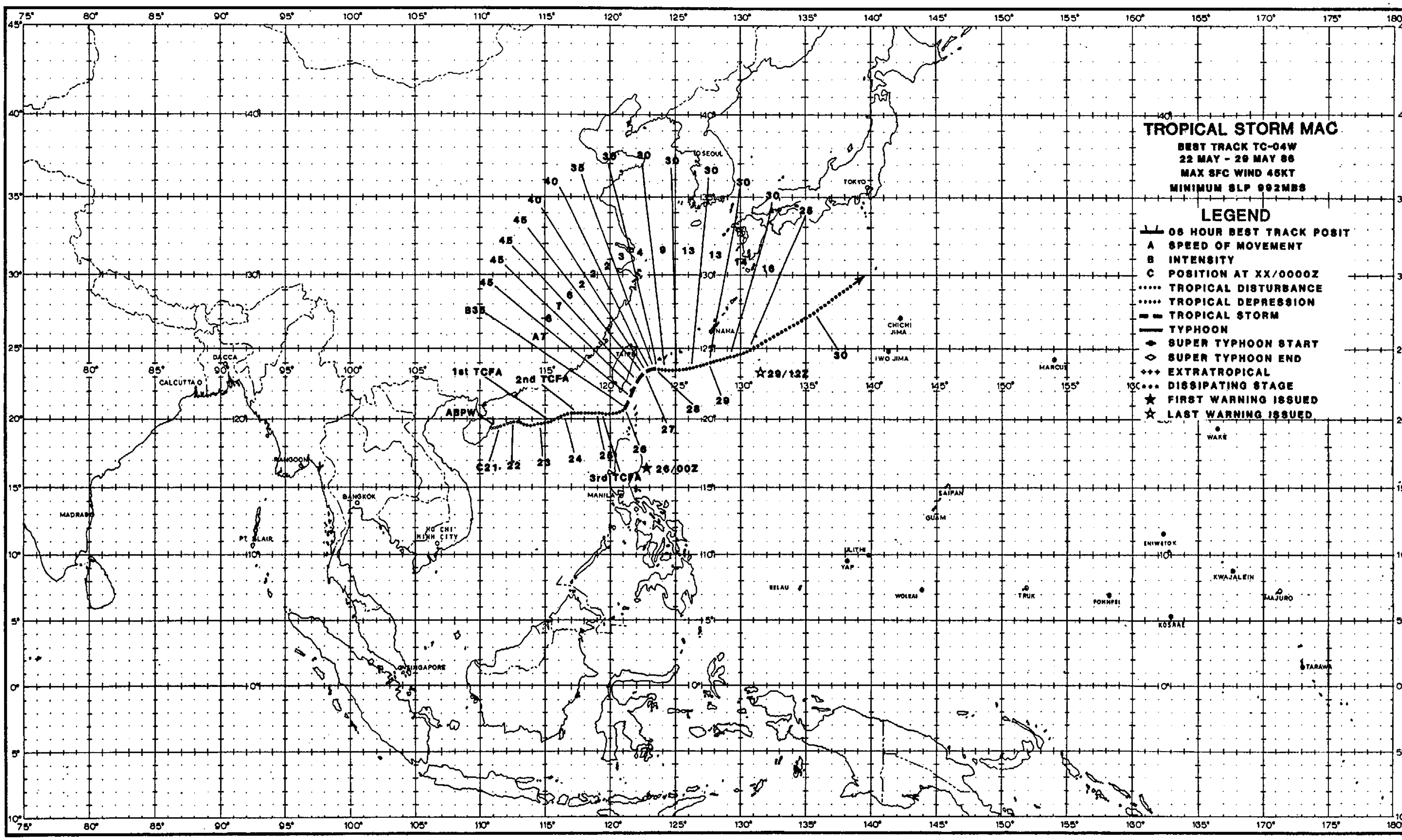


Figure 3-03-10. Lola transitioning to an extratropical system (212309Z May DMSP visual imagery).



NOCC GUAM 3142/20 (NEW 5 - 80)

Mac, from inception, was a "classic" monsoon depression - slow to develop, difficult to position and forecast. As Super Typhoon Lola (03W) was developing east of Guam, the precursor of Mac spawned in the monsoon trough in the South China Sea.

On May 20th, the Significant Tropical Weather Advisory (ABPW PGTW) mentioned a poorly defined area of convection in the monsoon trough, which was located over water and paralleled the southern coast of mainland China. Estimated maximum sustained surface winds of 20 kt (10 m/sec) and a minimum sea-level pressure (MSLP) of 998 mb were present. After several false starts, the organizing convection separated from the maximum cloudiness zone and a Tropical Cyclone Formation Alert was issued for the disturbance, at 230400Z, as it passed south of Hong Kong. The first warning was issued on Tropical Storm Mac (Figure 3-04-1) at 250000Z as development

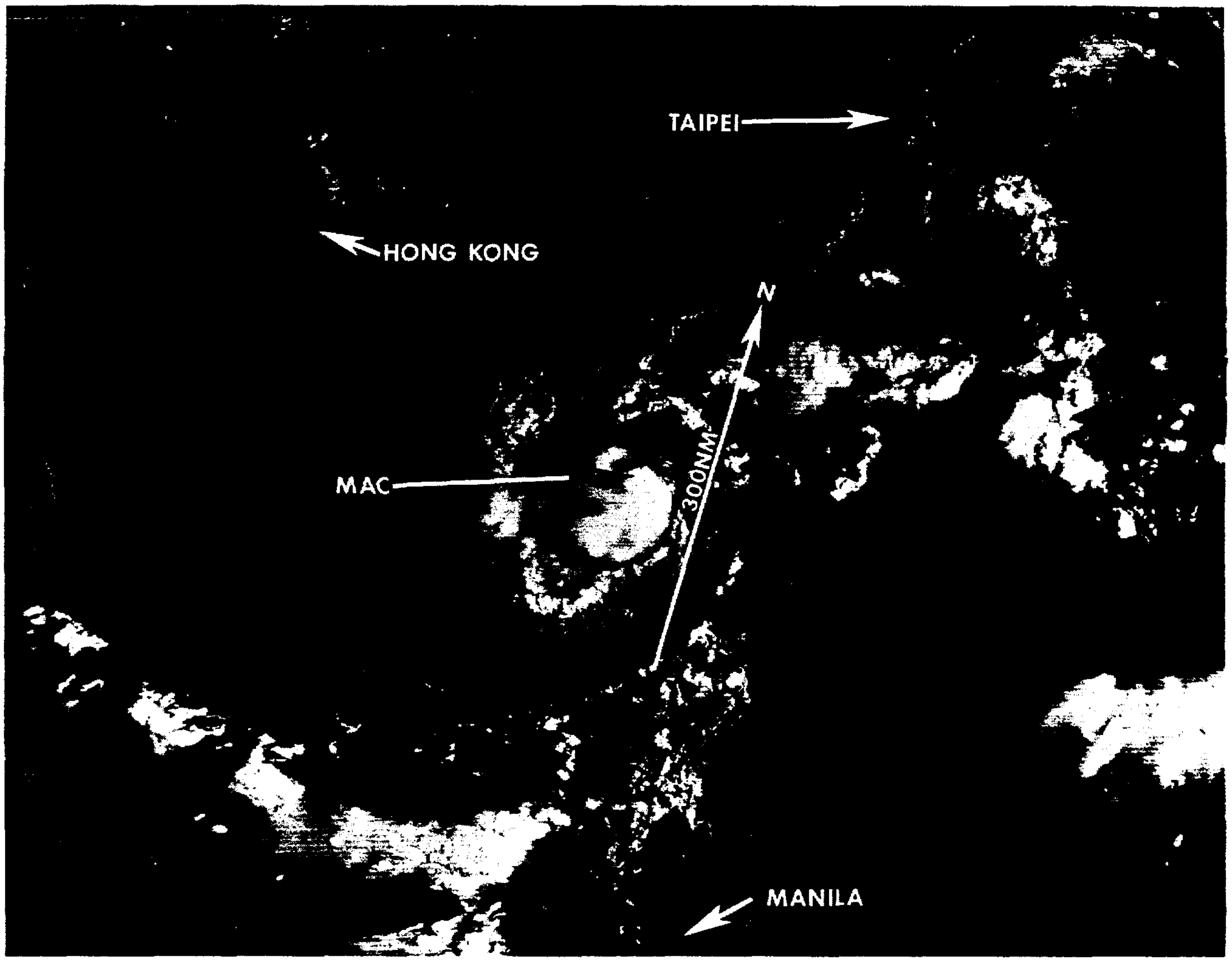


Figure 3-04-1. Tropical Depression 04W just an hour and a half after the first warning was issued (250131Z May DMSP visual imagery).

continued. Mac moved south of Taiwan and changed course toward the north-northeast as its intensity peaked at 45 kt (23 m/sec). At 270900Z, Mac appeared to become almost quasi-stationary. However, acceleration and an eastward movement commenced by 280600Z. Mac also weakened due to increased vertical shear and was, as a result, downgraded to a tropical depression on the 28th.

By May 29th, Mac's low-level circulation center was partially exposed (Figure 3-04-2). The last warning was issued at 291200Z as Mac began dissipating over water and redevelopment appeared less likely due to the persistent strong vertical wind shear.

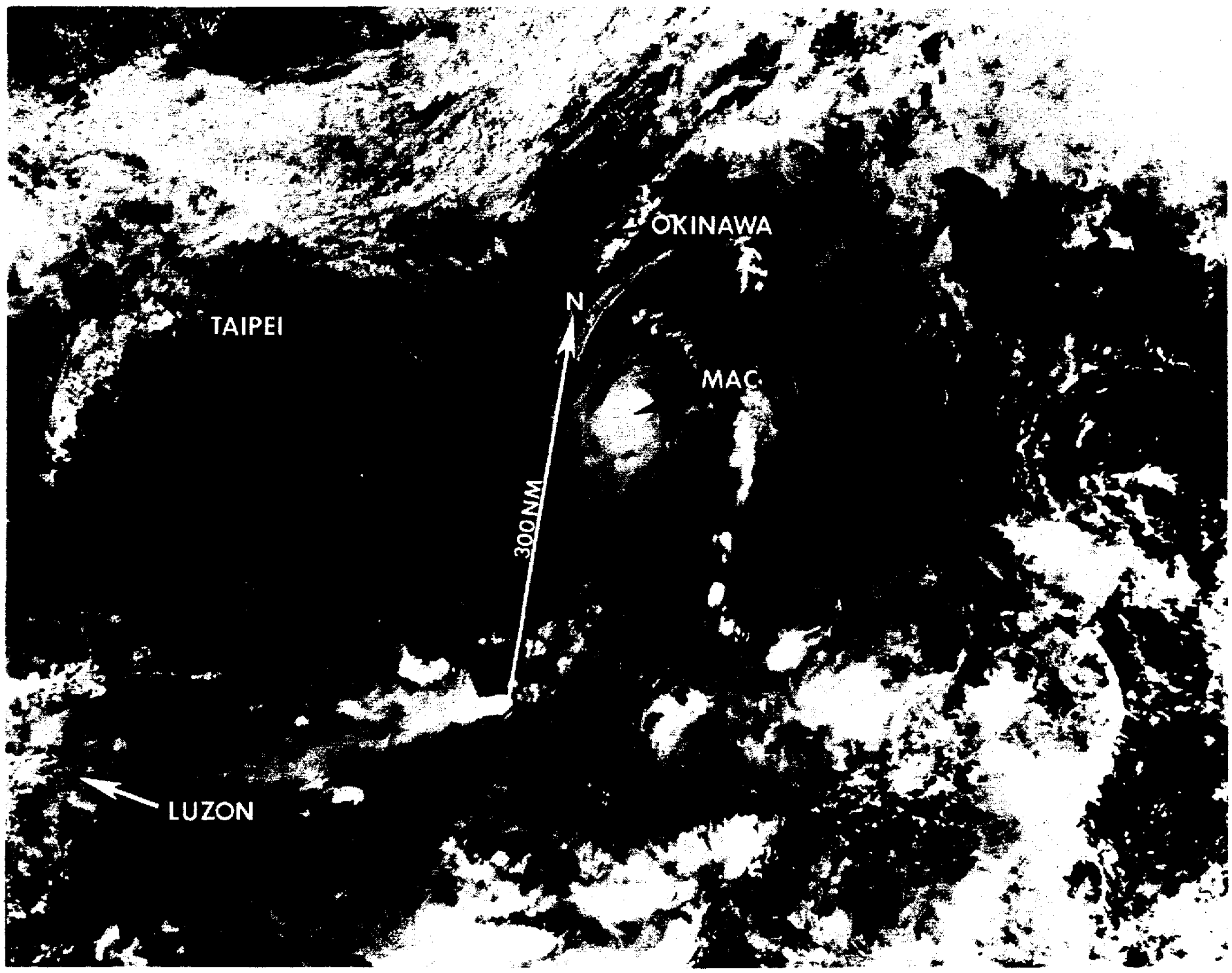
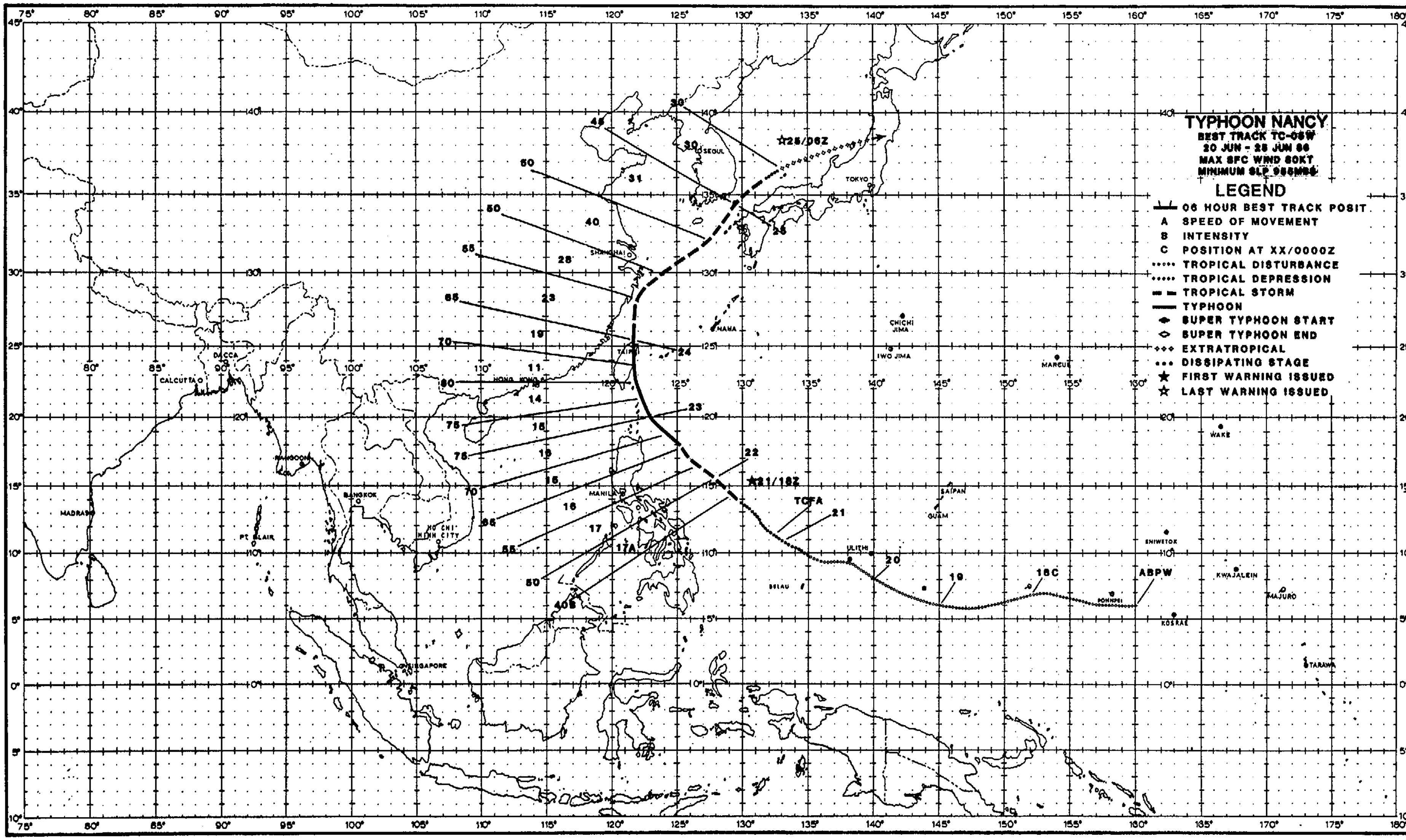


Figure 3-04-2. Mac's partially exposed low-level circulation center as seen six hours before the last warning was issued (290550Z May NOAA visual imagery).



NOCC GUAM 3142/20 (NEW 5 - 80)

For the first five months of 1986, the western North Pacific averaged less than one tropical cyclone per month. Nancy was the fifth tropical cyclone in the western North Pacific, but the first of the what is generally considered the summer typhoon season. After Typhoon Nancy, the summer season was in full swing.

The Significant Tropical Weather Advisory (ABPW PGTW) on 170600Z June mentioned an area of broad, disorganized convection which was developing 120 nm (222 km) southeast of Pohnpei. This area moved rapidly westward for the next two days, then slowed and began to consolidate. By 191200Z, an established cirrus outflow pattern, restricted to the northwest by an upper-level cold low 540 nm (1000 km) northwest of Guam, was detected on satellite imagery. Initial Dvorak intensity analysis of the cloud pattern estimated surface winds of less than 25 kt (13 m/sec). At 210330Z, a Tropical Cyclone Formation Alert (TCFA) was issued for the area. Within hours the convective curvature improved and the 211600Z Dvorak intensity estimate indicated winds of 30 kt (15 m/sec). Based on these data, the first warning for Tropical Depression 05W was issued at 211800Z.

Aircraft reconnaissance into Tropical Depression 05W at 220001Z reported maximum surface winds of 60 kt (31 m/sec) displaced 21 nm (39 km) east-southeast of the center of the system. Aircraft reconnaissance also observed a developing eyewall that was open on the west through north quadrants. As a result, the 220000Z warning upgraded Tropical Depression 05W to Tropical Storm Nancy. Less than 24-hours after the upgrading to tropical storm intensity, Nancy was upgraded to typhoon intensity. In retrospect, analyses of aircraft reconnaissance data and intensity trends indicate that tropical storm intensity was most probably attained at 211500Z, not 220000Z.

Throughout this period of development, Nancy (Figure 3-05-1) moved toward the northwest under the steering influence of the subtropical ridge to the north. Nearing the subtropical ridge axis on 23

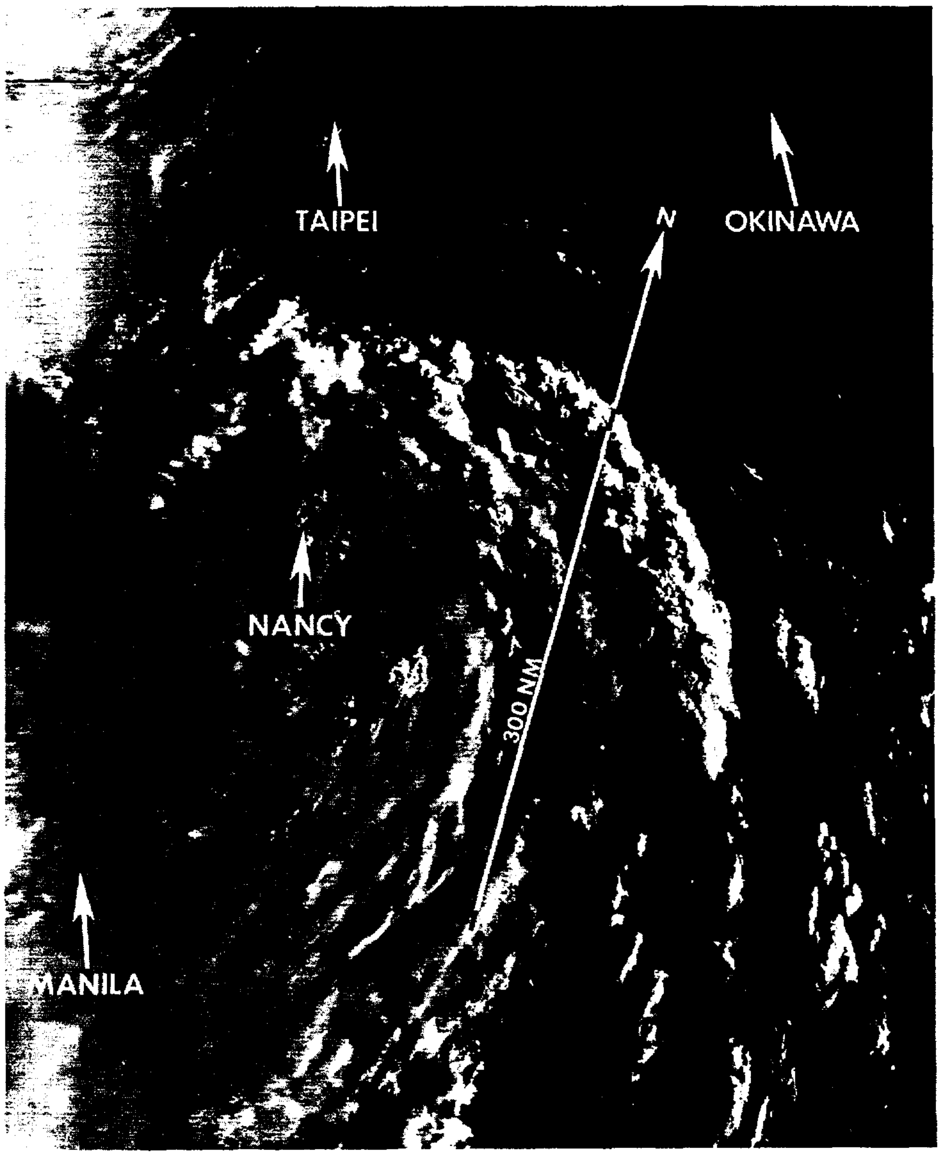


Figure 3-05-1. Typhoon Nancy approaching the island of Taiwan. The mountainous spine of the island is visible to the north of the tropical cyclone (222115Z June DMSP visual imagery).

June, the tropical cyclone assumed a more northerly course. For the next 24-hours aircraft reconnaissance data was unavailable due to the close proximity of land and airspace restrictions. Radar (Figure 3-05-2) and satellite (Figure 3-05-3) reports were particularly valuable during this time. These two figures, which were taken within one half hour of each other, provide strikingly different remotely sensed presentations of the eye. The radar detects the encircling rainbands, that are embedded in the clouds, and satellite sees the cold top of the central dense overcast as concentric patterns of gray shade. Just prior to making contact with the island of Taiwan, Nancy's intensity peaked at 80 kt (41 m/sec). The maximum surface wind reported from Taiwan was 63 kt (32 m/sec).

Continuing to move northward across the East China Sea, Nancy began interacting with a trough in the polar westerlies. The shape of the tropical cyclone became elongated as the low-level circulation center separated from the upper-level and the central convection decreased. At that time, Typhoon Nancy was downgraded to a tropical storm.

Later, aircraft reconnaissance at 242141Z was unable to locate a low-level circulation center due to airspace restrictions; however the peripheral data

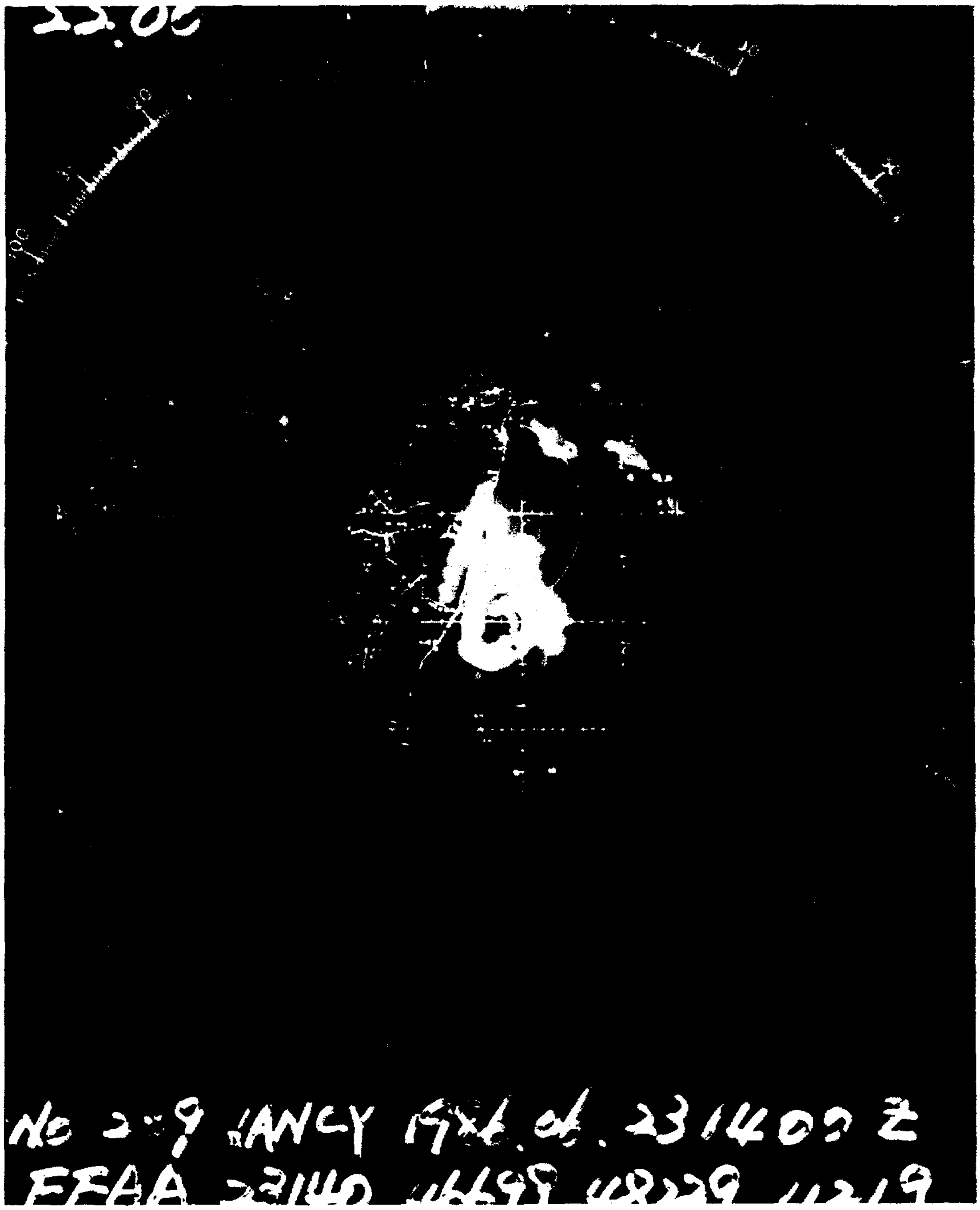


Figure 3-05-2. The eye of Typhoon Nancy as seen by radar from Hualien, Taiwan (WMO 46699) at 231400Z June (Photograph courtesy of Central Weather Bureau, Taipei, Taiwan).

proved most valuable and indicated the low-level center was displaced at least 60 nm (111 km) northwest of the 241800Z warning position. This warning position had been extrapolated from the previous warning. Unfortunately, the 241200Z warning was based on a low confidence nighttime position from infrared satellite imagery that was suspect, since Nancy was undergoing extratropical transition. The amended 241800Z warning, which followed immediately and was based on aircraft reconnaissance data, correctly forecast Nancy's movement through the Korea Straits instead of over the island of Kyushu, Japan. By that time increased vertical wind shear and entrained cooler, drier air had taken their toll on the tropical cyclone. Nancy continued to move rapidly northeastward through the Korea Strait and maintained the strongest low-level winds in the southeast semicircle. Southern Korea received torrential rains, which inundated 22,477 acres (9100 hectares) of farmland. Twelve people were reported dead or missing, as a result of the flooding.

Satellite analysis early on 25 June indicated extratropical transition had occurred in the Sea of Japan. The system was finalled on the 250600Z warning as the residual low pressure area swept eastward across northern Honshu 12-hours later.

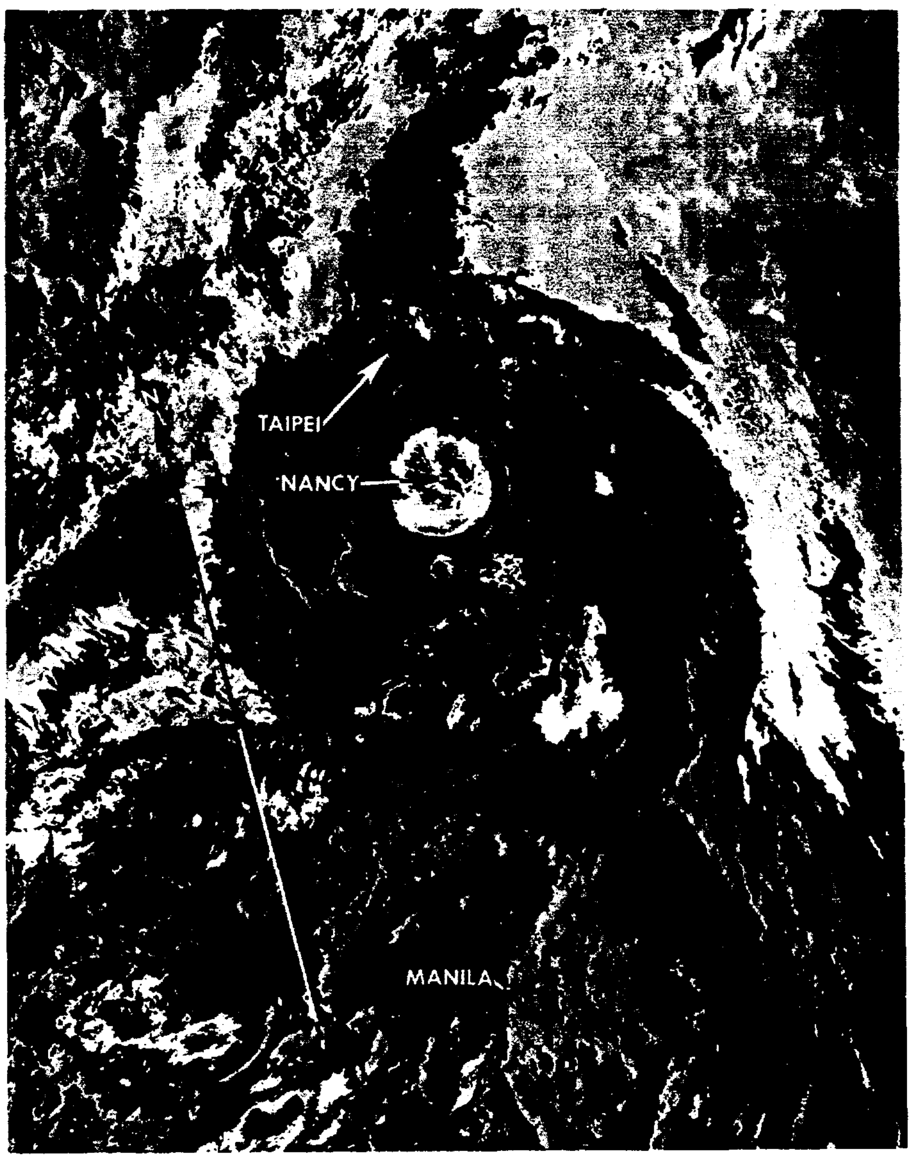
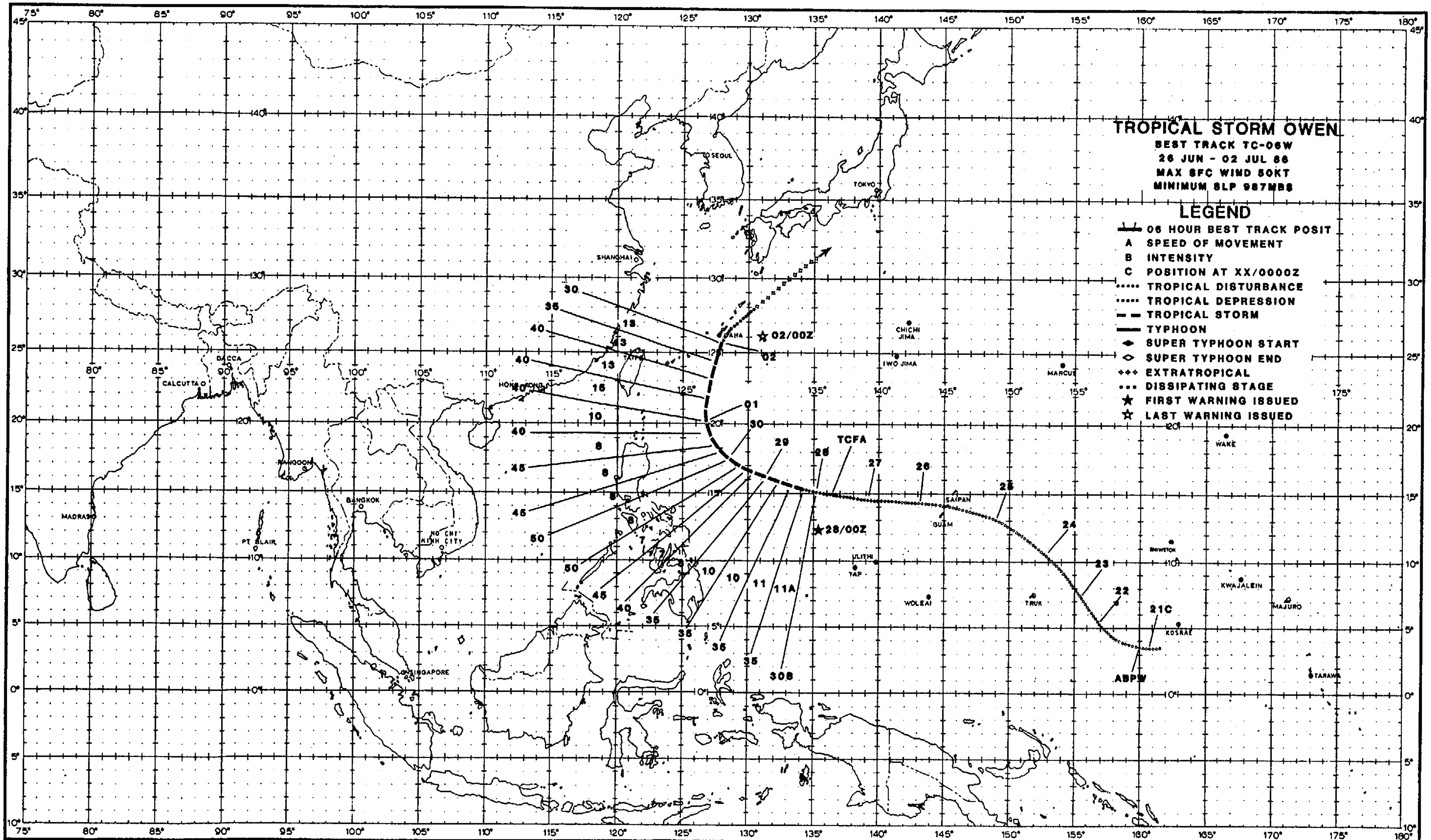
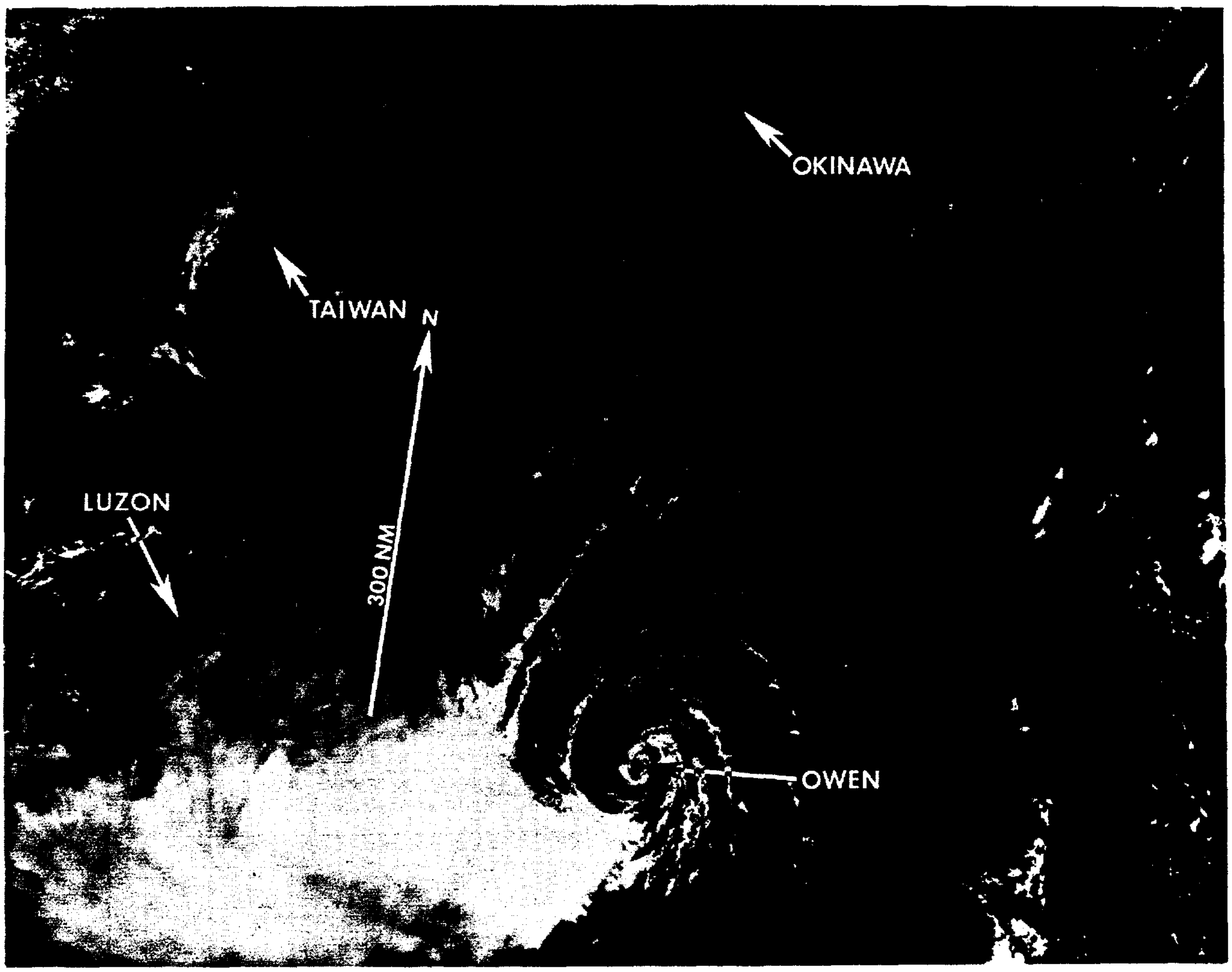


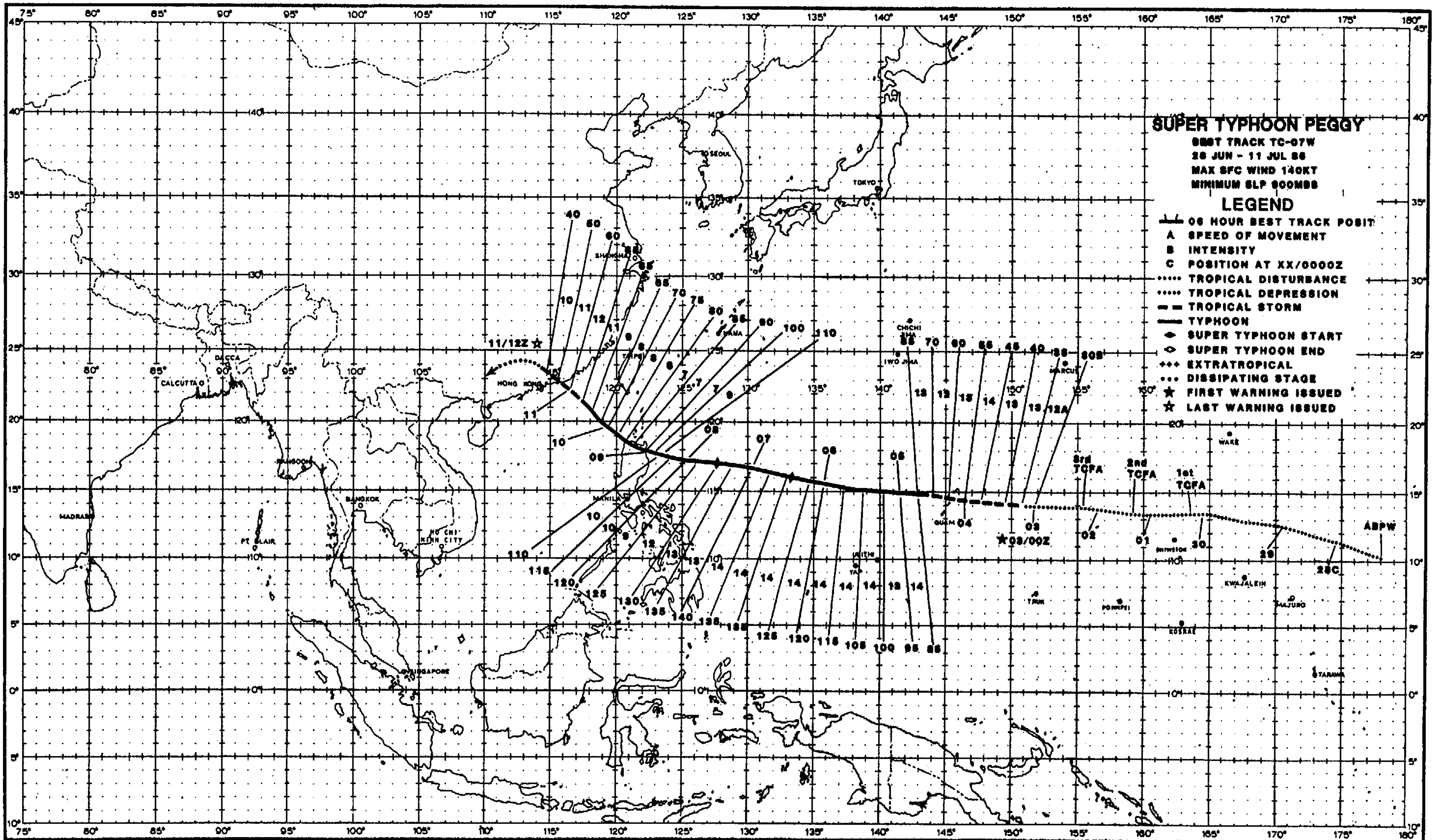
Figure 3-05-3. Specially enhanced infrared image of Typhoon Nancy's eye. The gray shading, which is used in conjunction with the Dvorak enhanced infrared technique, can provide an estimate of the intensity of the tropical cyclone (231428Z June DMSP infrared imagery).



NOCC GUAM 3142/20 (NEW 5 - 80)

Figure 3-06-1. Tropical Storm Owen had a long history as a disturbance. It was first noted as a suspect area on the Significant Tropical Weather Advisory (ABPW PGTW) at 0600Z on the 21st of June. As the system became more organized, its intensity increased. This prompted the issuance of a Tropical Cyclone Formation Alert at 271800Z when it was west of Guam in the Philippine Sea. Based on aircraft reconnaissance reports (272325Z) of 30 kt (15 m/sec) maximum sustained winds and a minimum sea-level pressure of 1001 mb, JTWC began warning on the system at 280000Z. On the 29th, Owen reached its maximum intensity of 50 kt (26 m/sec). As Owen moved northwestward around the periphery of the subtropical ridge, it came into an area of increased vertical shear. This resulted in the deep convection becoming displaced toward the west-southwest. By the 2nd of July, it had lost its tropical characteristics and dissipated over water. The imagery shows Owen's exposed low-level circulation center during the system's weakening phase (300108Z June DMSP visual imagery).





NOCC GUAM 3142/20 (NEW 5 - 80)

Peggy was the second super typhoon of the 1986 WESTPAC season. With the help of the Theta-E intensity forecast technique, intensity errors were kept to a minimum. In contrast, forecast track problems arose due to erroneous guidance from the One-way Interactive Tropical Cyclone Model (OTCM) which had a consistent northward bias at 72-hours.

During the latter part of June, the low-level, low-latitude tropical easterlies between the eastern Caroline Islands and the International Dateline were weaker than normal. In this area between the equator and 10 North Latitude, the light and variable winds, in conjunction with the tropical easterlies to the north, formed a vortex 600 nm (1111 km) east of Kwajalein Atoll in the Marshall Islands. It was first mentioned on the 270600Z June Significant Tropical Weather Advisory (ABPW PGTW) after satellite imagery showed persistent convection had developed. The circulation moved west-northwestward for six days before reaching tropical storm intensity (35 kt (18 m/sec)) 350 nm (648 km) east of Guam. Throughout this period the cloud signature caused heightened concern for Guam, however aircraft reconnaissance flights did not locate any supporting strong winds. At 030000Z July, JTWC issued its first warning on Tropical Depression 07W based on maximum winds of 25 kt (13 m/sec) from synoptic reports and the potential for intensification near Guam. Twelve hours later Peggy was upgraded to a tropical storm, when aircraft reconnaissance found a band of 35 kt (18 m/sec) surface winds displaced 20-40 nm (37-74 km) northwest of the vortex center.

Continuing to move west-northwestward, Peggy passed 58 nm (107 km) north of Guam at 040700Z. Peak winds experienced on Guam were 28 kt (14 m/sec) with gusts to 48 kt (25 m/sec). There was limited damage to Guam, restricted primarily to power poles and crops. The islands of Rota, Tinian and Saipan experienced more extensive damage - primarily to crops.

During the period 042352Z to 062040Z, Peggy's mean sea-level pressure (MSLP) dropped from 973 mb to 900 mb - a decrease of 73 mb. This corresponds to a drop of approximately 1.6 mb/hour which is classified

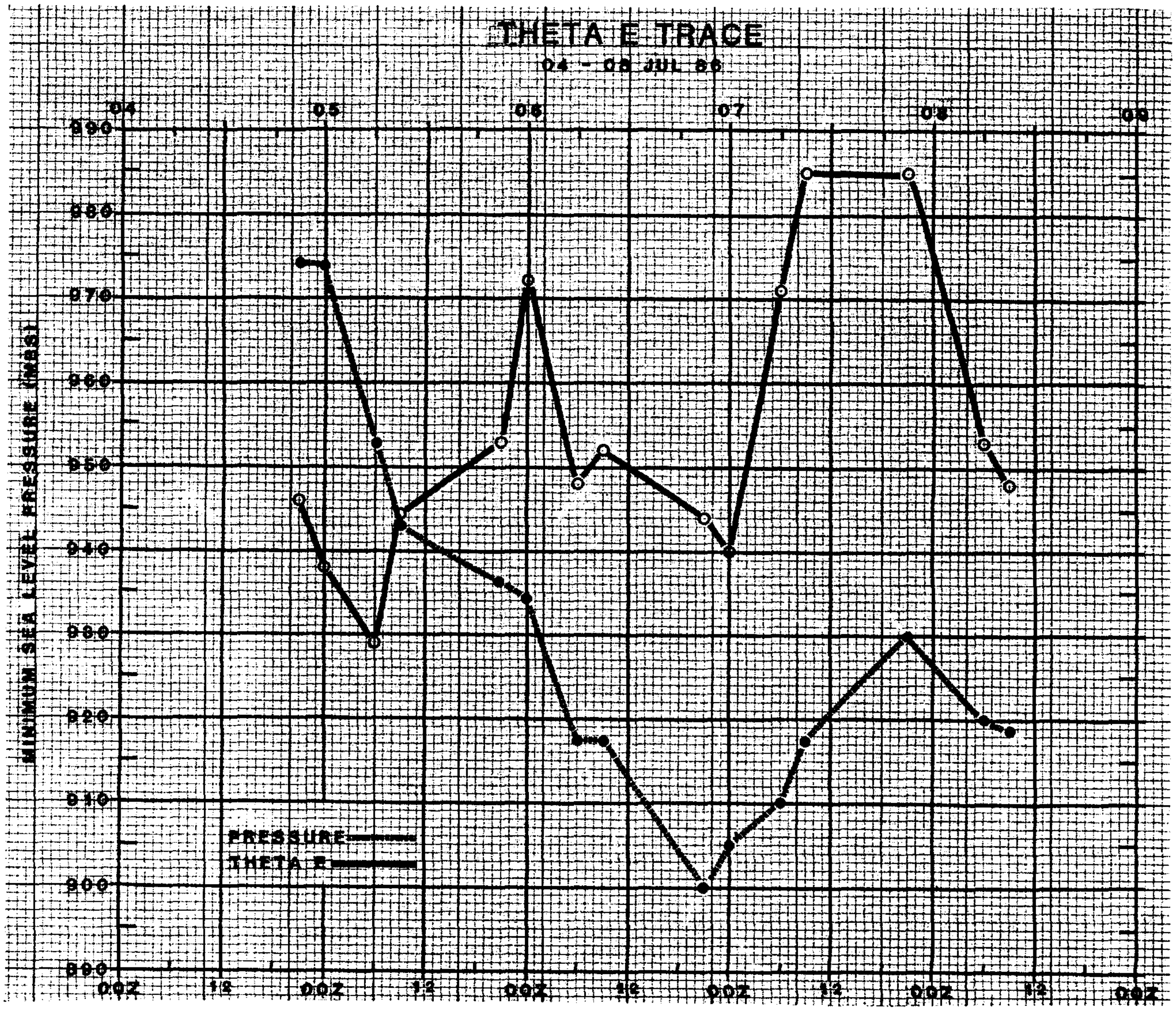


Figure 3-07-1. Plot of Peggy's central minimum sea-level pressure and the Theta-E line with the intersection at 050800Z. Rapid deepening occurred with a 1.6 mb/hour drop in central pressure from 973 mb to 900 mb.

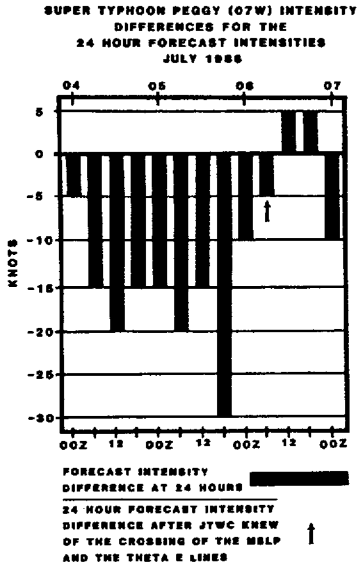


Figure 3-07-2. A graph of the difference between the actual best track intensities and the 24-hour forecast intensities before and after JTWC knew the sea-level pressure and Theta-E line intersected (reference Figure 3-07-1).

as rapid deepening (Holliday and Thompson, 1979). The rate of deepening does not meet the 2.5 mb/hour criterion used to define explosive deepening. As mentioned earlier, JTWC was able to significantly decrease forecast intensity errors, with the guidance provided by Theta-E intensity forecast technique (Dunnavan, 1981). The technique uses equivalent potential temperature (Theta-E), calculated from aircraft recon 700 mb temperature and dew point reports, as a measure of the tropical cyclone's thermodynamic energy. When the plots of Theta-E and MSLP intersect near the critical values of 950 mb and 360 degrees Kelvin, central pressure can be expected to drop to below 925 mb. Figure 3-07-1 shows the plot of Peggy's Theta-E and MSLP values during the period 042050Z to 080856Z. The intersection point is at 050800Z. The graph of the 24-hour forecast intensity (Figure 3-07-2) demonstrates the difference before and after the knowledge of the Theta-E crossing. The average 24-hour forecast intensity error before 050600Z (the first foreknowledge of increased potential for explosive or rapid deepening) was 16 kt (8 m/sec). The average 24-hour forecast intensity error after 050600Z was 5 kt (3 m/sec). With regard to 48-hour forecast intensities, only one warning benefited because two days after 050600Z, Super Typhoon Peggy's intensity peaked at 140 kt (72 m/sec).

Figure 3-07-3 shows Super Typhoon Peggy at its maximum intensity. Peggy remained on the west-northwestward track and slammed into northern Luzon at 082200Z with 95 kt (49 m/sec) surface winds. Newspaper accounts of Peggy's fury reported ninety-three people died, 16 were missing, over 116,000 families were homeless, and damage was estimated at 2.5 million dollars. Most of this damage, primarily to crops and villages, was the result of torrential rain. Also, two people lost their lives in southern Taiwan.

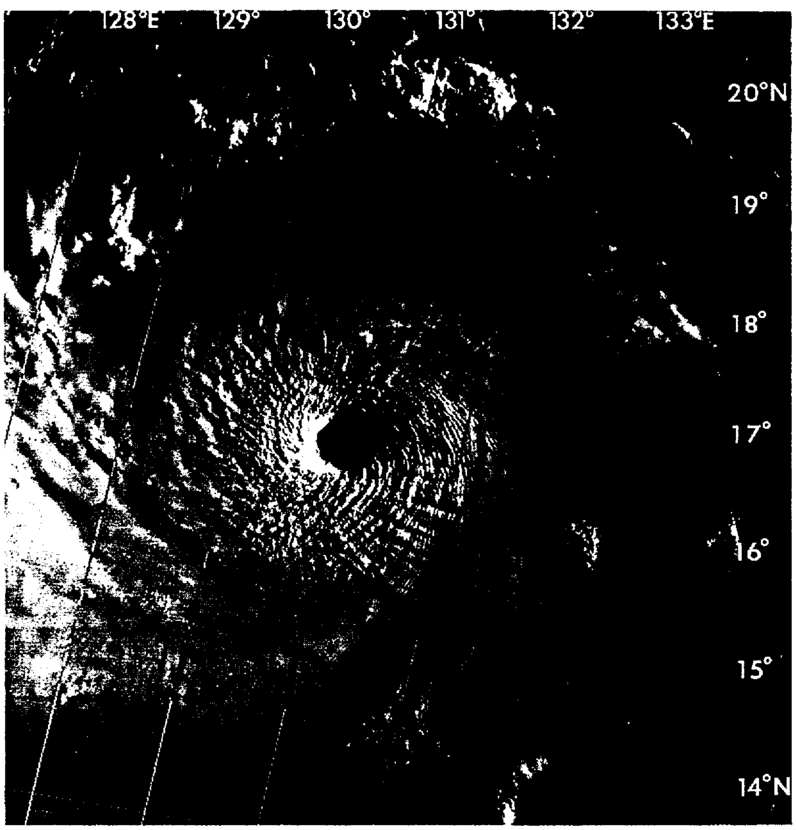


Figure 3-07-3. Super Typhoon Peggy at maximum intensity of 140 kt (72 m/sec) (062120Z July DMSP visual imagery courtesy of H and HS Weather, MCAS Futenma).

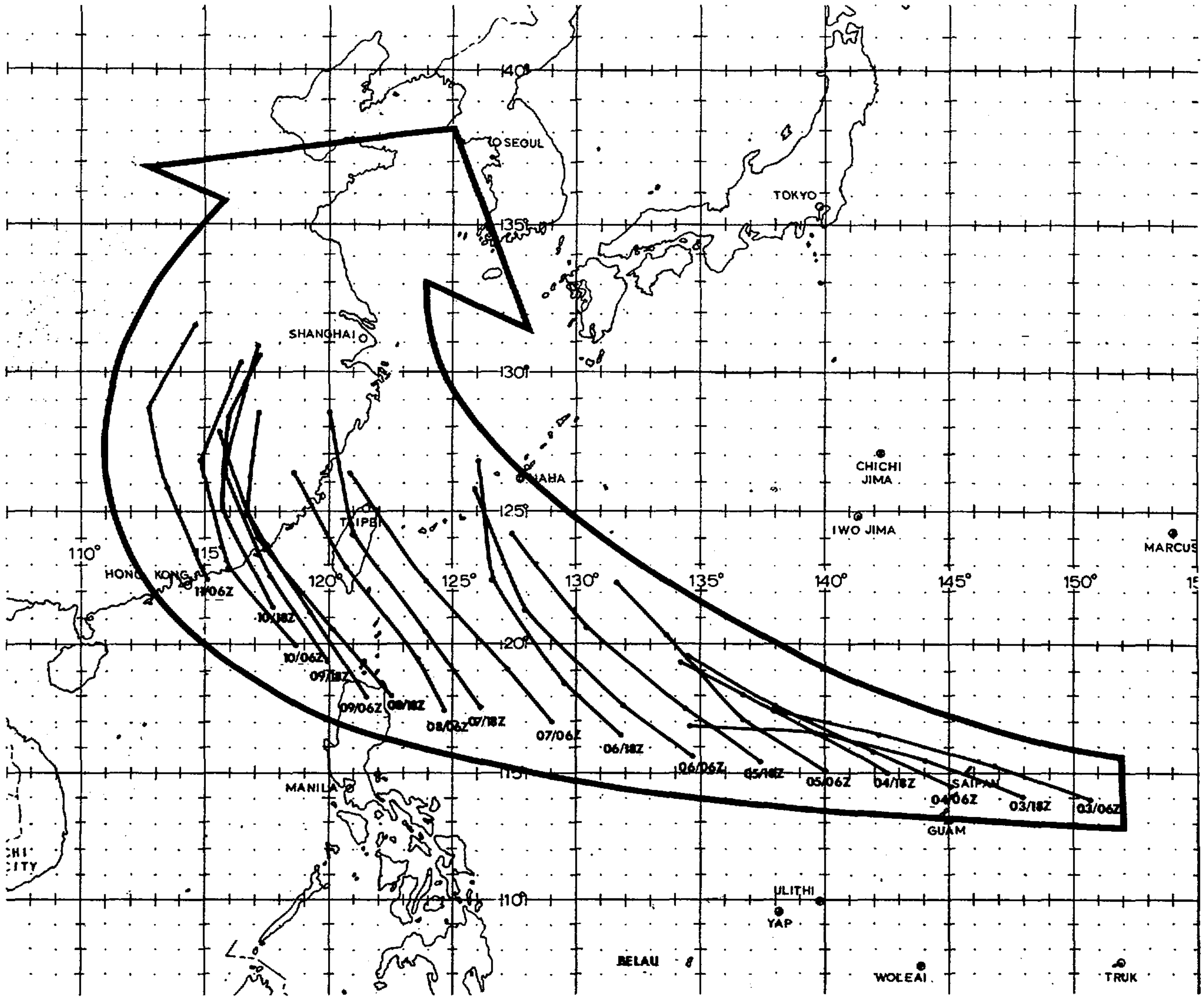


Figure 3-07-4. Plot of OTCM guidance through 72-hours for each twelve hour period. Note the continuous northward bias from the loci of initial points.

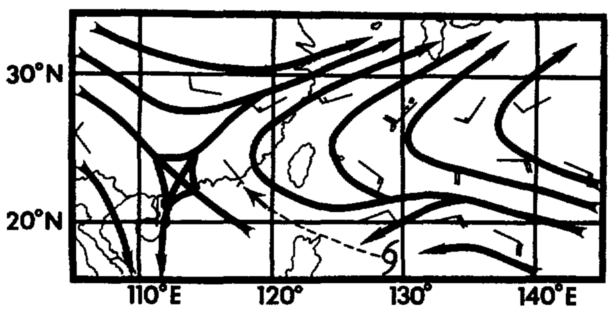
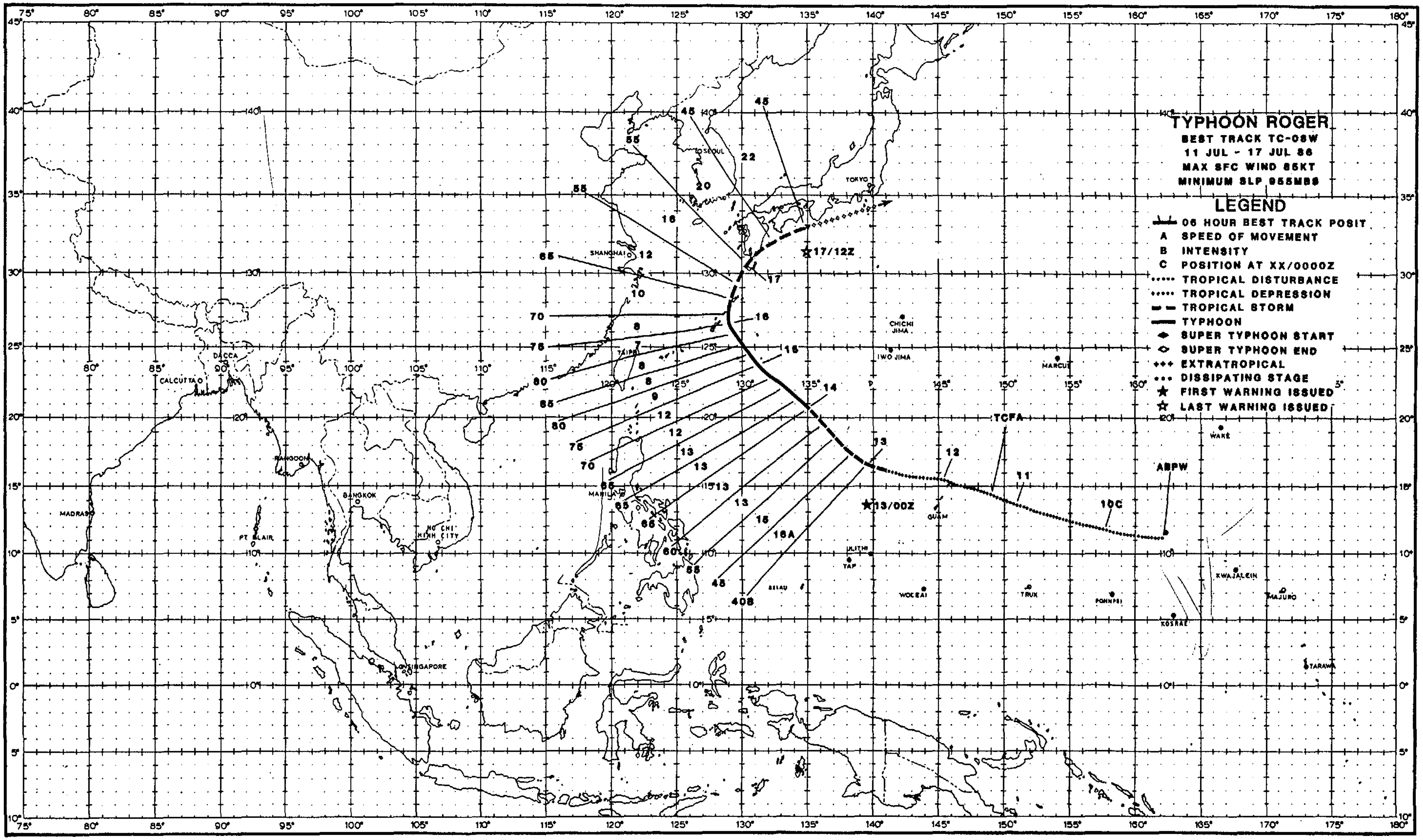


Figure 3-07-5. The 400 mb Numerical Variational Analysis (NVA) for 071200Z July with Peggy's position. The effect of the subtropical ridge can be implied from the plot of the final best track.

After crossing northern Luzon and moving into the South China Sea, Peggy continued to slowly weaken. It made landfall over southern China 80 nm (148 km) east of Hong Kong at 110200Z with an intensity of 55 kt (28 m/sec) Widespread flooding resulted across southern China and over 200 people were reported dead.

The track forecasts from the first warning through the 21st warning (at 080000Z) repeatedly called for a more northerly track than was observed. Guidance from the OTCM hinted at recurvature (Figure 3-07-4). Initially the NOGAPS prognoses, 021200Z to 060000Z, indicated slow weakening of the subtropical ridge poleward of Peggy. However, from 061200Z through 120000Z the NOGAPS prognoses reversed this trend and began slow ridge building. Although NOGAPS suggested a stronger subtropical ridge, guidance from OTCM persistently called for a more northerly track. The 400 mb NVA analysis at 071200Z (Figure 3-07-5) shows the location of the ridge and Peggy's ultimate track.



NOCC GUAM 3142/20 (NEW 5 - 80)

Typhoon Roger was initially enhanced by a Tropical Upper-Tropospheric Trough (TUTT) cell as described by Sadler (1976). On 4 July 1986, as Typhoon Peggy was moving toward the west, away from Guam, a TUTT cell was observed moving west-northwestward from a location 780 nm (1445 km) east of Wake Island. The well-developed TUTT cell and its associated convection continued this movement for the next five days. By 8 July, a tropical disturbance had developed from this area of convection about 30 nm (56 km) southwest of Enewetak Atoll. It persisted into the next day when it was included in the Significant Tropical Weather Advisory (ABPW PGTW) for the first time. Initially, Roger showed little potential for development into a tropical disturbance. Over the next two days, however, the convective area became more organized as cross-equatorial westerlies converged with the tradewind easterlies at low-levels and an anticyclone formed aloft.

The divergent upper-level flow southeast of the TUTT cell continued to provide a favorable environment for the tropical disturbance to develop slowly during the next three and a half days. A Tropical Cyclone Formation Alert (TCFA) was issued for the system at 110717Z. Satellite imagery (Figure 3-08-1) at 120024Z July shows the tropical depression. The first warning was issued at 130000Z, because the system continued to increase in convective organization and a minimum sea-level pressure of 999 mb was observed by aircraft reconnaissance at 122245Z.

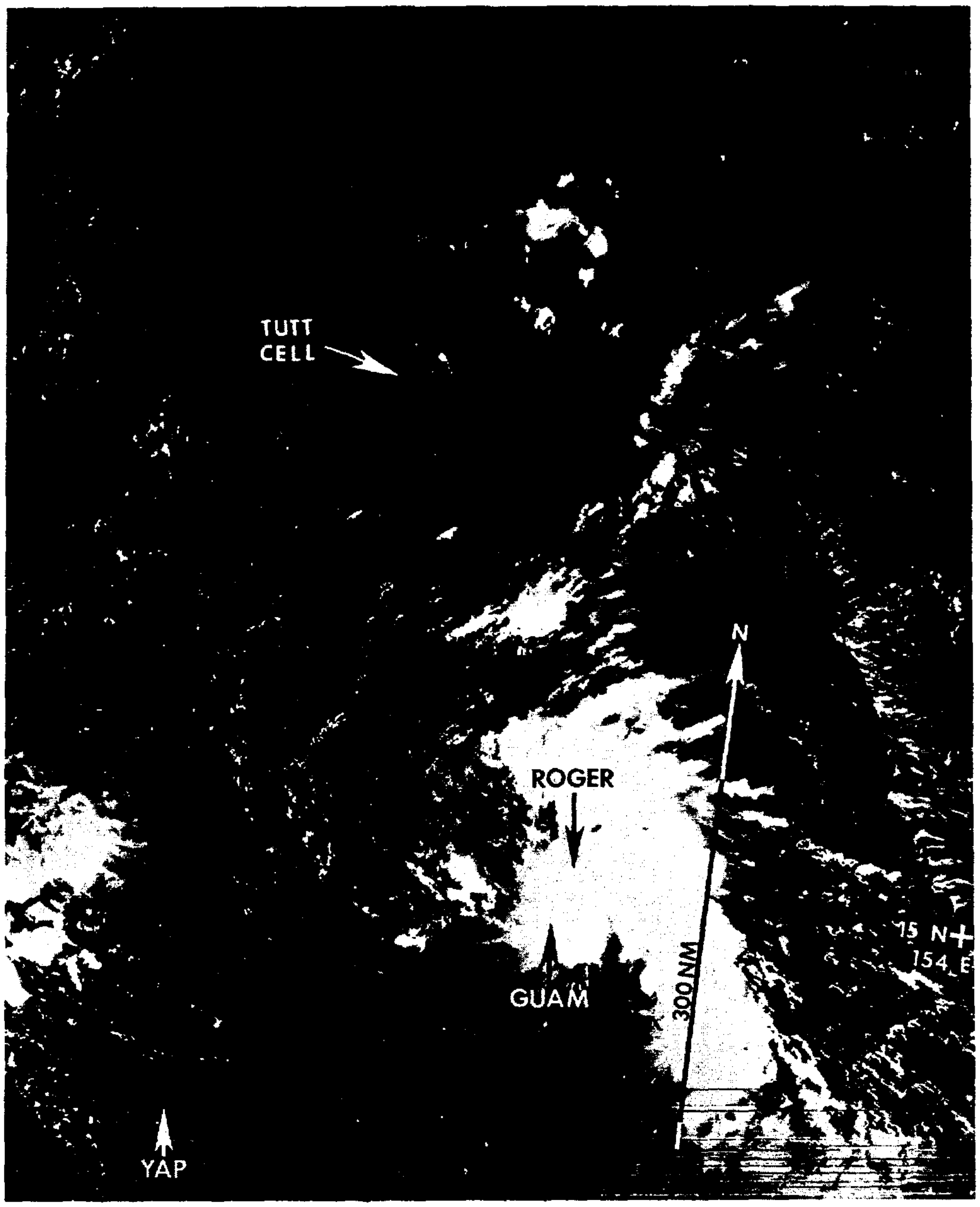


Figure 3-08-1. Roger as a tropical depression. Note the effect of the TUTT cell northwest of the depression which causes a deformation and enhancement of the cirrus outflow pattern to the southeast (120024Z July DMSP visual imagery).

During all stages of development, Typhoon Roger remained small in size. Aerial Reconnaissance Weather Officers flying into Roger consistently reported the diameter of the light and variable surface wind center as 1 nm (2 km) to 4 nm (7 km). Figure 3-08-2 shows Roger's small eye and central convective mass.

JTWC accurately forecast Roger's track and point of recurvature. Roger moved west-northwestward while south of the 700 mb subtropical ridge; then northward, and later northeastward as it recurved around the western end of the ridge. Figure 3-08-3 shows the location and orientation of the subtropical ridge as reflected in the 700 mb data on 131200Z July. The guidance from the One-way Interactive Tropical Cyclone Model (OTCM), JTWC's primary forecast aid, was generally good although the model repeatedly suggested a tighter recurvature track at the 24-hour point (approximately 180 nm (333 km) farther to the east) than was actually observed. Figure 3-08-4 is a plot of the initial and 24-hour points from the OTCM showing this bias toward the east.

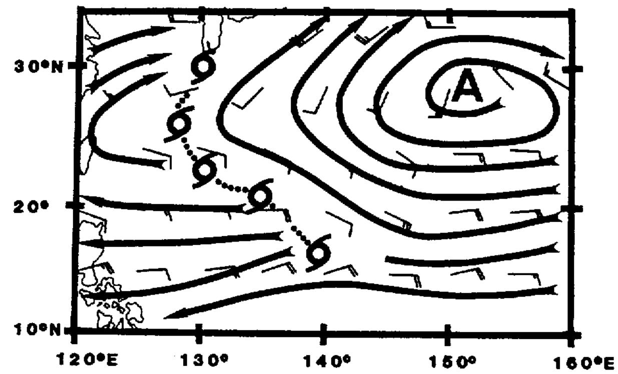


Figure 3-08-3. The 700 mb Wind Analysis on 131200Z July showing location and orientation of the subtropical ridge that influenced Roger's movement. The dashed line shows Typhoon Roger's eventual track.

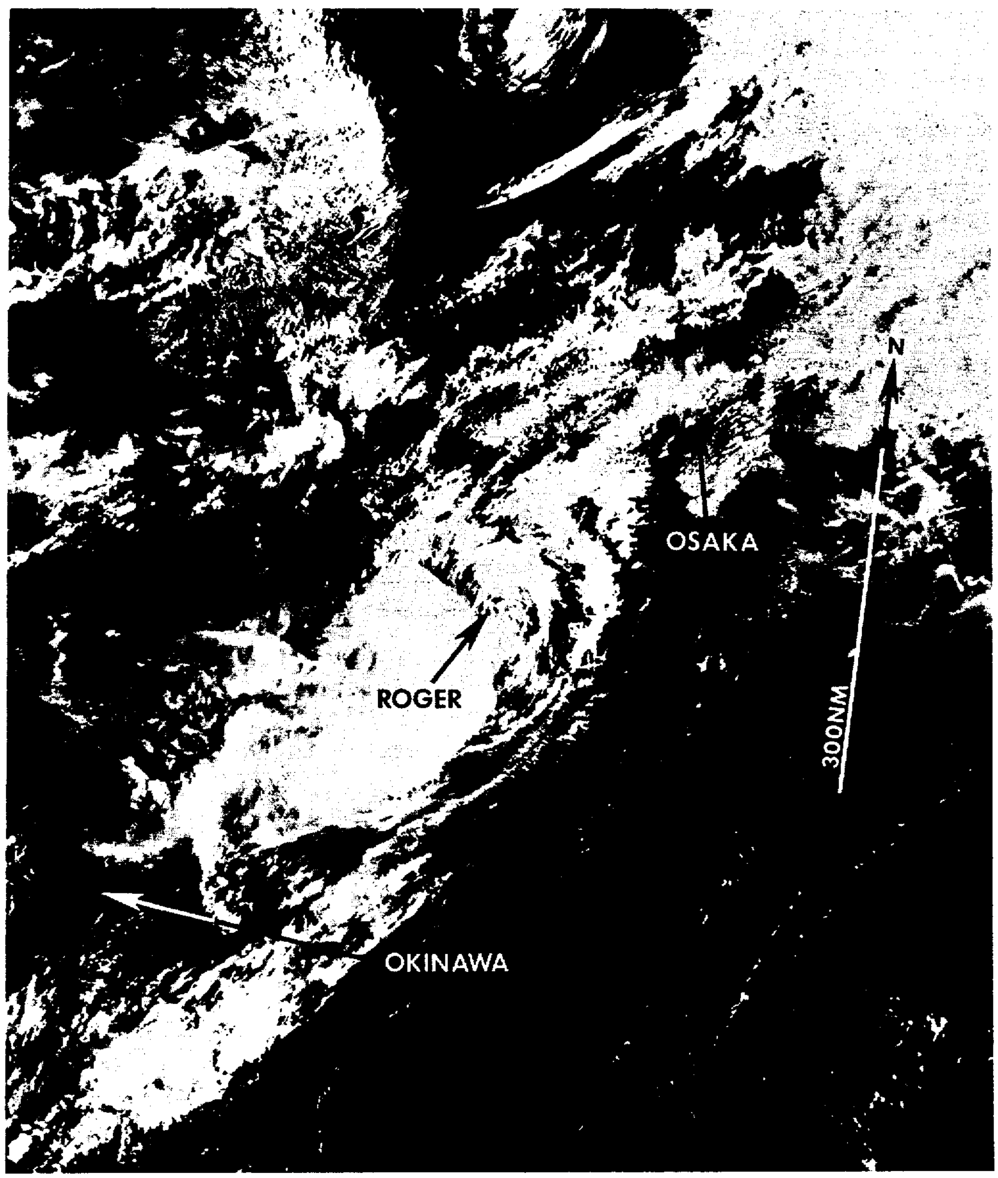


Figure 3-08-2. Typhoon Roger near maximum intensity. A small eye is present in the central convective mass (150104Z July DMSP visual imagery).

After recurvature toward the northeast, Typhoon Roger began extratropical transition as it encountered the shearing environment that caused its convection to be displaced to the southwest of the low-level circulation center (Figure 3-08-5). This shearing away of the central convection caused Roger to weaken further. The stratified nature of the low-level cloud (in Figure 3-08-5) is indicative of extratropical transition.

Although Typhoon Roger passed just 45 nm (83 km) east of the island of Okinawa and Kadena Air Base, the effect was minimal due to its small size. Peak gusts of 43 kt (22 m/sec) were reported and the northern part of the island received about 1 inch (254 mm) of rainfall. "U.S. military installations on Okinawa spent most of Wednesday (16 July) in typhoon condition one .... (and) Japanese schools were closed during the day. Approximately 4000 tourists were stranded briefly at Naha Airport during the day as 21 flights were cancelled because of the storm. Airline officials said all those passengers were on their way by late afternoon." There were no reports of injuries or significant damage on Okinawa or to shipping.

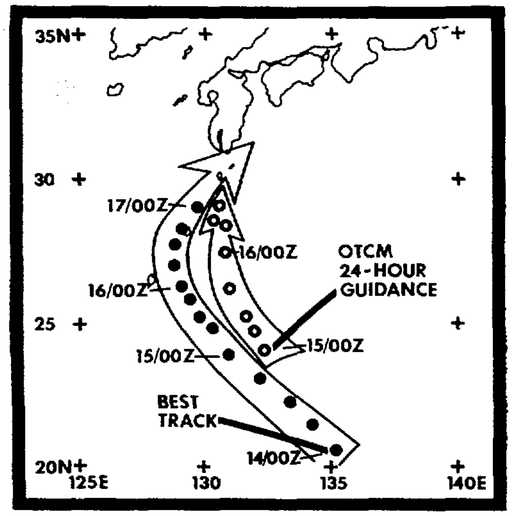


Figure 3-08-4. Plot of OTCM (One-way Interactive Tropical Cyclone Model) forecast tracks for period 140000Z to 161800Z July.

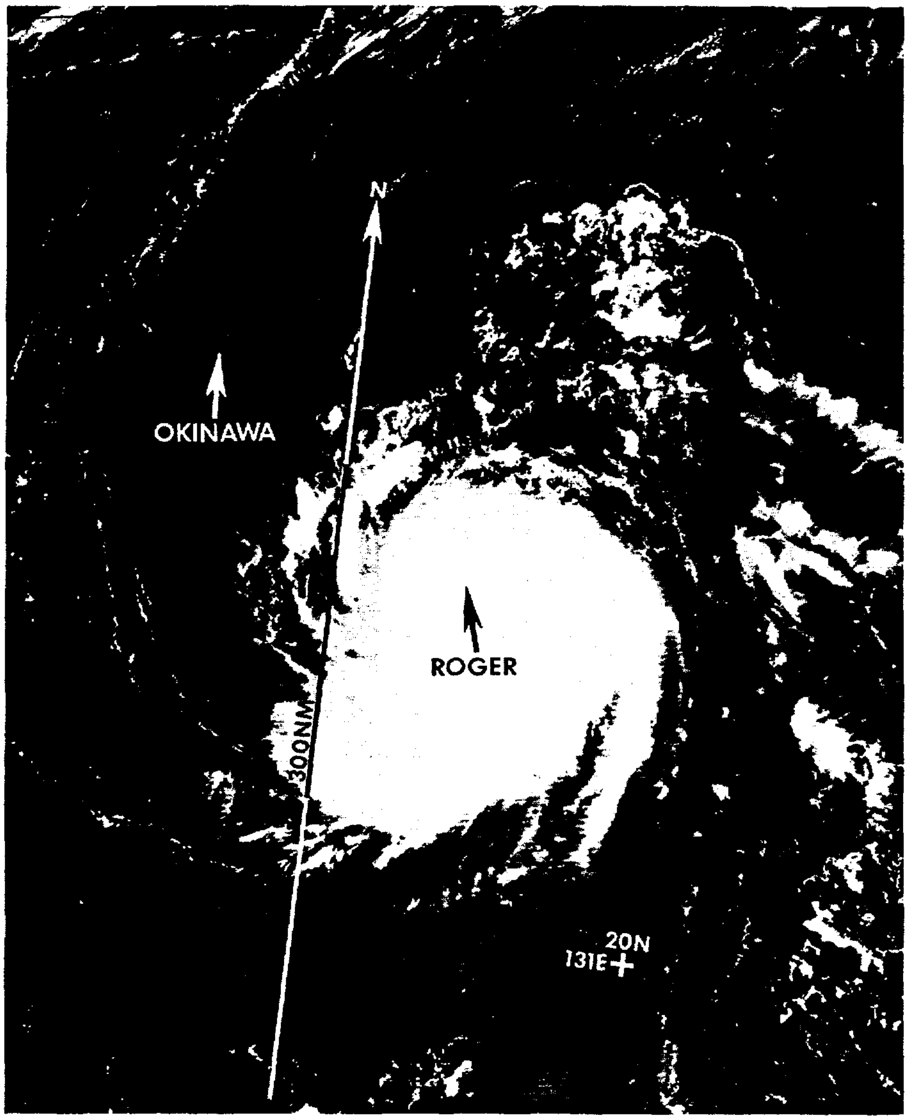
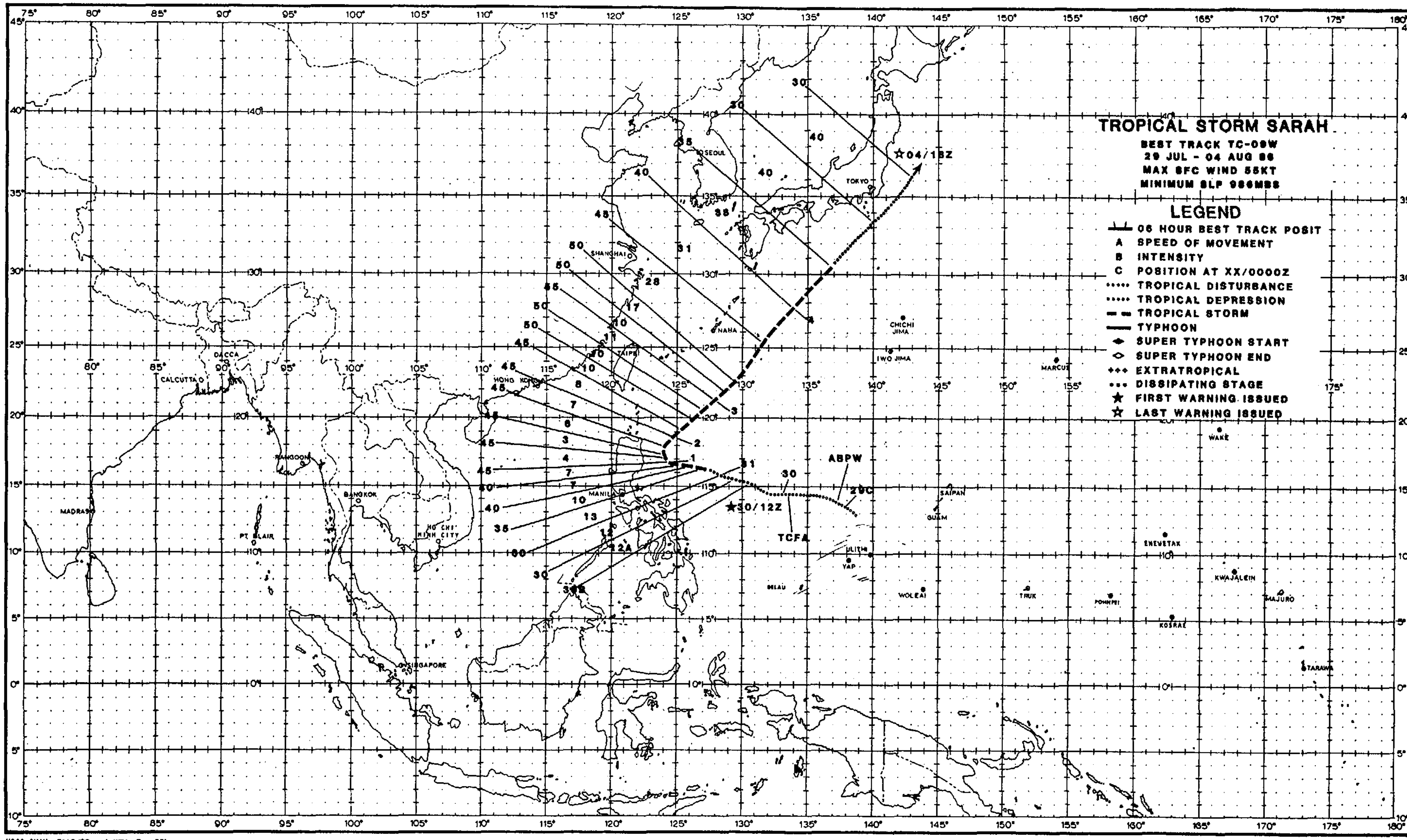


Figure 3-08-5. Satellite imagery of Roger showing the exposed low-level circulation center and central convection displaced to the southwest. Note the stratified nature of the low-level clouds associated with extratropical transition (170527Z July NOAA visual imagery).



NOCC GUAM 3142/20 (NEW 5 - 80)

The summer monsoon was well established and had stronger than normal low-level westerlies from the Caroline to the Marshall Islands by mid-July. From the 21st of July onward, the conditions were ripe for cyclogenesis. After daily mention in the Significant Tropical Weather Advisory (ABPW PGTW) and several false alarms, a Tropical Cyclone Formation Alert (TCFA) was issued for a rapidly developing area of convection in the Philippine Sea 420 nm (778 km) north of Belau.

The aircraft reconnaissance flight investigating this disturbed area at 300152Z located a weak, low-level circulation center with maximum surface winds of 18 kt (9 m/sec) and a minimum sea-level pressure (MSLP) of 1001 mb. The first warning for Tropical Depression 09W followed at 301200Z as convection and winds increased on the south side of the vortex.

Subsequent intensification of this system was masked from satellite imagery by the heightened convective activity in the monsoonal westerlies. Aircraft reconnaissance into the tropical cyclone at 311525Z found 40 kt (21 m/sec) surface winds, which prompted the upgrade to Tropical Storm Sarah. During this period, the tropical cyclone's west-northwestward movement slowed and the system, which appeared to be following an under-the-ridge scenario, continued to consolidate.

Later aircraft reconnaissance at 3112138Z and 010009Z confirmed the slowing trend and the Aerial Reconnaissance Weather Officer (ARWO) reported that multiple circulation centers might be present. Additionally, the ARWO estimated the ring of maximum surface winds as nearly symmetrical with slightly weaker winds in the northern semicircle displaced 20 to 60 nm (32 to 96 km) from the center.

As Sarah moved closer to the island of Luzon, it became increasingly more difficult to locate the circulation center. The major convective area shifted to the northwest quadrant (see Figure 3-09-1). Aircraft reconnaissance at 011300Z (Figure

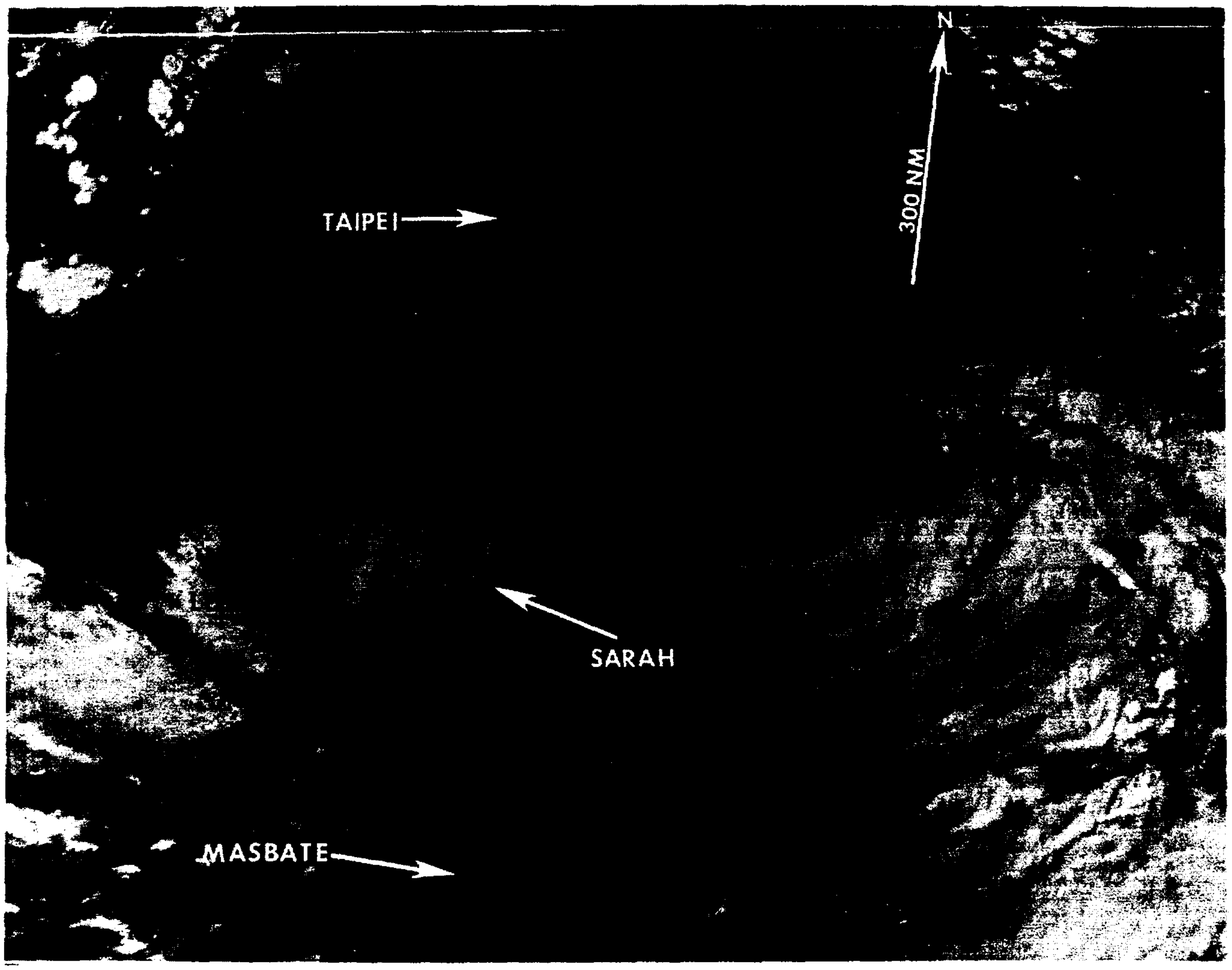


Figure 3-09-1. "Where is Sarah?" That was the question when this image was received. The trend from previous satellite imagery was for the deep convection to continue westward movement across northern Luzon appears to be maintained (010608Z August NOAA visual imagery).

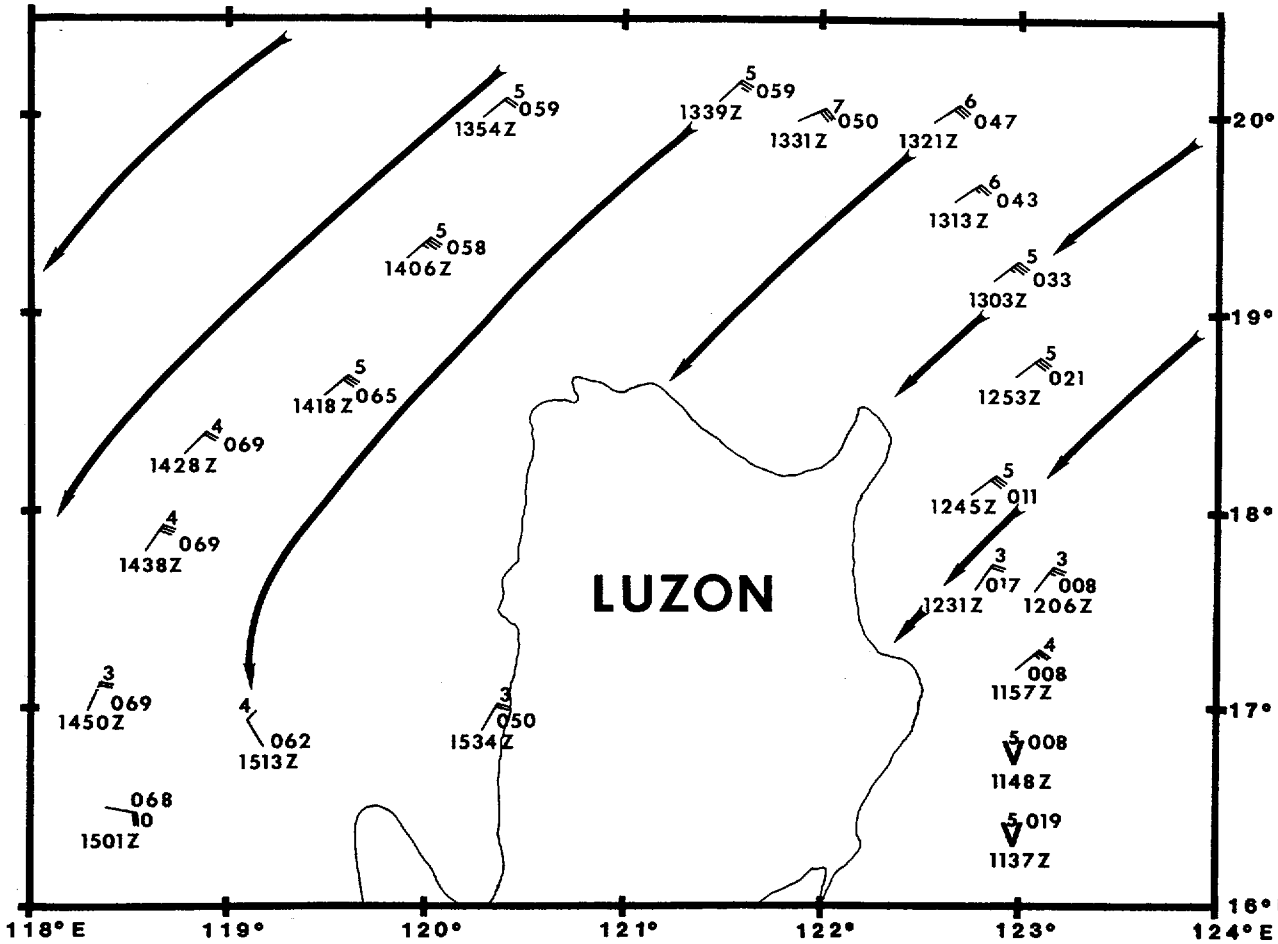


Figure 3-09-2. A plot of the 011300Z August aircraft reconnaissance mission around northern Luzon. These data imply that the low-level circulation in the monsoon trough (i.e., Sarah) may have remained in the Philippine Sea.

3-09-2) flew around northern Luzon and detected only broadscale northeasterly flow without a trace of a low-level circulation center. These northeasterly winds should have provided a valuable clue as to the location of Sarah. (In retrospect, it took more than 24-hours to get the forecast back on the right track.) In the interim, the persistent deep cloudiness across northern Luzon as viewed by the meteorological satellite imagery implied that Sarah was continuing into the South China Sea and towards mainland China. The dynamic guidance provided by Nested Tropical Cyclone Model (NTCM) and One-Way Interactive Tropical Cyclone Model (OTCM) endorsed this movement into the South China Sea.

Again, aircraft reconnaissance between 012100Z and 020000Z was unable to locate a Sarah. This time the flight was west of Luzon in the South China Sea. An aircraft mission previously scheduled to investigate a TCFA area northeast of Luzon, however, did find Sarah in the Philippine Sea. Satellite imagery after 012100Z also showed a reorganization of deep convection east of Luzon. This resulted in a relocation and an abrupt change in forecast philosophy. No longer was Sarah following the under-the-ridge scenario into the South China Sea, but now was moving northeastward (Figure 3-09-3).

After 030600Z August, Sarah started accelerating toward the northeast in response to increasing westerly wind flow aloft. By 050000Z, the system moved to a position east of the island of Honshu and transitioned to an extratropical cyclone.

Reanalyses of aircraft, satellite, radar and conventional data after-the-fact revealed the following. As Sarah approached northern Luzon, the upper-level circulation center became displaced from the low-level center and moved across the mountainous terrain of the island and dissipated in the South China Sea. The residual low-level vortex, which was weak and difficult to locate, remained east of Luzon in the active monsoon trough. The monsoon trough changed its orientation gradually from east-west to northeast-southwest, as Sarah reintensified and moved northeastward. The aircraft mission at 011300Z (Figure 3-09-2) was a key piece of data in reconstructing what happened in this difficult situation. The broad northeasterly flow across northern Luzon implied that Sarah remained in the Philippine Sea and was masked by the monsoon trough and vigorous convection closeby.

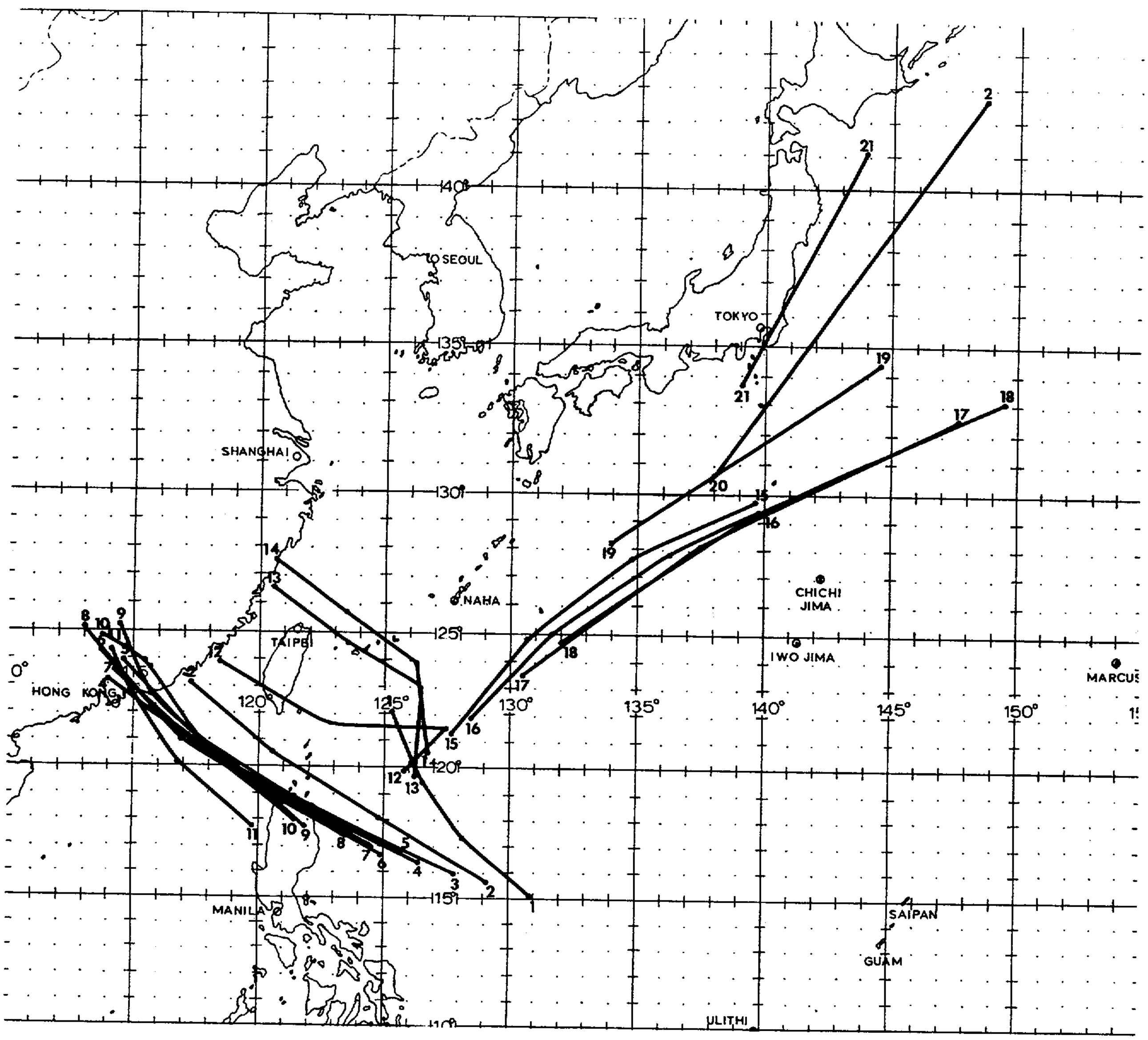
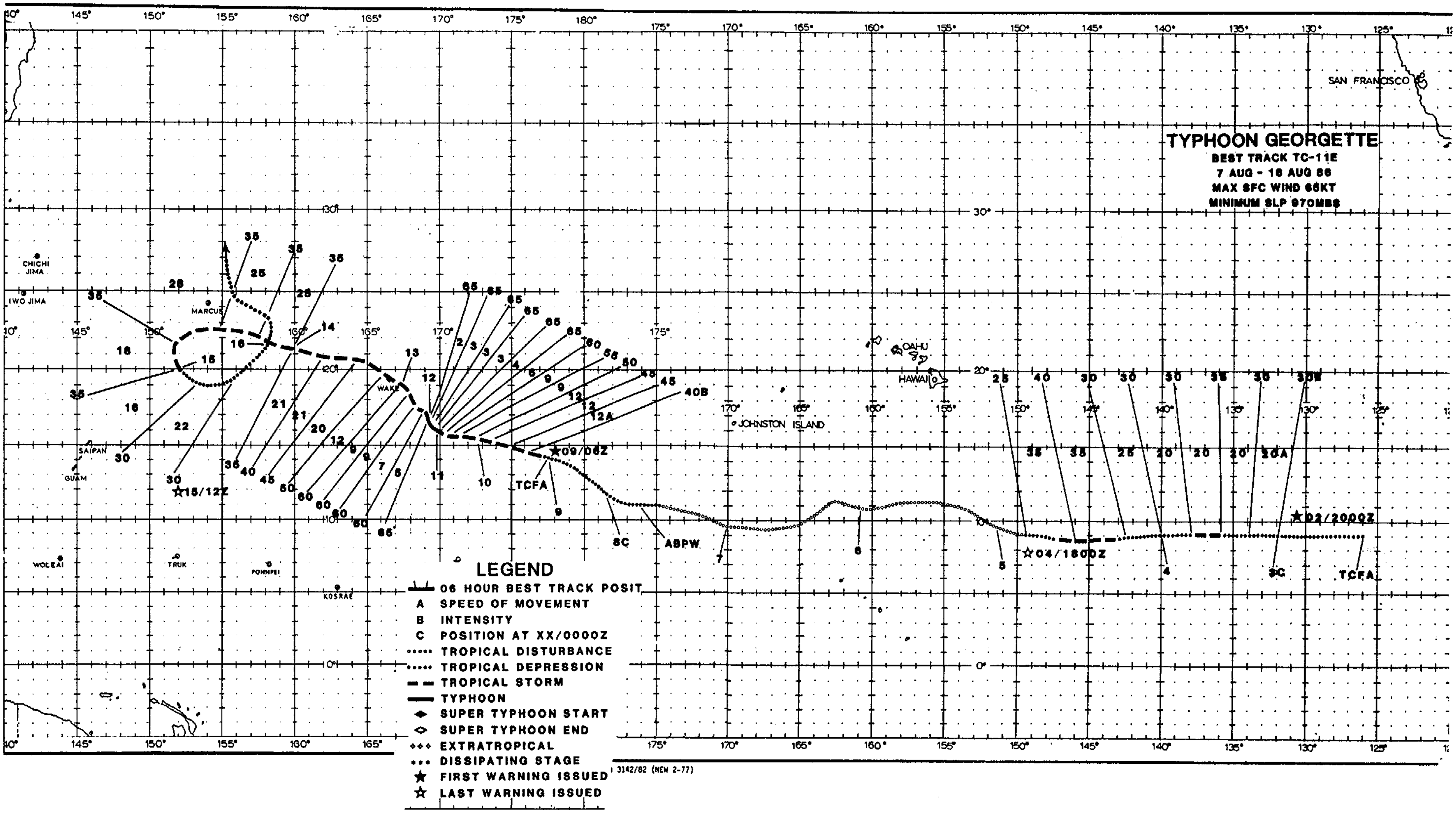
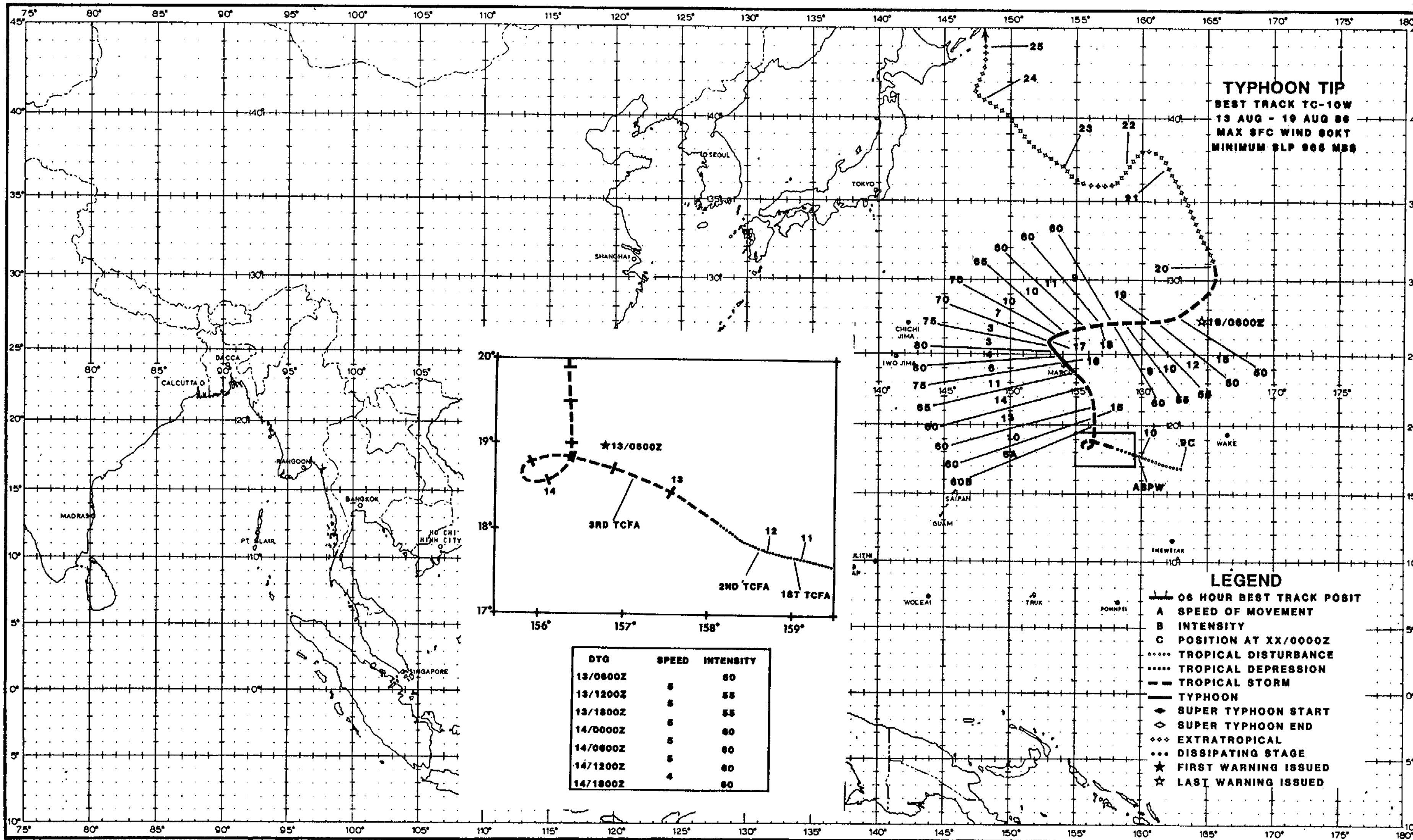


Figure 3-09-3. Plots of the forecast tracks for Sarah. Note the abrupt change between warnings 11 and 15. The difficulty in locating the low-level circulation center and understanding the changing synoptic situation prolonged the time (warnings 9 through 14) it took to get the forecasts back on the right track.


TYPHOON GEORGETTE
BEST TRACK TC-11E
7 AUG - 16 AUG 86
MAX SFC WIND 65KT
MINIMUM SLP 970MBS
LEGEND
06 HOUR BEST TRACK POSIT
A SPEED OF MOVEMENT
B INTENSITY
C POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
DISSIPATING STAGE
FIRST WARNING ISSUED
LAST WARNING ISSUED
SAN FRANCISCO
OAHU
HAWAII
JOHNSTON ISLAND
CHICHI JIMA
IWO JIMA
MARCUS
WAKE
SAIPAN
GUAM
WOLEAI
TRUK
POHNPEI
KOSRAE
TCFA
02/2000Z
04/1800Z
09/06Z
15/12Z
3142/82 (NEW 2-77)



NOCC GUAM 3142/20 (NEW 5 - 80)

Typhoons Georgette and Tip provided one of the more intriguing forecasting opportunities of the 1986 western North Pacific Tropical Season for JTWC as they circled one another in a complex binary interaction. Georgette was a rare tropical cyclone which traveled from the eastern North Pacific region across the central region and became a typhoon in the western region (see Figure 3-10-1). During its two-week lifespan Georgette traveled nearly 5,600 nm (10,371 km).

Typhoon Georgette had an interesting early history. It began as a tropical disturbance in the eastern North Pacific 1,600 nm (2,963 km) south-southwest of Los Angeles on August 2nd and initially moved westward. The Naval Western Oceanography Center located in Pearl Harbor, Hawaii issued a Tropical Cyclone Formation Alert (TCFA) on the system at 020700Z after observing convective bands on satellite imagery. Later that same day, at 022000Z, the Eastern Pacific Hurricane Center (EPHC), located in San Francisco, issued the first advisory on Tropical Depression 11E. The system was upgraded to Tropical Storm Georgette (11E) on the fourth advisory at 031500Z, then downgraded to a tropical depression again on the fifth through seventh advisories when a decrease was noticed in the amount of convective organization. It was upgraded once more to a tropical storm on the eighth advisory and then finally downgraded for the last time and forecast to dissipate over water on the ninth advisory as it passed south of Hawaii. The Central Pacific Hurricane Center (CPHC) issued the sixth through ninth advisories after Georgette had moved into the central North Pacific. A total of nine advisories were issued on Georgette by EPHC and CPHC combined. All nine corresponding tropical cyclone warnings for the Department of Defense customers were issued by the Naval Western Oceanography Center.

Georgette maintained its identity as a tropical disturbance after the final downgrade and was tracked by JTWC before it crossed the dateline. It was first mentioned at 071500Z on the Significant Tropical Weather Advisory (ABPW PGTW) as a 20 kt (10 m/sec) disturbance 420 nm (778 km) southwest of Johnston Island. It crossed the dateline on 8 August while moving on a northwestward trajectory.

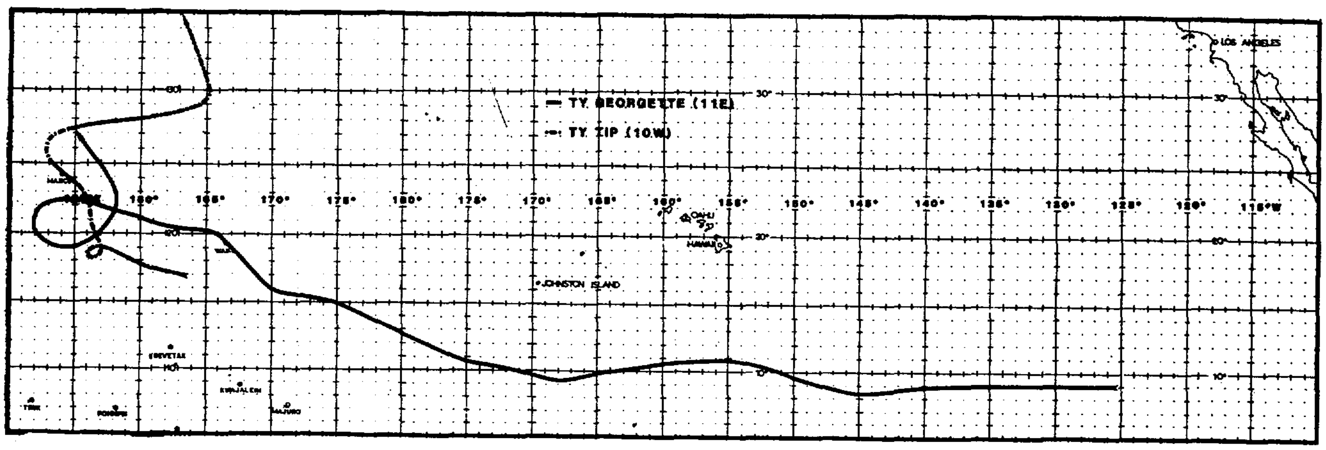


Figure 3-10-1. A composite plot of Tip's and Georgette's best tracks shows how closely linked the two were at the end of Georgette's long journey.

JTWC issued a TCFA on regenerated Tropical Storm Georgette (11E) at 090130Z based on analysis of satellite imagery which showed improved organization. A few hours later, JTWC followed with its first warning (#10 on the system), valid at 090600Z, when Georgette re-developed a central dense overcast.

The aircraft reconnaissance investigative mission into Georgette on 10 August at 0044Z discovered winds of 45 kt (23 m/sec) and a minimum sea-level pressure (MSLP) of 990 mb. Georgette continued to develop over the next 18-hours reaching minimal typhoon status by 101800Z. Aircraft reconnaissance confirmed this at 102135Z, reporting estimated maximum surface winds of 65 kt (33 m/sec) and a MSLP of 973 mb.

Georgette remained a typhoon for 36-hours, slowed in forward speed, and reverted to a tropical storm again after 120000Z (see Figure 3-10-2). This was apparently due to the proximity of a Tropical Upper-Tropospheric Trough cell to the north and increased vertical shear.

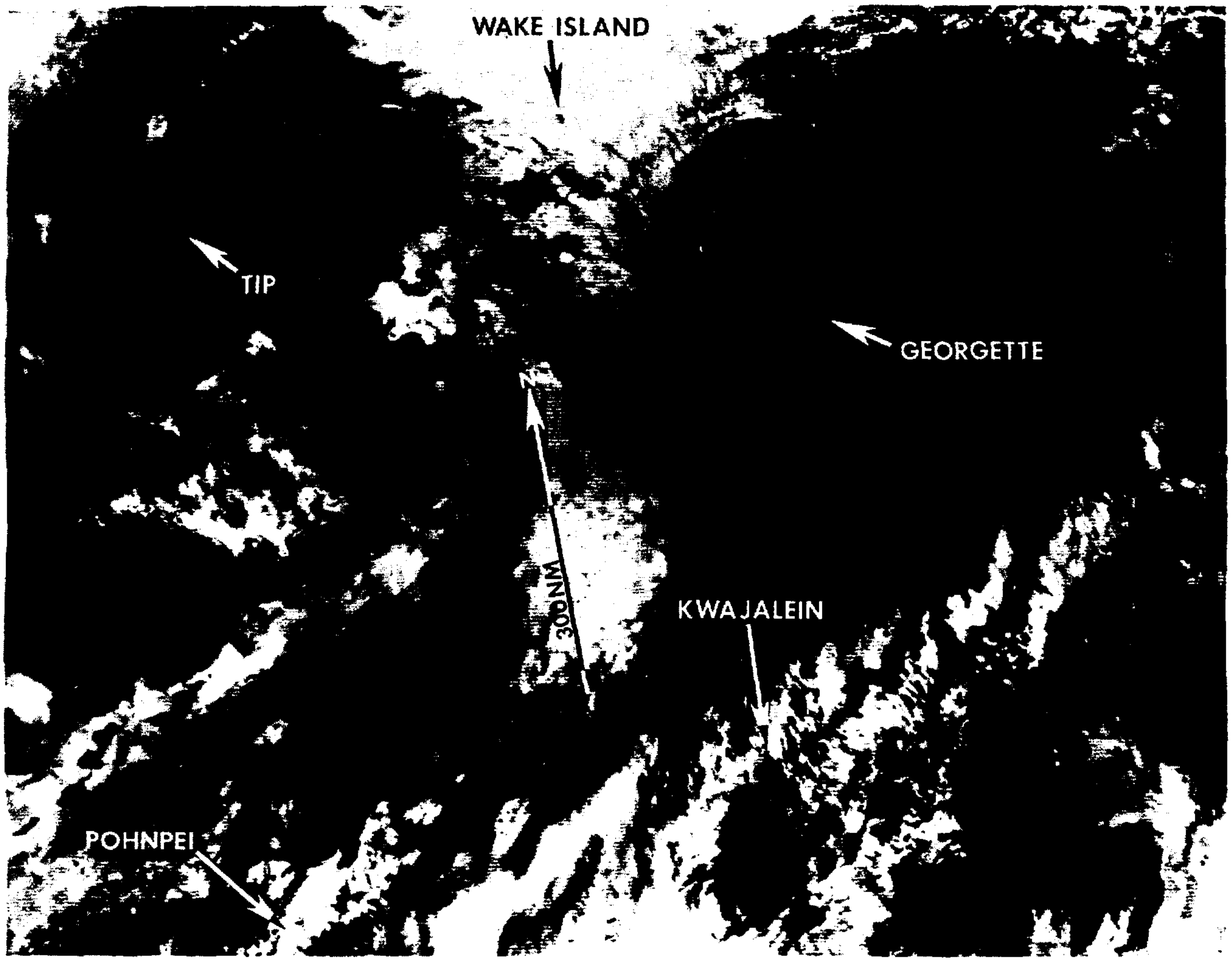


Figure 3-10-2. Georgette (to the east) was weakening as Tip was developing rapidly to its west (121059Z August DMSP infrared imagery).

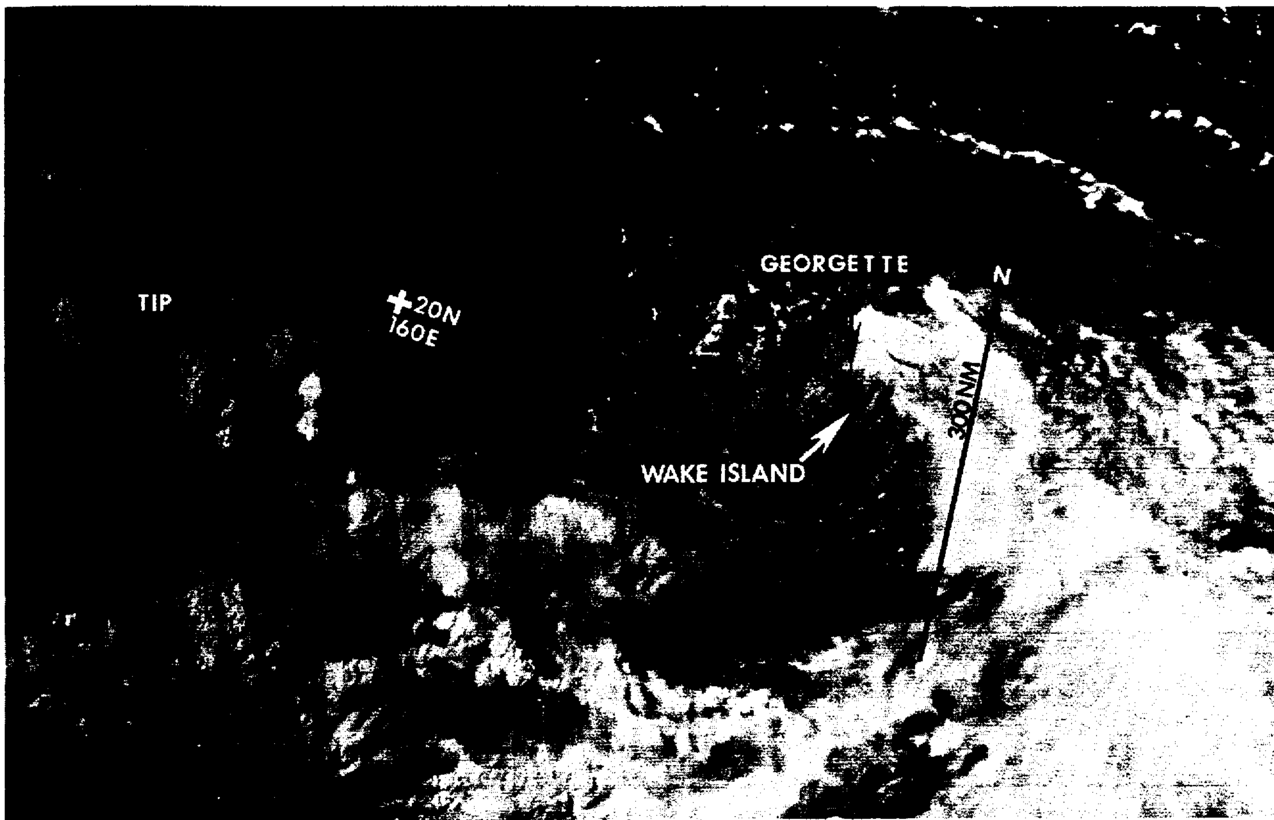


Figure 3-10-3. Georgette just after passing within 30 nm (56 km) to the north of Wake Island. Upper-level shear on the system from the west has exposed the low-level center. Tip, located to the west-southwest of Georgette, was just a few hours away from the first warning (130358Z August DMSP visual imagery).

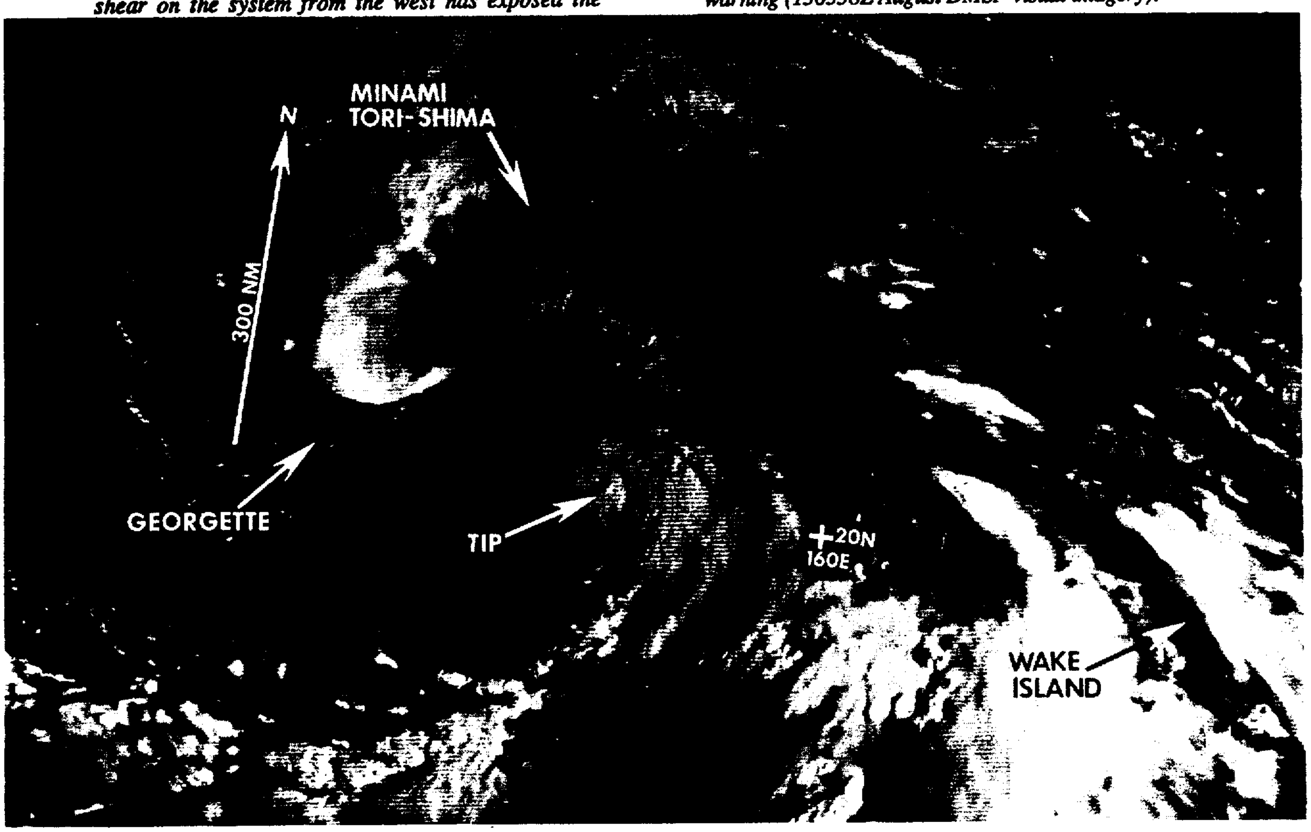


Figure 3-10-4. Tropical Storm Tip as it became the dominant system. Georgette was still a minimal tropical storm and its exposed low-level center was visible as it circled counterclockwise about Tip (142259Z August DMSP visual imagery).

Georgette continued moving toward the northwest, passing almost directly over Wake Island early on the 13th (see Figure 3-10-3). They received maximum sustained winds of 43 kt (22 m/sec) at 130101Z out of the north. No damage was reported by the seven Air Force personnel stationed there. Despite strong shear at upper-levels, it retained minimal tropical storm intensity until after it had circled completely around Typhoon Tip. Georgette weakened to tropical depression intensity for the last time on 15 August (see Figure 3-10-4). Georgette remained distinguishable from Tip for only a day longer (see Figure 3-10-5), then was absorbed into Tip's major convective inflow band.

Tip began early on 9 August as a tropical disturbance located 250 nm (463 km) southwest of Wake Island. The disturbance was placed on the ABPW PGTW by JTWC after it persisted for a day on satellite imagery. The first TCFA was issued at 110430Z on Tip based on an aircraft reconnaissance investigative mission that found a low-level circulation center with maximum winds of 20 to 40 kt (10 to 21 m/sec). The strongest winds were on the north side of the circulation associated with the maximum pressure gradient. The MSLP was 1001 mb.

The second TCFA was issued the next day (12 August) when aircraft reconnaissance did not find a closed circulation center but only a broad surface pressure trough with a MSLP of 998 mb. No substantial winds were noted and the system appeared

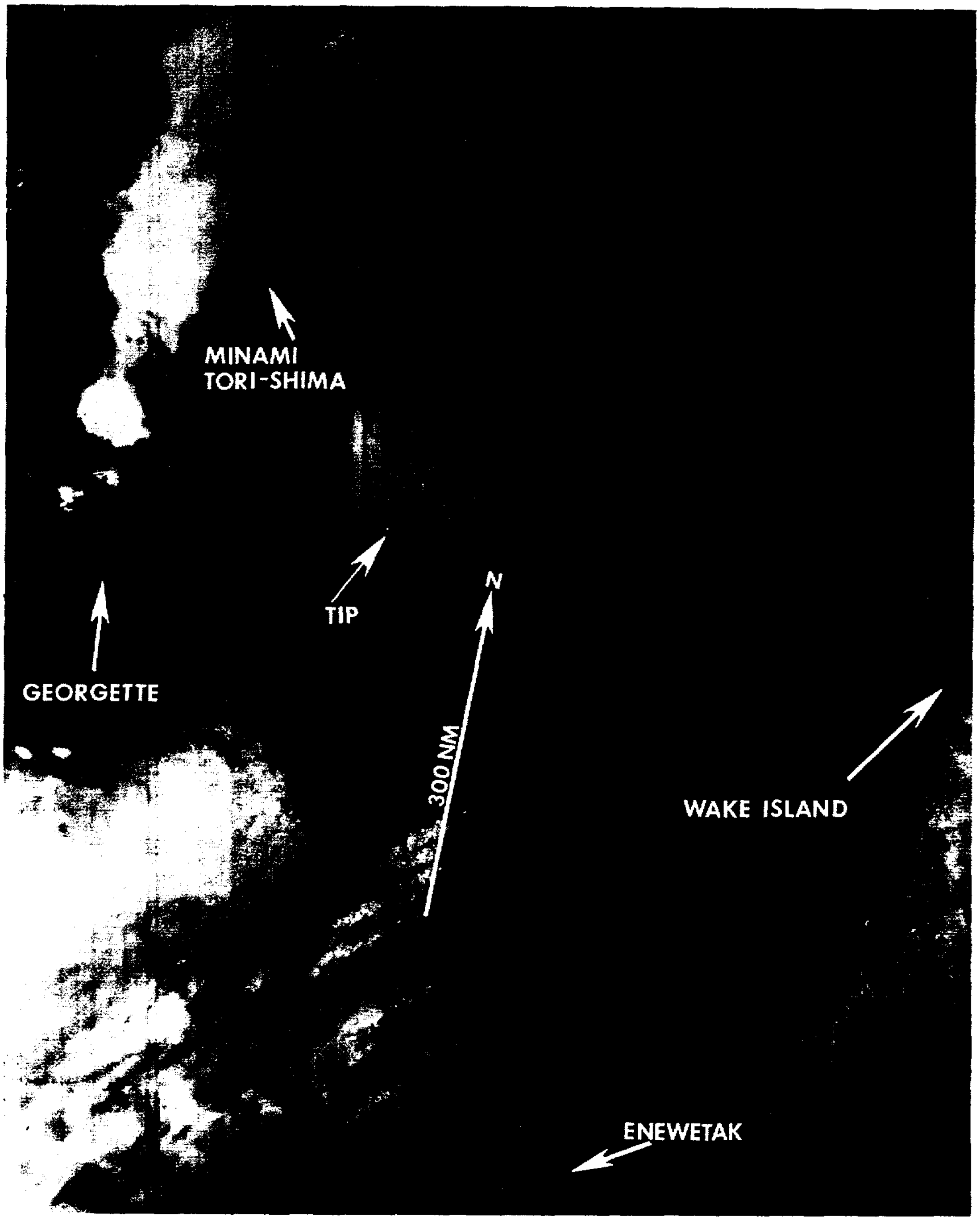


Figure 3-10-5. Tropical Depression 11E (Georgette) retains only its low-level circulation. All the heavy convective activity has become concentrated around Tropical Storm Tip (150336Z August DMSP visual imagery).

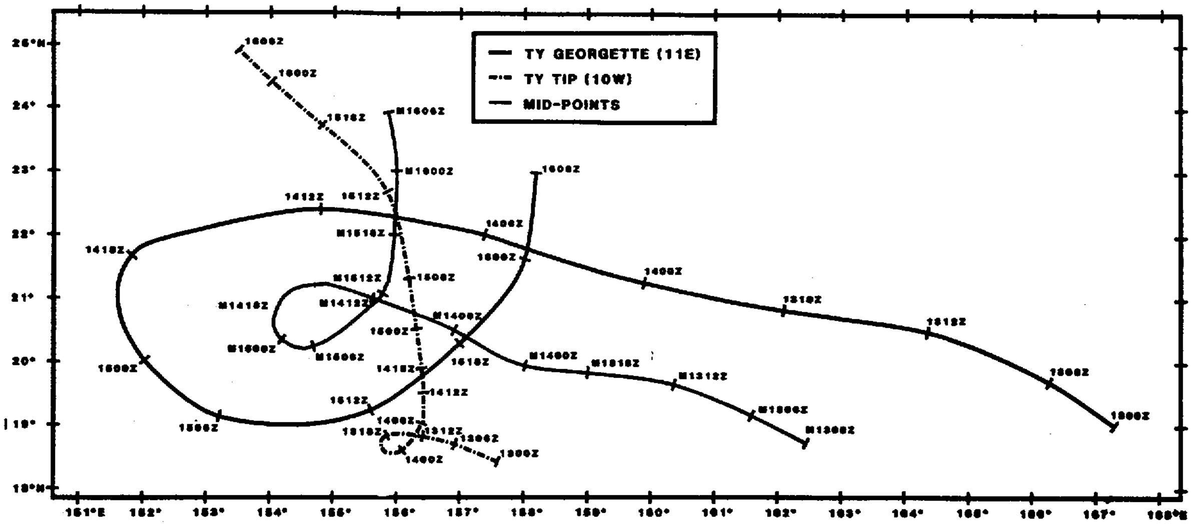


Figure 3-10-6. The binary interaction between Georgette and Tip. The plot of their respective best tracks and midpoints are shown between 130000Z and 160600Z August 1986.

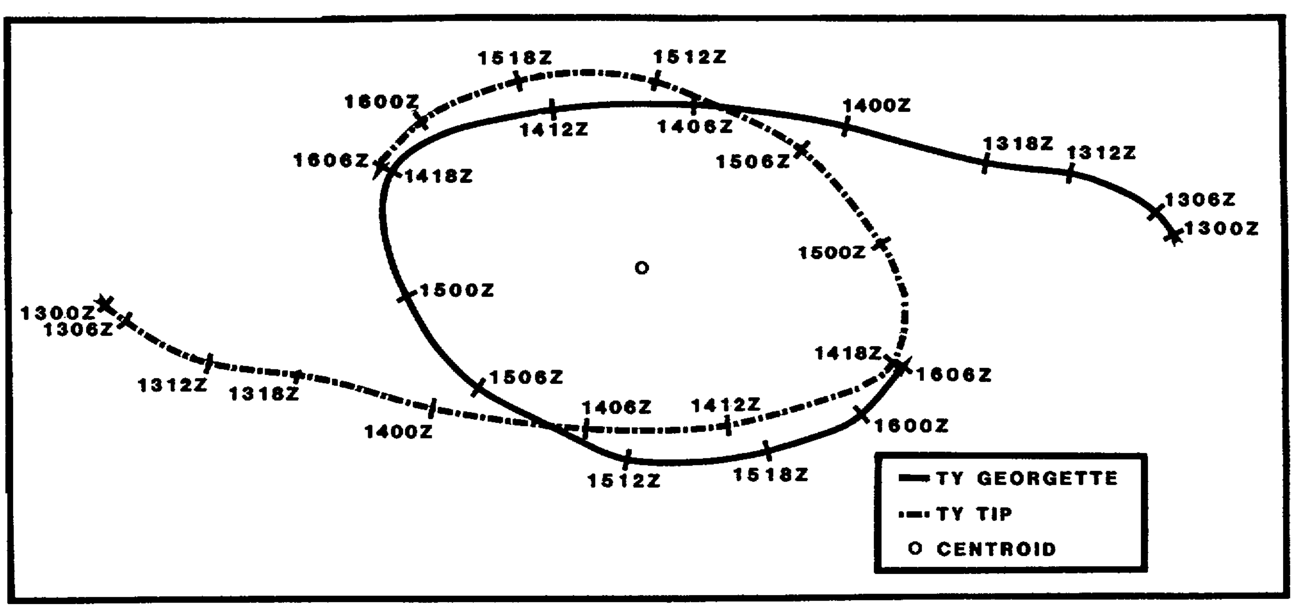


Figure 3-10-7. When the translational motion is removed from both Georgette and Tip, their distinctive center-relative counterclockwise movement about the centroid of their midpoints becomes apparent.

to be quasi-stationary, perhaps due to its proximity to Georgette.

The third TCFA was issued on 13 August without new aircraft reconnaissance information due to the lack of available reconnaissance assets. Later, after an aircraft reconnaissance investigative mission found winds of 50 kt (26 m/sec) and a MSLP of 987 mb, JTWC issued its first warning on Tip, valid at 130600Z. The same aircraft also fixed Georgette 160 nm (296 km) northwest of Wake Island (see Figure 3-10-3). The two tropical cyclones were 450 nm (833 km) apart at this time. At 131800Z, they were only separated by 400 nm (741 km) and it appeared that Tip was capturing the low-level inflow of Georgette and was becoming more intense.

A binary interaction occurred between Georgette and Tip with Georgette tracking west-northwestward and circling around Tip in a counterclockwise motion (see Figure 3-10-6). Initially, Tip was moving very slowly in the same direction, but it eventually did a small counterclockwise loop. Tip benefited from Georgette's passage to the north because it acted as a shield from the unfavorable upper-level shearing effect of the strong westerlies aloft. Removing the translational motion and plotting the relative motion of the two systems about the centroid of their midpoints (Figure 3-10-7) verifies the binary interaction as the pair circled one another in a broad elliptical path.

During the latter part of the binary interaction, as Tip was moving north-northwestward, it increased in intensity and in the process passed over Minami Tori Shima (formerly Marcus Island). At 160600Z, Tip peaked with 80 kt (41 m/sec), then turned to the right on the 17th and headed off toward the northeast (see Figure 3-10-8).

Tip transitioned to an extratropical cyclone on the 19th (see Figure 3-10-9) and eventually dissipated (4 days later) east of Japan. JTWC issued its final warning on the system at 190600Z. No reports of damage or fatalities were received on these two tropical cyclones.

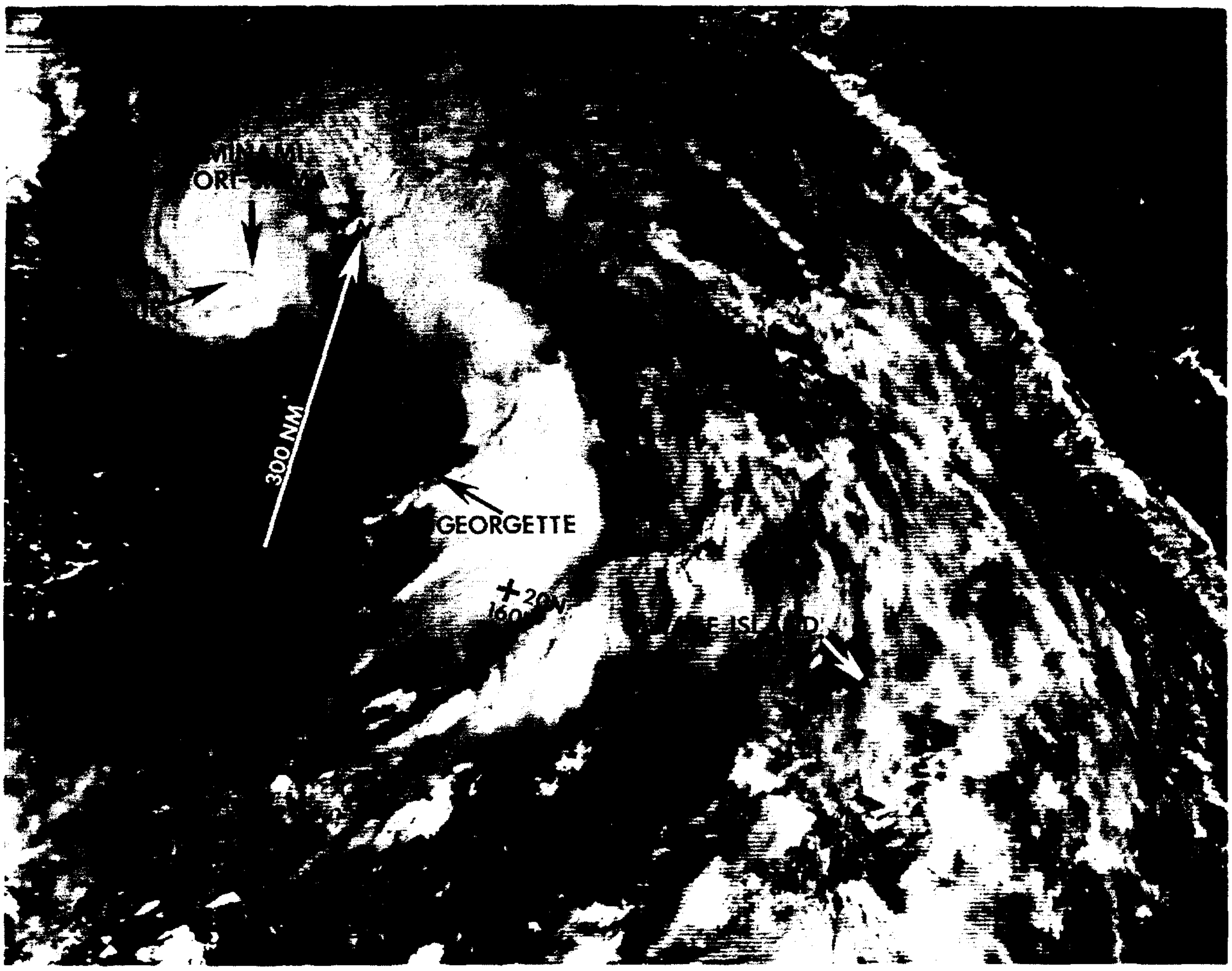


Figure 3-10-8. Typhoon Tip passing within 30 nm (56 km) to the northeast of Minami Tori Shima (formerly Marcus Island) (152239Z DMSP visual imagery).

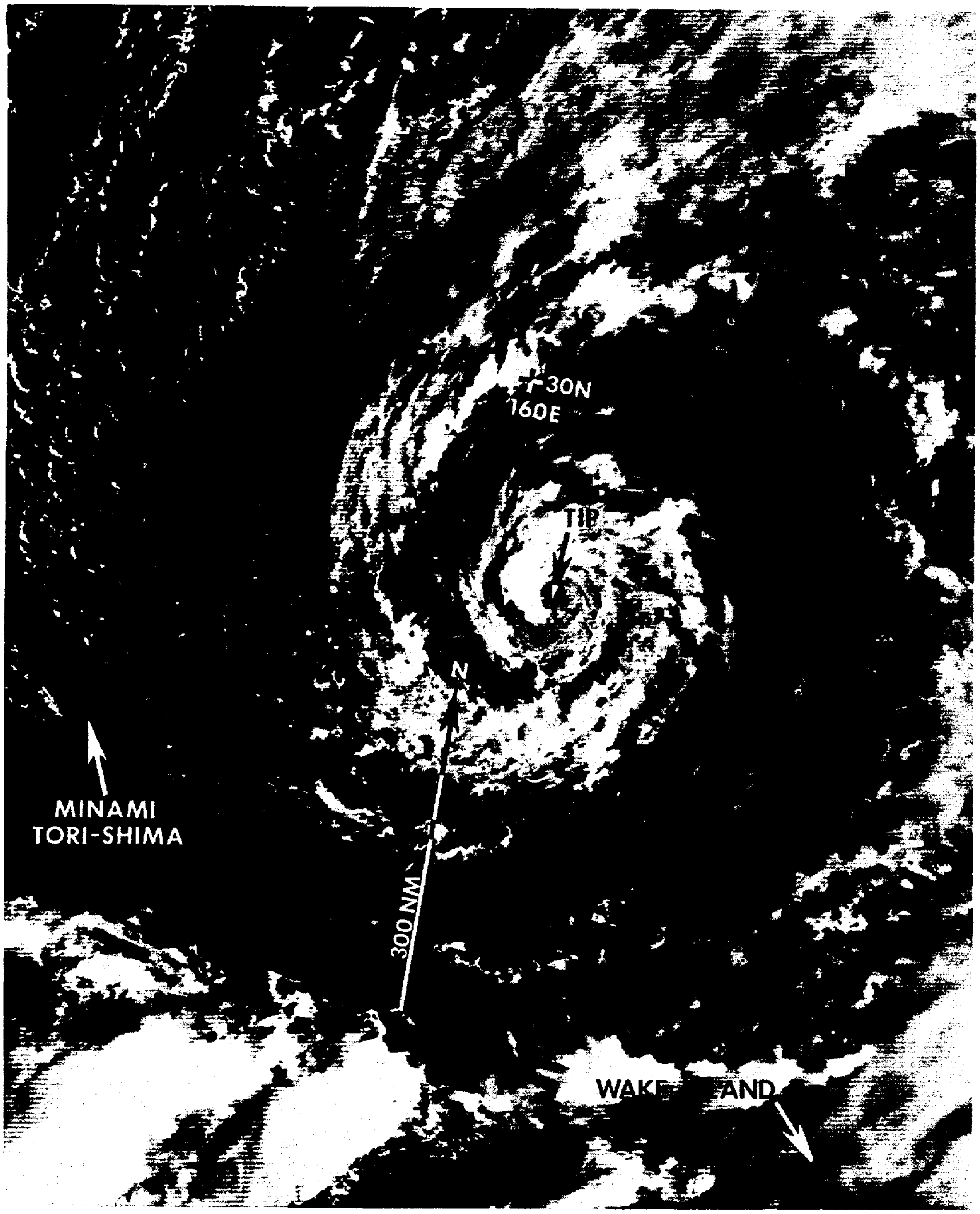
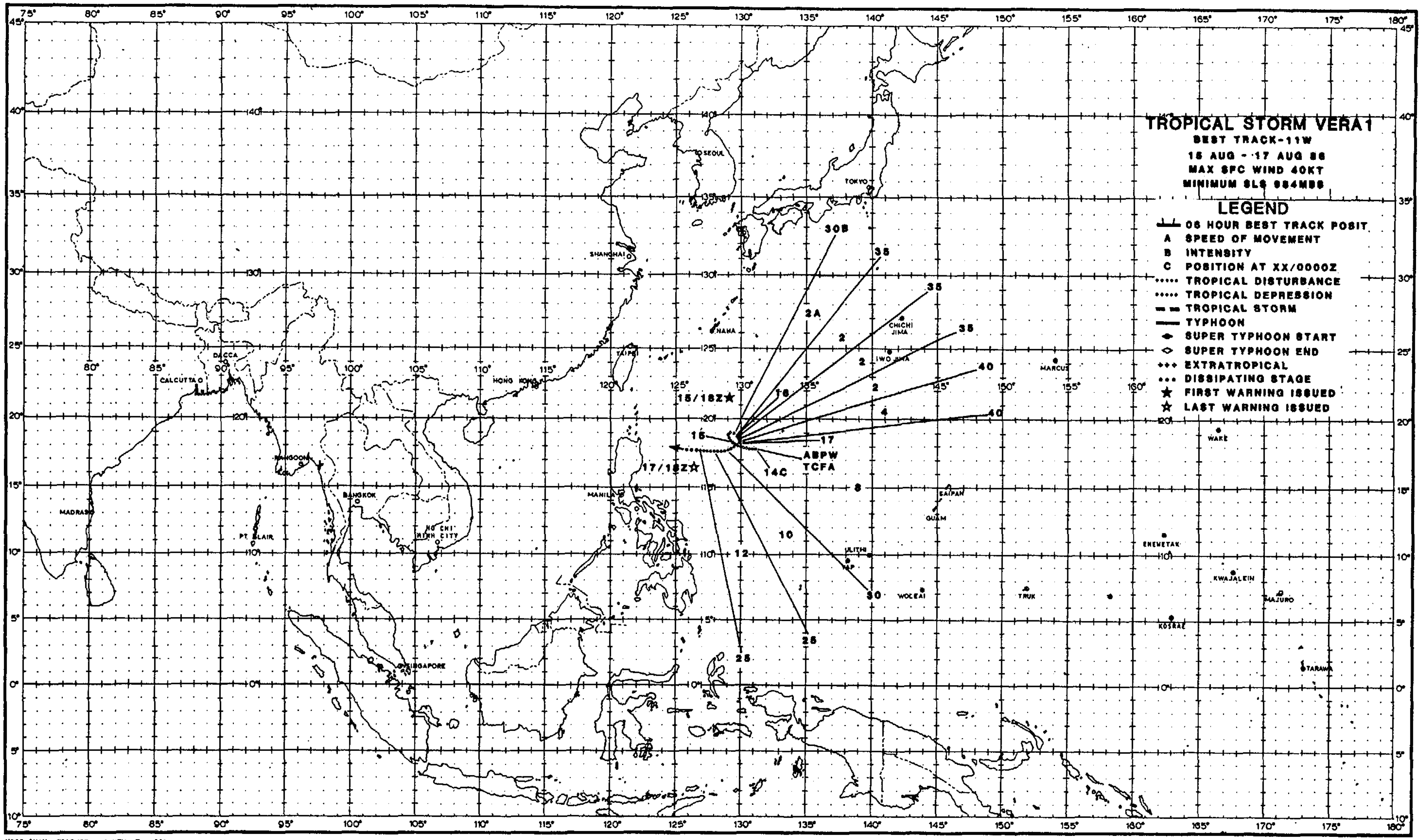
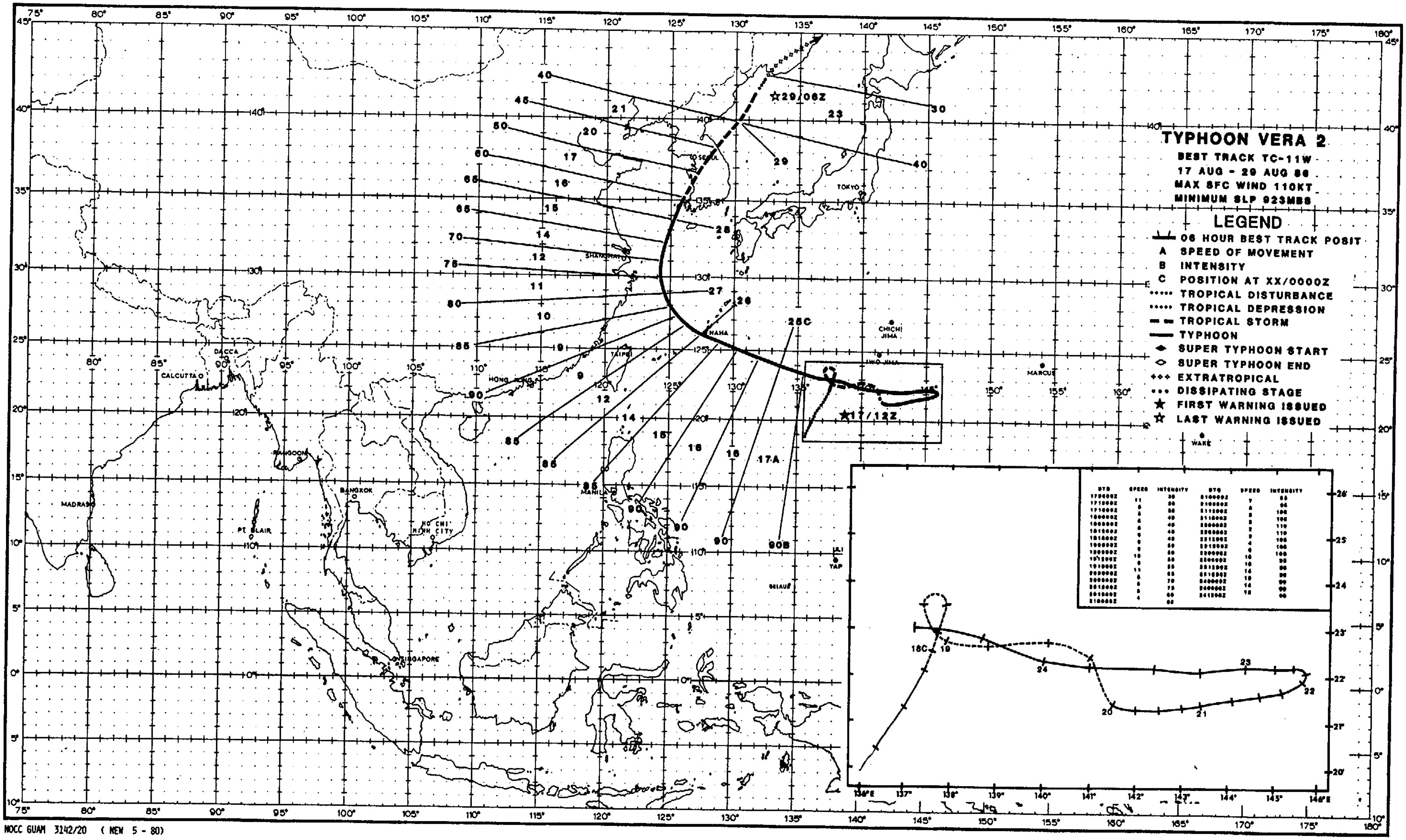


Figure 3-10-9. Tropical Storm Tip becoming extratropical. Note the wrapping of the relatively clear area around the center and the ragged appearance of Tip's central convection (182318Z August DMSP visual imagery).



NOCC GUAM 3142/20 (NEW 5 - 80)


TYPHOON VERA 2
BEST TRACK TC-11W
17 AUG - 29 AUG 86
MAX SFC WIND 110KT
MINIMUM SLP 923MBS
LEGEND
06 HOUR BEST TRACK POSIT
A SPEED OF MOVEMENT
B INTENSITY
C POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
DISSIPATING STAGE
FIRST WARNING ISSUED
LAST WARNING ISSUED
☆29/06Z
★17/12Z
TOKYO
NAHA
TAIPEI
SHANGHAI
HONG KONG
MANILA
BANGKOK
HO CHI MINH CITY
SINGAPORE
CALCUTTA
DACCA
MADRAS
PT BLAIR
RANGOON
CHICHI JIMA
IWO JIMA
MARCUS
WAKE
YAP
PELAU
NOCC GUAM 3142/20 (NEW 5 - 80)

Typhoon Vera was another classic "monsoon depression" (see Tropical Storm Sarah (09W)) which formed in the most intense and extensive monsoon trough in the western North Pacific since 1974. Locating and forecasting the initial phases of Vera (from 14 to 18 August 1986) within this extensive trough presented unique problems for JTWC. Vera was relocated several times within the monsoon trough as the low-level flow attempted to stabilize around one circulation center. In post analysis, it was determined that Vera was actually two systems: the first (Vera #1) stabilized only briefly, reached tropical storm intensity then dissipated in the central Philippine Sea; the second (Vera #2) formed at the northeast periphery of the monsoon trough, over 360 nm (667 km) from Vera #1, developed slowly and reached typhoon intensity before crossing Okinawa and the Korean peninsula. The problems in locating and forecasting Vera's low-level circulation center were exacerbated by limited aircraft availability (due to other high priority missions for WC-130 aircraft and multiple tasking problems with Typhoons Tip (10W) and Georgette (11E)), sparse synoptic data and inconclusive satellite imagery.

Vera #1 developed on the heels of two typhoons, Tip (10W) and Georgette (11E). On 12 August, Georgette (11E) was moving west-northwestward and was located to the southeast of Wake Island. The onset of the intense and extensive monsoon trough associated with Georgette's inflow region was first noticed at that time, as southwesterly gradient winds of near 30 kt (15 m/sec) were observed at Yap (WMO 91413), Truk (WMO 91334) and Pohnpei (WMO 91348). Georgette (11E) was positioned at the eastern end of this trough (Figure 3-11-1), which extended from the Philippine Islands to the dateline. The onset of the

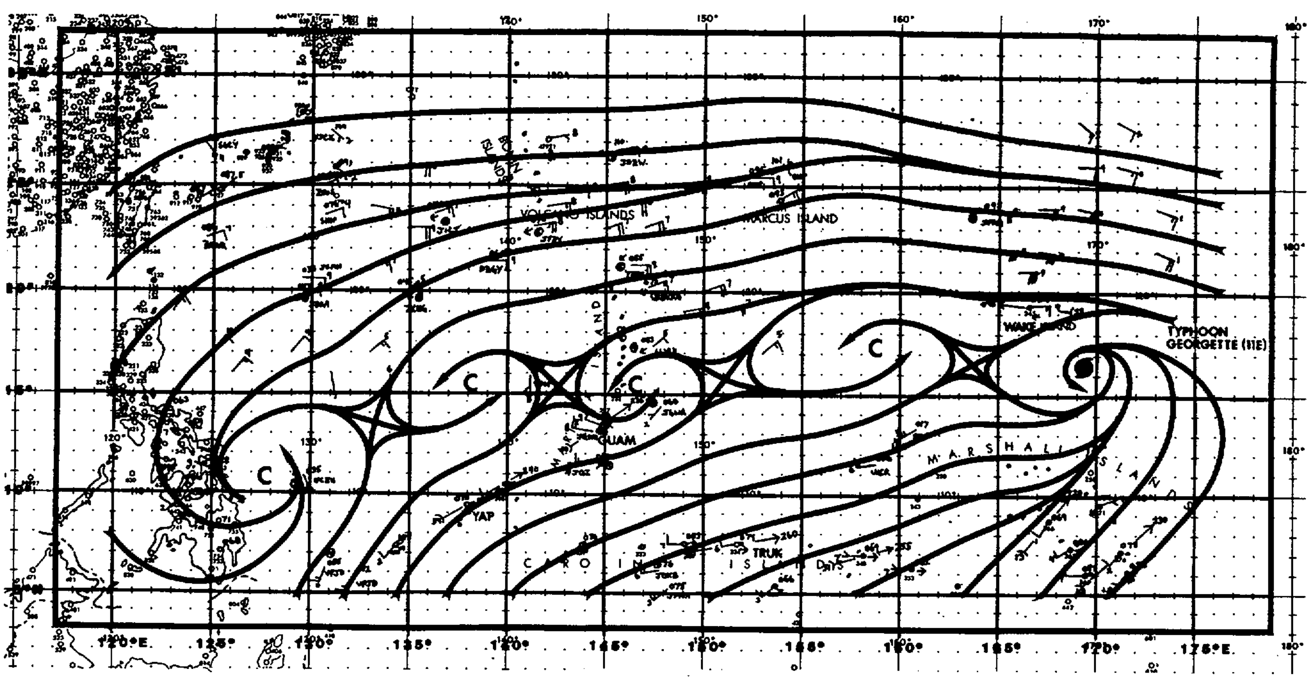


Figure 3-11-1. The surface/gradient analysis at 120000Z August showed the onset of the intense monsoon trough extending from the Philippine Islands to the dateline. Note the strong gradient wind reports at Yap (WMO 91413), Truk (WMO 91334), and Pohnpei (WMO 91348).

monsoon trough was accompanied by an extensive cloud maximum in the Philippine Sea (Figure 3-11-2) where Vera #1 formed. An interesting feature of the trough was the unusually low pressures, which were evident along the axis of the trough between 12 and 15 August. These pressures ranged from 996 to 1006 mb.

By the end of the second week of August gale force westerly winds were present in the southern Philippine Sea and transitory light and variable circulation centers formed along the trough axis. Satellite imagery provided little help in locating any of these circulation centers in the wind field due to the transitory nature of the central convection. Consequently, the circulation that eventually became Vera #1 was never mentioned on the Significant Tropical Weather Advisory (ABPW PGTW) as a suspect area, although several other areas in the monsoon trough were being reported on.

The first Tropical Cyclone Formation Alert (TCFA) was issued on 14 August at 0000Z. This was based on convection that had persisted for 12-hours and was colocated with an analyzed circulation center in the surface/gradient wind field. The TCFA was reissued at 150000Z, as satellite imagery indicated a slight increase in convective curvature. It appeared that the low-level flow was beginning to stabilize around an area located approximately 420 nm (778 km) south-southeast of Okinawa, Japan.

Figure 3-11-2. The area of intense convection that prompted the first TCFA on Vera #1. Note the extensive area of convection in the southwest monsoonal flow in the southern Philippine Sea (132119Z August DMSP visual imagery).

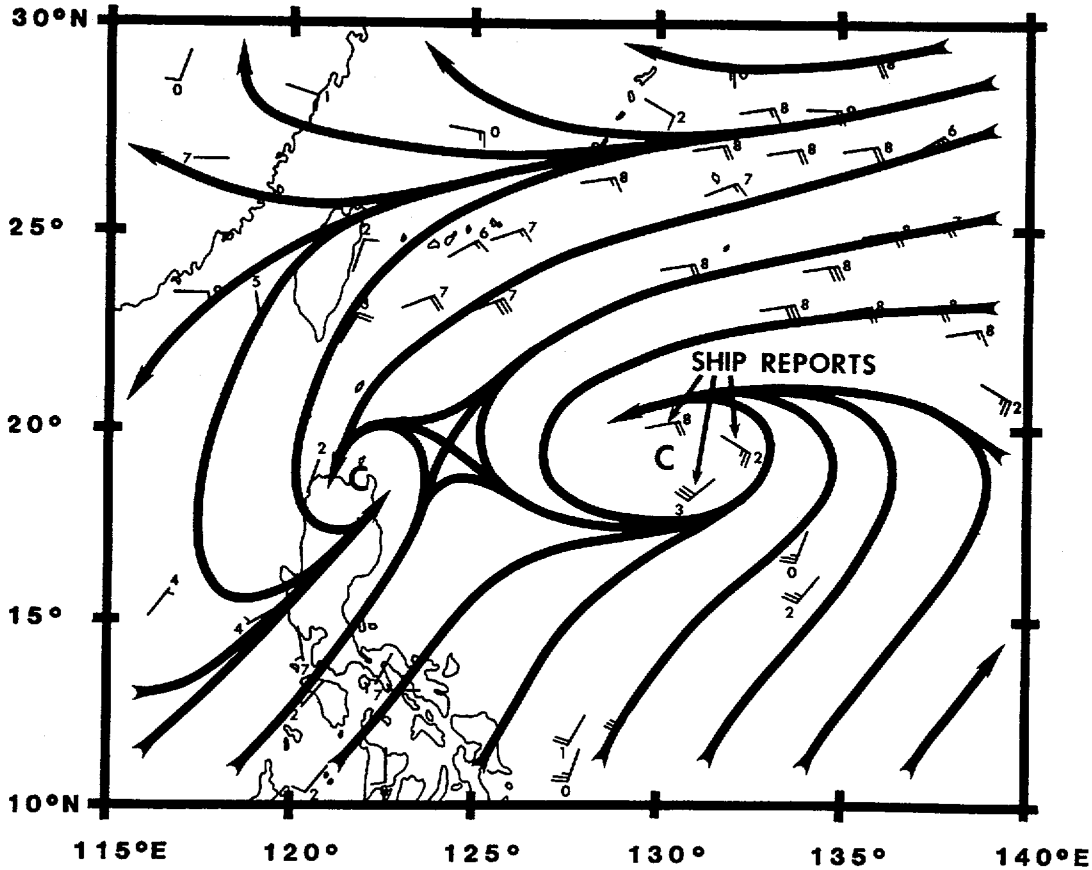


Figure 3-11-3. The 151200Z August ship reports which prompted first warning on Vera #1 at 151800Z August.

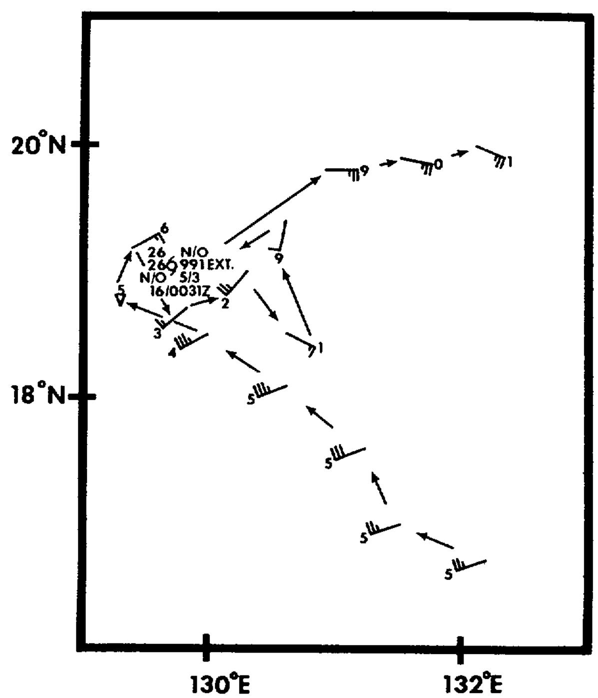


Figure 3-11-4. The August 16th daylight aircraft reconnaissance investigative mission into Vera #1 fixed the low-level circulation center.

At 151200Z, the first warning was issued on Vera #1 (the first system). This warning was prompted by three ship reports (Figure 3-11-3) that defined three quadrants of the 30 kt (15 m/sec) tropical depression. Twelve hours later, the aircraft investigative flight into Vera #1 found winds of 35 kt (18 m/sec) and a minimum sea-level pressure (MSLP) of 991 mb (Figure 3-11-4), confirming the ship report and justifying an upgrade to tropical storm intensity.

The forecast reasoning from 15 August to 17 August, prior to the formation of Vera #2 (the second system) to the northeast, was for Vera #1 to move slowly toward the west-northwest. This was based on the anticipation of the strengthening of the subtropical ridge to the north. However, Vera #1 remained confined to the lower troposphere and embedded in the monsoon trough. Aircraft reconnaissance at 850 mb (5000 ft (1524 m)) was unable to locate the circulation center during a nighttime fix mission on 16 August. At 162333Z, a daylight 1500 ft (457 m) fix mission indicated Vera #1 had moved about 60 nm (111 km) south-southeast of the the last fix mission. At that point Vera #1 was elongated east-west and relatively ill-defined. The surface/gradient analysis at 170000Z (Figure 3-11-5) indicated that the monsoon trough had elongated considerably with a large area of extremely low pressures (about 993 mb). At 171200Z the surface analysis indicated that Vera #1 was no longer evident.

Satellite imagery at 171240Z (Figure 3-11-6) indicated an apparent circulation center (Vera #2) southwest of Tip (10W), which was moving slowly northward and had become the dominant system in the monsoon trough. The analysis (Figure 3-11-5) was 12-hours prior to the formation of Vera #2 that was (perhaps mistakenly) maintained as Vera after being relocated more than 360 nm (667 km) to the east-northeast. The satellite data prompted the first warning on Vera #2 at 171200Z. The dramatic relocation was verified at 180716Z, when the first aircraft reconnaissance fix position in over 30-hours (Figure 3-11-7) confirmed the presence of the 50 kt (26 m/sec) system embedded in the monsoon trough.

The sudden and dramatic formation of Vera #2 caused many problems for the fleet customers as well as for the forecasters. In essence, Vera #1 had been forecast to move slowly toward the west-northwest for three days when the relocation occurred, placing the system 360 nm (667 km) to the east-northeast in a six hour period. Confusing and conflicting satellite imagery provided little insight into the location of the system during these stages. At 171200Z, Vera #2 was at tropical depression intensity and moving slowly northward. For the next three days, Vera #2 intensified slowly, moving erratically at first, and then slowly eastward within the monsoon trough. The intense trough was again asserting its influence on the system's track, as the remnants of Tip (10W) provided the "anchor" at the eastern end of the monsoonal flow. Vera #2 continued to move eastward with the monsoon west-southwesterlies until the 22nd, when it slowed and began to track northward.

The synoptic situation governing Vera #2's movement began to change on the 21st, when a small surface ridge appeared to be building to the north of Vera #2. This ridge continued to build, helped perhaps by increasing upper-level convergence to the east-northeast of Vera #2, enhancing subsidence in the upper troposphere and ridging at the surface.

Between 220000Z and 221200Z, Vera #2 turned northward, and then westward, as the low- to mid-level ridge became firmly established to the north. The shift in the steering flow is evident in the change in the 700 mb Numerical Variational Analysis (NVA) streamline analysis between 220000Z and 221200Z (Figures 3-11-8 and 3-11-9). Apparently, the mid-level trough associated with the remnants of Tip (10W) had completely disappeared by 221200Z and was replaced by ridging northeast of Vera #2. This ridge provided the steering flow until Vera #2's recurvature on 27 August. Vera #2 reached its maximum intensity of 110 kt (57 m/sec) and MSLP of 923 mb on 21 August, just prior to turning westward toward Okinawa.

Vera #2 continued to move west-northwestward from the 22nd through the 26th, passing directly over the island of Okinawa late on the 25th (Figure 3-11-10). The forecast had provided those on Okinawa with 66-hours of warning before the closest point of approach (CPA) occurred. All aircraft and ships had been evacuated, sortied, or secured long before Vera #2 hit with maximum sustained winds (over water) of 85 kt (44 m/sec).

The recurvature and extratropical transition phase of Vera #2's track began on 26 August. Upon reaching the western periphery of the subtropical ridge, Vera #2's movement had slowed to 9 kt (17 km/hr) and turned northwestward at approximately 260600Z. Vera #2 turned northward at about 270000Z and passed 160 nm (296 km) east of Shanghai 12-hours later. After passing east of Shanghai, Vera #2 began to accelerate north-northeastward. By the 28th, the tropical cyclone had lost its connection with the low-level monsoonal westerlies and weakened to 60 kt (31 m/sec). Figure 3-11-11 shows Vera #2 just prior to landfall near Kunsan AB, Republic of Korea, with a large cirrus shield to the north of the exposed low-level circulation, indicative of a tropical cyclone transitioning into an extratropical system. Vera #2 cleared the Korean peninsula at 281800Z with an intensity of only 45 kt (23 m/sec) and continued accelerating northeastward. It completed extratropical transition at 290600Z in the Sea of Japan.

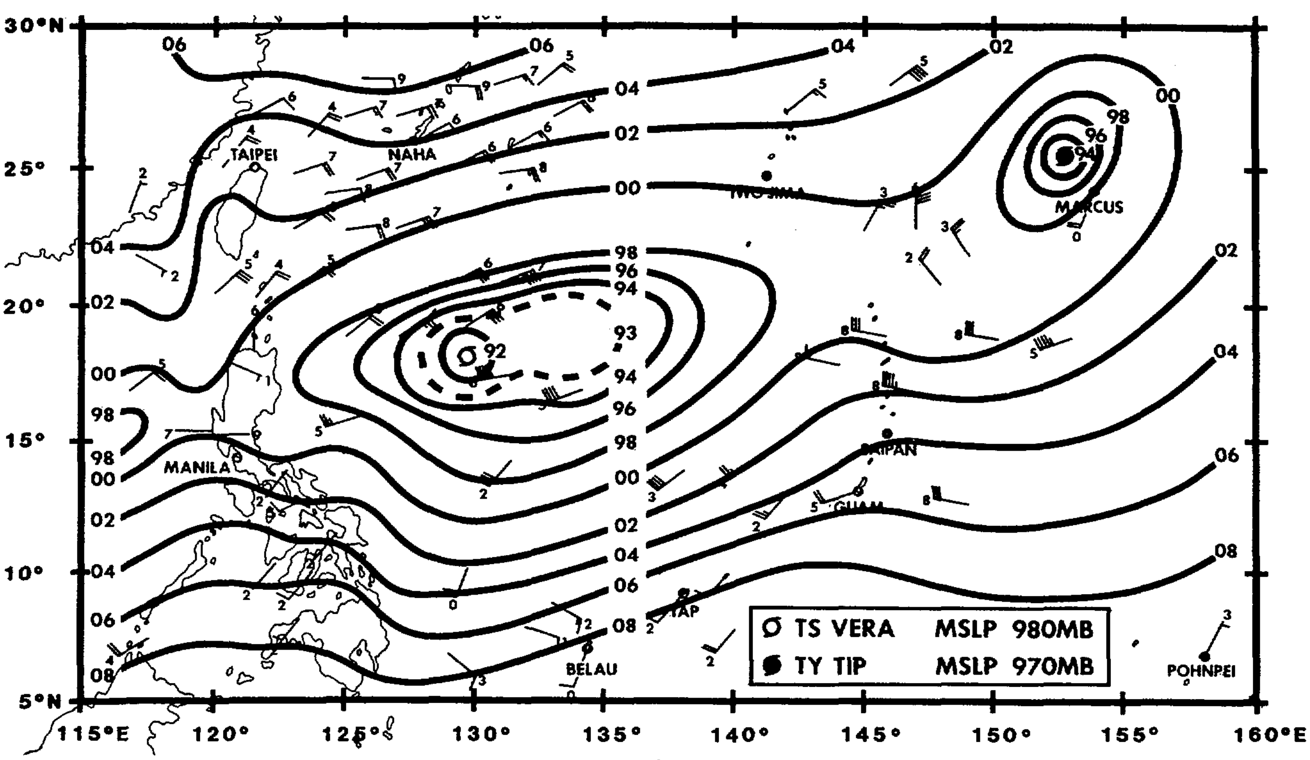


Figure 3-11-5. The surface/gradient analysis at 170000Z (12-hours prior to the formation of Vera #2). Note the elongated trough to the east and west of Vera #1.

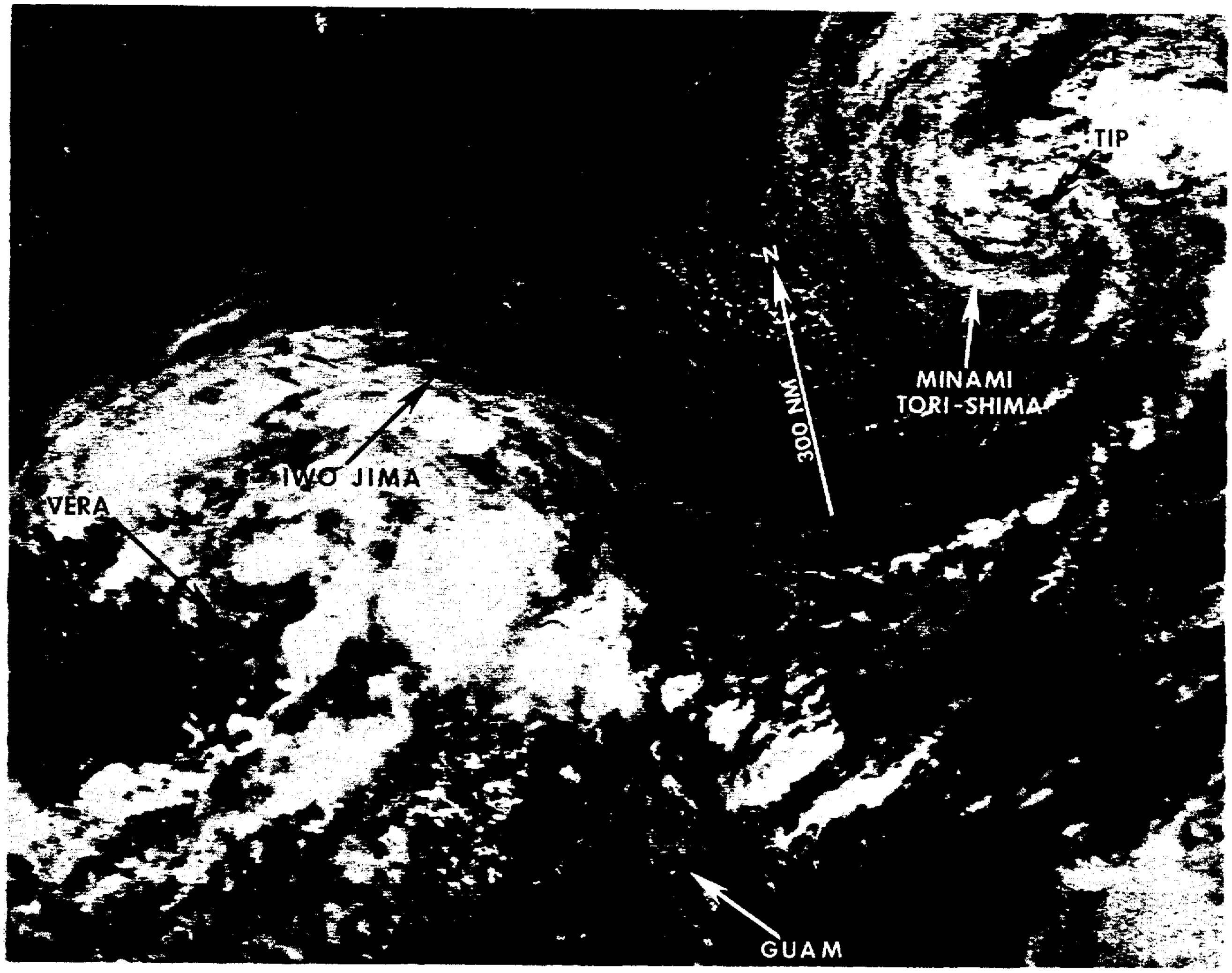


Figure 3-11-6. Typhoon Tip and the early stages of Vera #2 (171240Z August DMSP visual imagery).

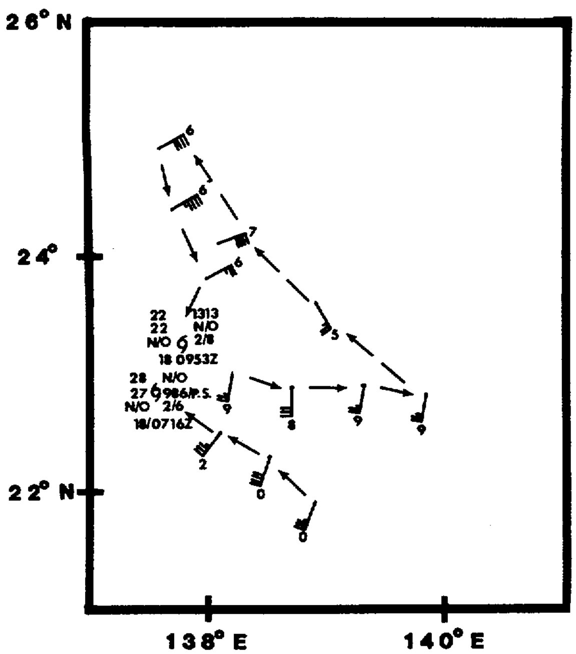


Figure 3-11-7. First aircraft reconnaissance fix mission after relocation to Vera #2 (180716Z).

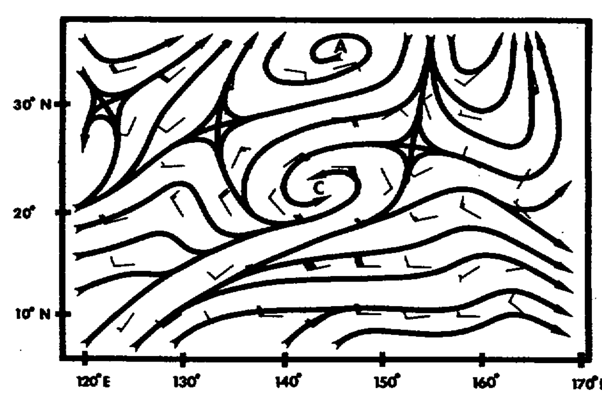


Figure 3-11-8. The 220000Z August 700 mb NVA analysis showing the trough (associated with the remnants of Typhoon Tip (10W)) to the northeast of Vera #2.

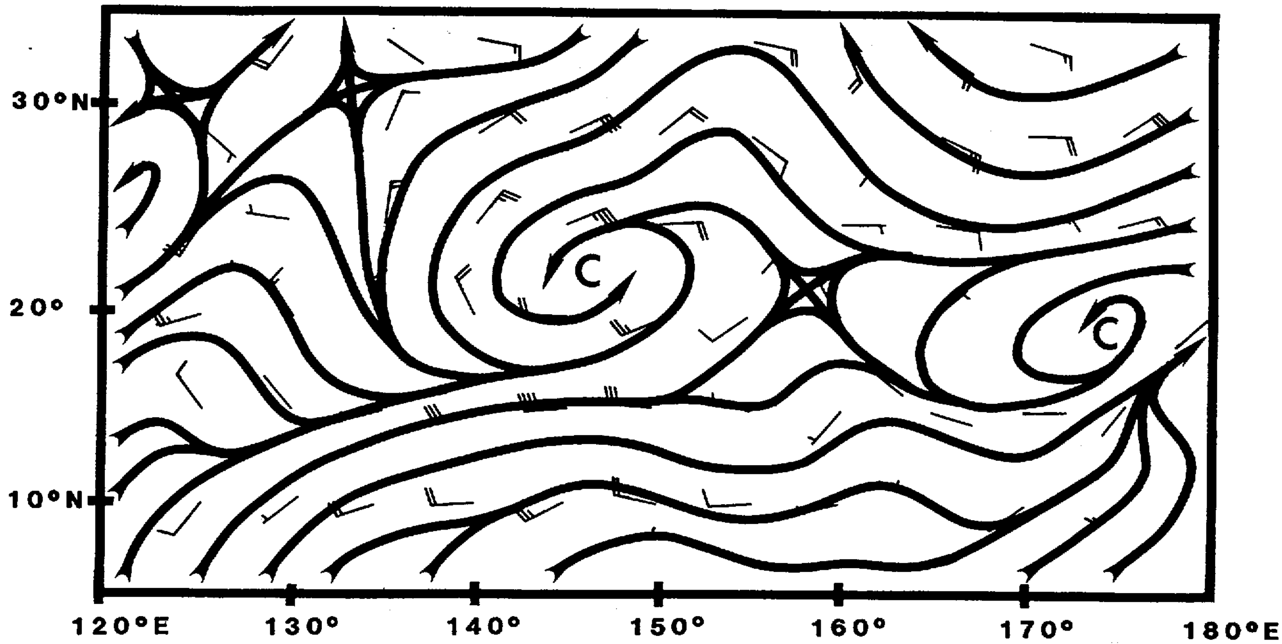


Figure 3-11-9. The 221200Z August 700 mb NVA analysis showing a ridge (in place of the trough 12-hours earlier) north and northeast of Vera #2.

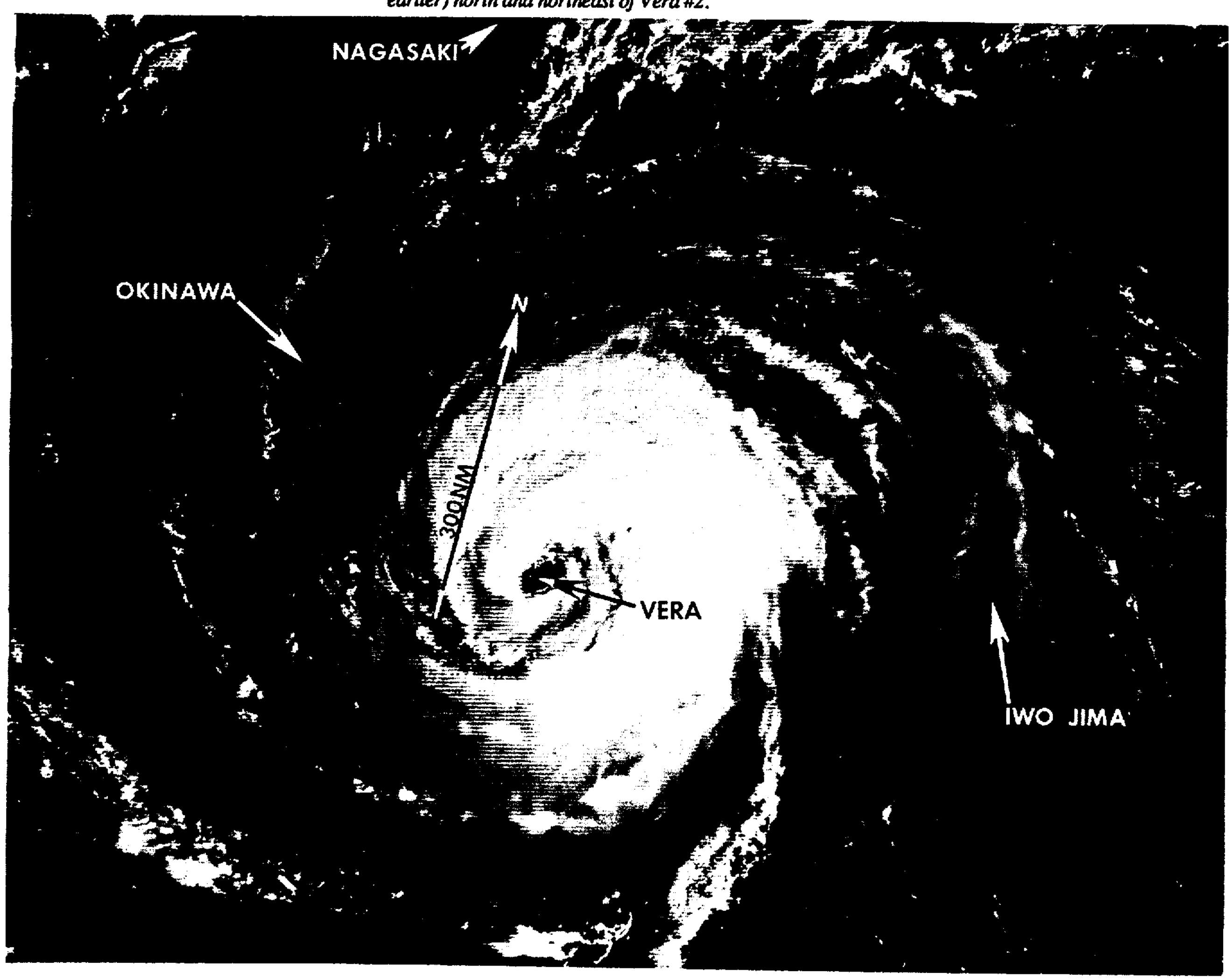


Figure 3-11-10. Vera #2 at typhoon intensity as it approached Okinawa (250039Z August DMSP visual imagery).

In addition to the problems of finding and forecasting the initial low-level center, Vera #2 caused considerable damage and loss of life. It severely impacted civilian shipping and military operations at sea. Okinawa, in contrast, because of the early warning provided, experienced only slight damage; mostly to power lines for private homes. One fisherman was killed. Kadena AB recorded peak wind gusts of 84 kt (43 m/sec). High seas, however, placed several ships at sea in distress. In Shanghai, seven people were killed and 28 injured when Vera #2 passed 160 nm (296 km) east of the city. The New China News Agency (NCNA) reported more than 500 homes were destroyed and 3,000 emergency workers were recalled to restore electrical supplies and to ensure dikes along the Huangpu river and the coast were secure. NCNA also reported that more than 3,000 vessels sought shelter as Vera #2 approached. On the Island of Cheju, 28 houses were destroyed, leaving 50 people homeless. In South Korea, six people were killed and over one million dollars worth of damage was reported. The most extensive damage to U.S. military facilities was reported at Taegu AB, where more than 75 trees were felled and power lines were downed. The roofs of several buildings were blown away.

In retrospect, Vera underscores the difficulty of positioning and forecasting tropical cyclones that form in strong monsoonal troughs. In addition, the eastward movement of Vera #2 for three days was an interesting anomaly that was perhaps influenced by the intense monsoon trough that extended throughout the entire western North Pacific for most of August.

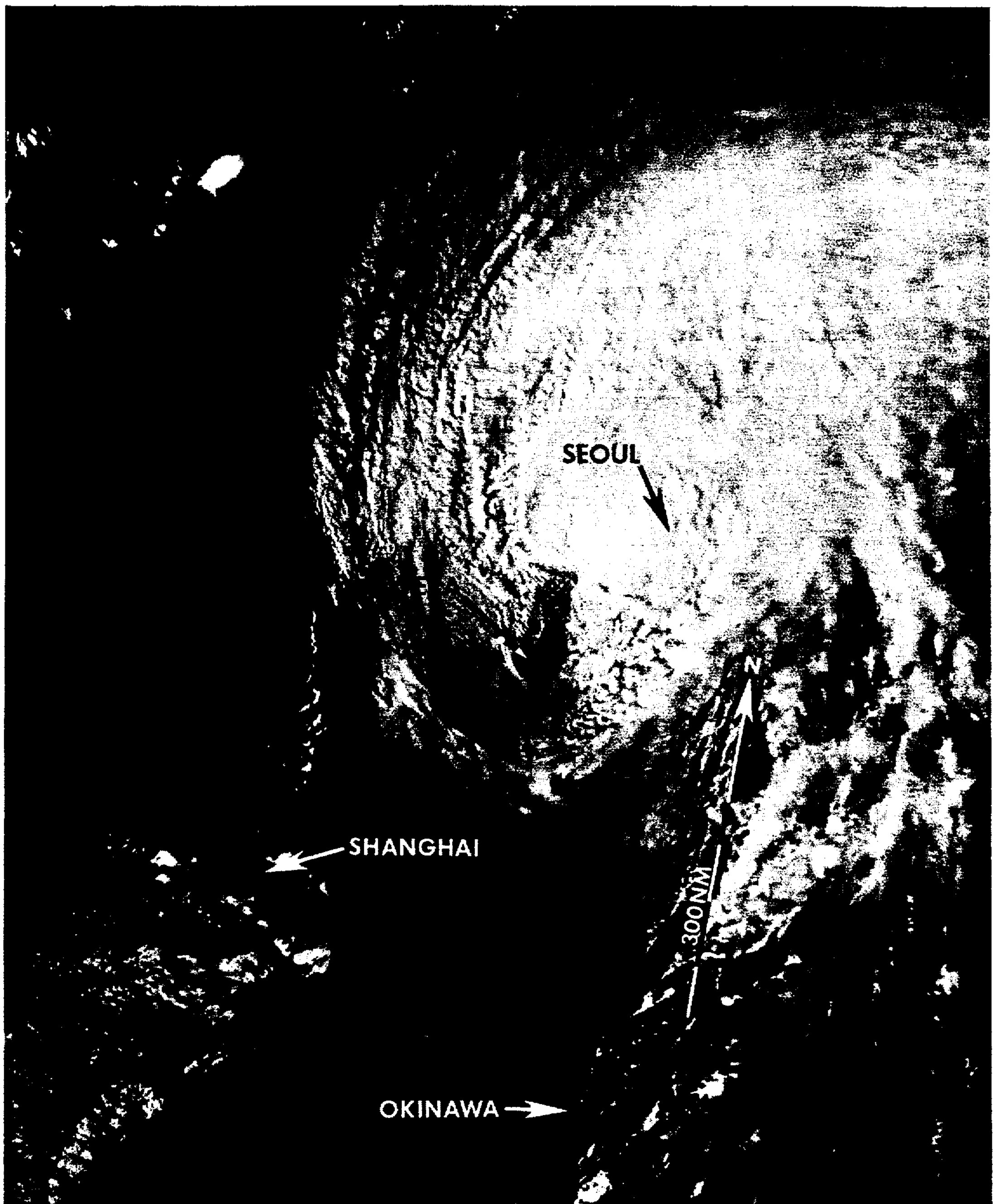
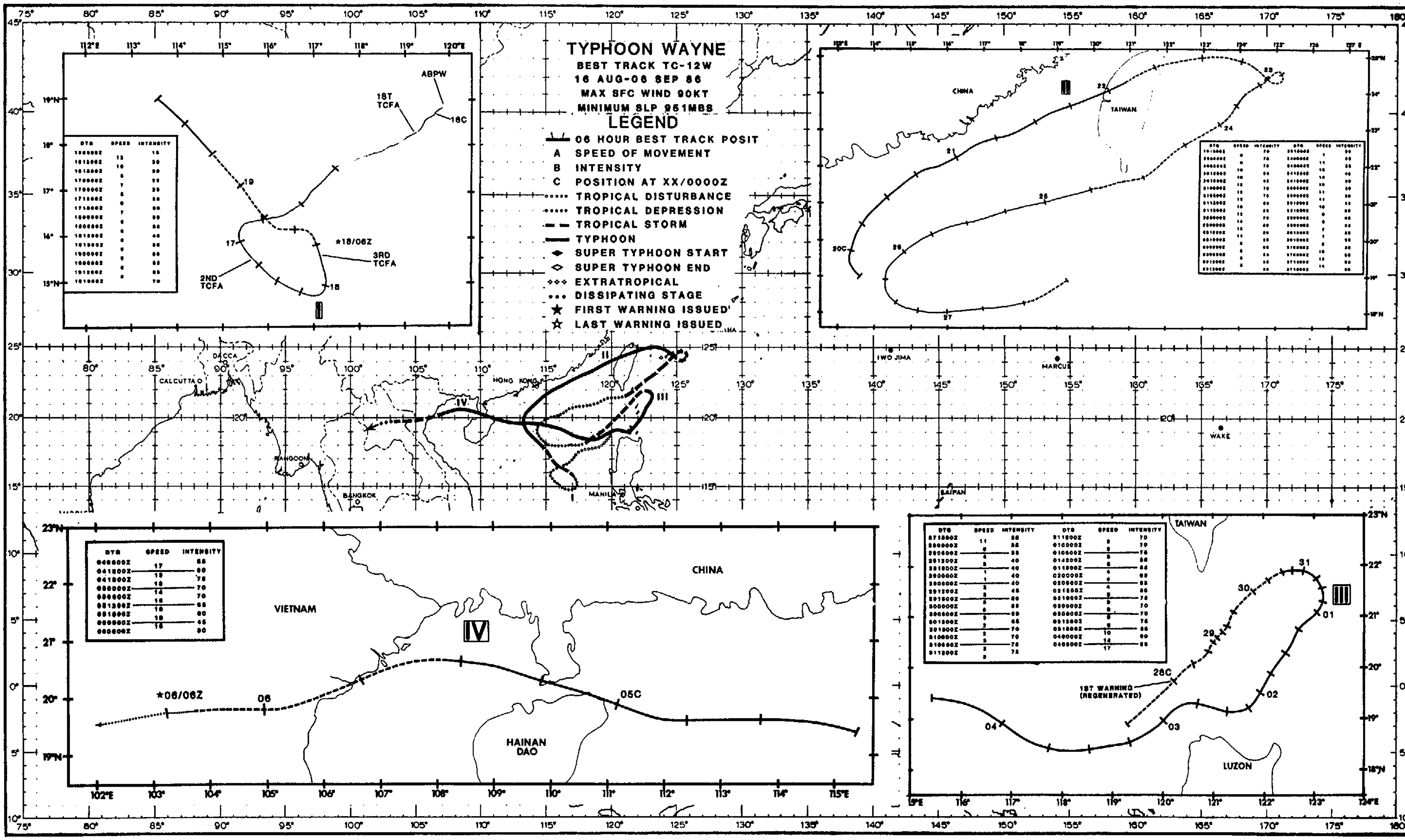


Figure 3-11-11. Vera #2 in the beginning stages of extratropical transition just prior to landfall near Kunsan AB, Republic of Korea (280621Z August NOAA visual imagery).



NOCC GUAM 3142/20 (NEW 5 - 80)

Typhoon Wayne was one of the longest-lived tropical cyclones in the 28-year history of the Joint Typhoon Warning Center (JTWC). Wayne had more warnings (67) issued on it than any other tropical cyclone of 1986. Another unusual fact concerning Typhoon Wayne was that it never fully emerged from the monsoon trough. Due to its highly atypical track, Wayne caused significant forecasting problems for JTWC.

Wayne was a small system that remained in the northern South China Sea and the western Philippine Sea throughout its entire life. Its best track includes three loops and a figure eight. To further complicate matters, Wayne also dissipated and then regenerated while still over tropical waters.

During the middle of August, the monsoon trough was well established in the western North Pacific and the South China Sea. Between 15 and 20 degrees North Latitude, it extended from central Vietnam eastward to Wake Island. Stronger than normal low-level westerlies equatorward of the trough axis were characteristic of the monsoon trough throughout the month of August and into early September. North of the monsoon trough, the subtropical ridge was also well established.

On August 15th, a small area of persistent convection moved westward across the island of Luzon into the South China Sea. Synoptic data at 150000Z and 151200Z indicated a surface circulation with 20 kt (10 m/sec) winds and a minimum sea-level pressure (MSLP) of 1002 mb. These data prompted JTWC to reissue the Significant Tropical Weather Advisory (ABPW PGTW) at 152100Z. Over the next two to three days, the disturbance moved southwestward and increased in organization. Three Tropical Cyclone Formation Alerts (TCFAs) were issued at 0400Z on the 16th, 17th and 18th of August to advise customers of the good potential for development of a significant tropical cyclone in the area.

After receiving aircraft reconnaissance reports of 40 kt (21 m/sec) and a MSLP of 985 mb at 180724Z (Figure 3-12-1), the first warning was issued on

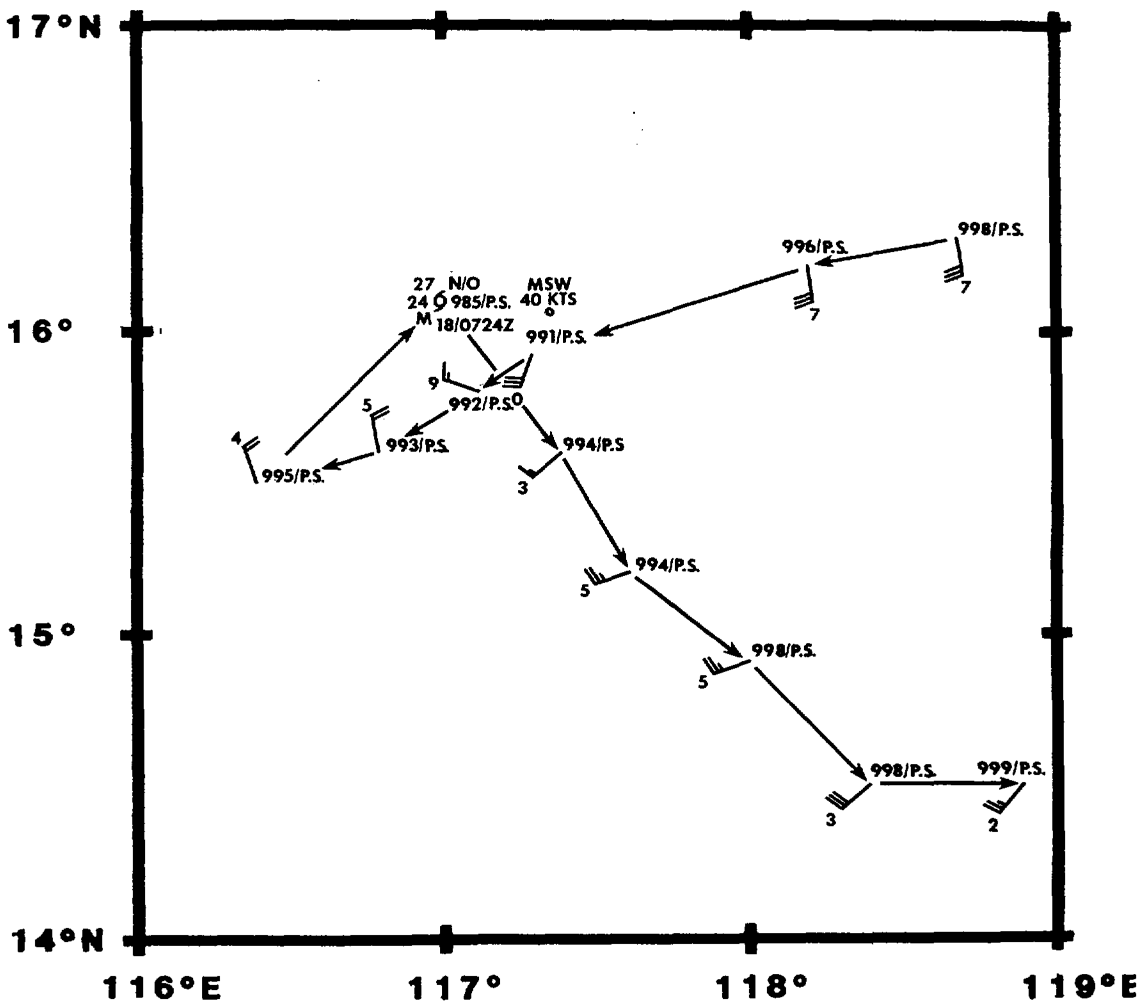


Figure 3-12-1. Aircraft reconnaissance investigative mission located maximum surface winds of 40 kt (21 m/sec) and a minimum sea-level pressure of 985 mb at 180724Z.

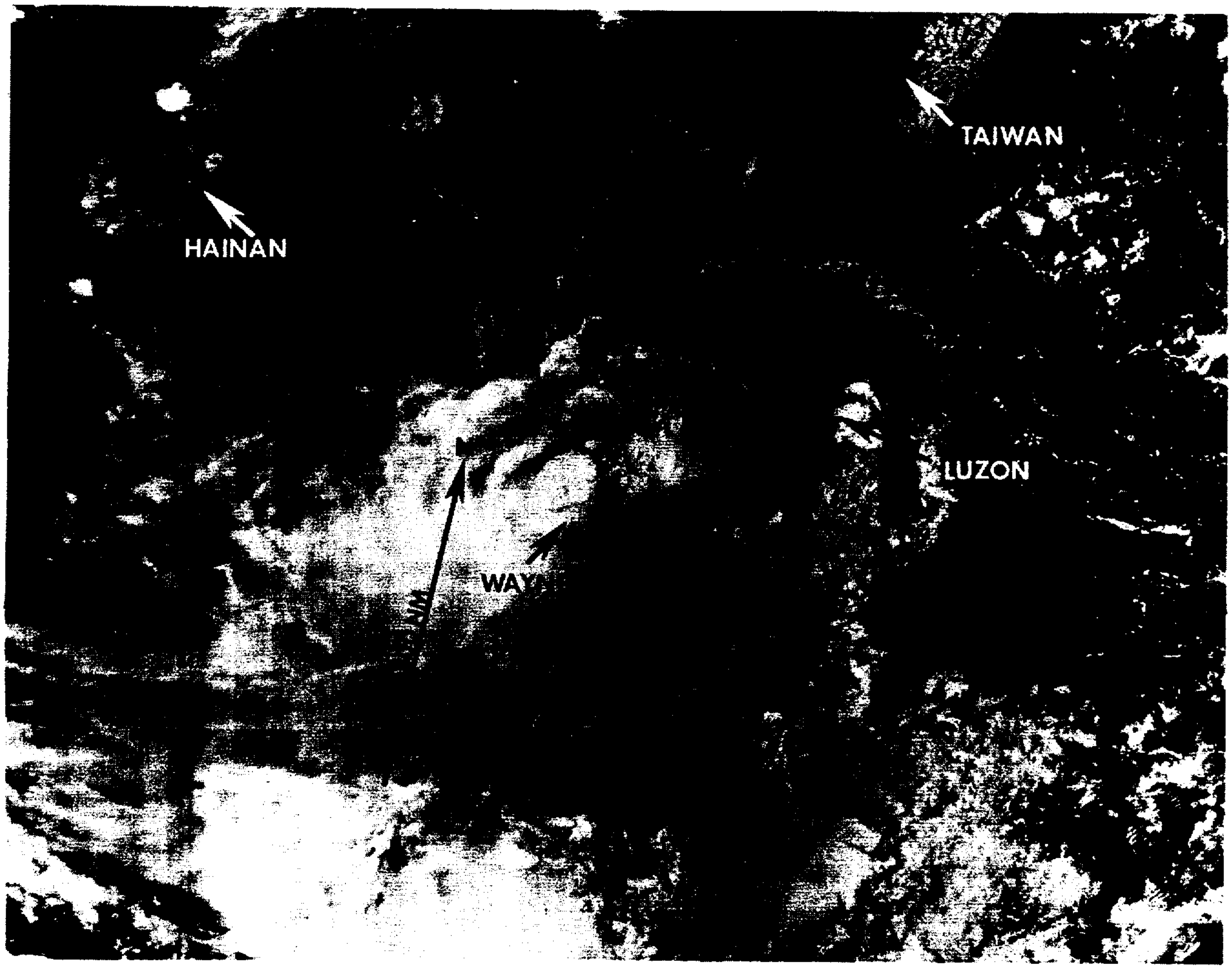


Figure 3-12-2. Wayne shortly before the aircraft reconnaissance mission (Figure 3-12-1) and first warning (180628Z August NOAA visual imagery).

Tropical Storm Wayne (Figure 3-12-2) valid at 180600Z.

Over the next two days, the synoptic scale monsoon trough shifted to the north about five degrees. Wayne responded by moving northwestward also. Throughout this period of position readjustment, gradual development brought Wayne to typhoon intensity at 190600Z. Meanwhile, a weak mid-latitude trough began to deepen and move eastward across mainland China toward the East China Sea. At 200000Z, this trough, and associated front, extended across the Yellow Sea southward to the southeast coast of China. Also, at 200000Z, Wayne assumed a northeastward track towards Hong Kong and the south coast of mainland China. Hong Kong's radar, at 202104Z (210504H Hong Kong local time) digitally

digitally depicted the rainbands surrounding the eye (Figure 3-12-3) as Wayne passed to the south and east. Another view shows the eye of the typhoon as it was remotely sensed, five-hours later, 450 nm (833 km) from space (Figure 3-12-4). On 22 August, Typhoon Wayne moved northeastward across northern Taiwan and weakened to tropical storm intensity after interacting with Taiwan's rugged mountains. In the meantime, Typhoon Vera (11W) had become the dominant system in the Philippine Sea and began moving rapidly toward the west-northwest. On the 24th, Wayne had moved rapidly west-southwestward and through the Luzon Strait (for the first time) in response to the northeasterly steering flow associated with the subtropical ridge. As Vera (11W) approached, Wayne decreased significantly in intensity and central convection. Increased vertical shear and subsidence associated with Vera (11W) stripped Wayne of its supporting central convection. As a result, only a small low-level exposed circulation center remained. A final warning on Wayne was issued at 250600Z, but JTWC continued to monitor the disturbance for possible redevelopment.

As Vera (11W) moved northward (261200Z), the remains of Wayne became entrained in Vera's extensive low-level inflow and began to move east-northeastward

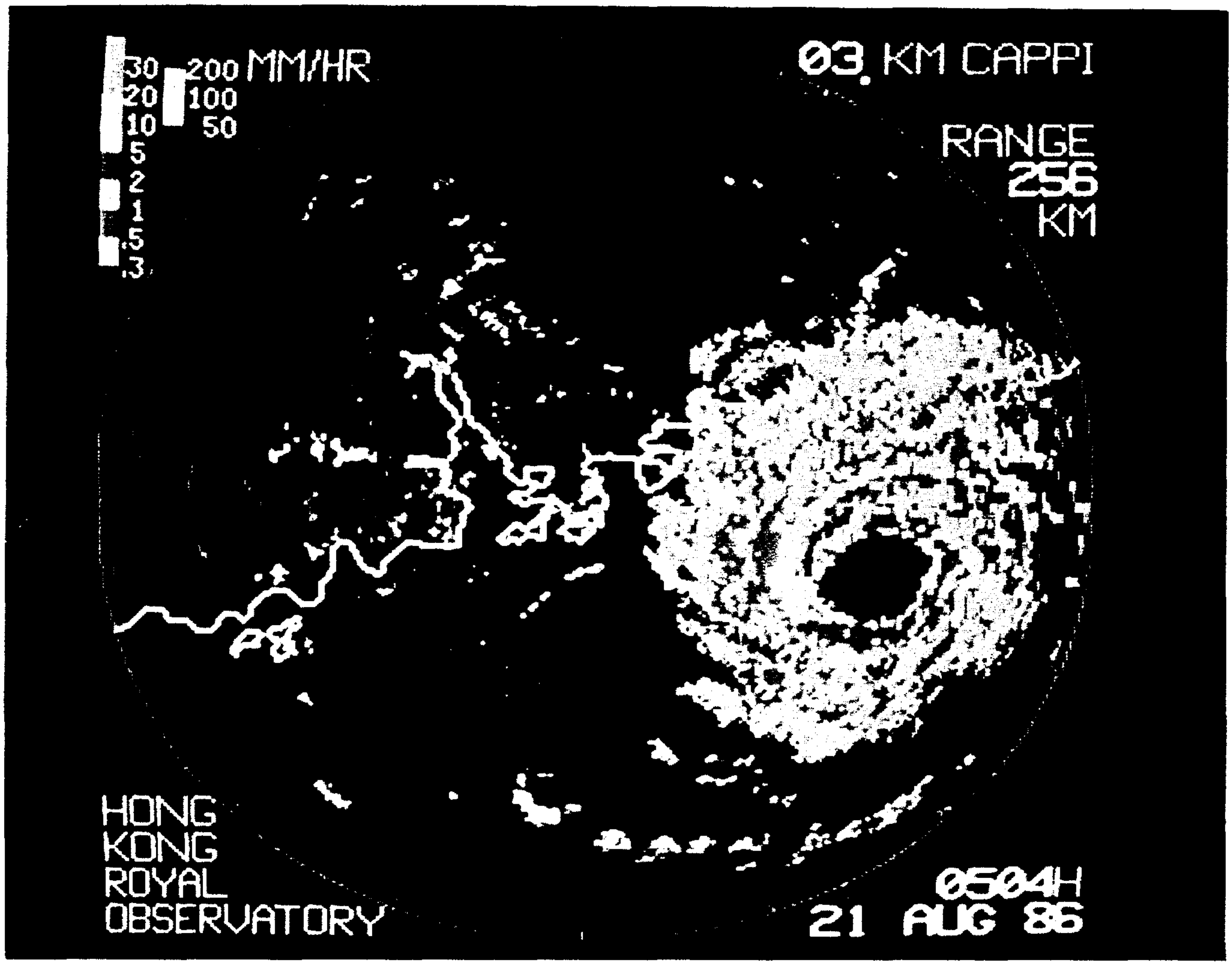


Figure 3-12-3. Digitized radar presentation of Typhoon Wayne at 202104Z (Photograph courtesy of the Hong Kong Royal Observatory).

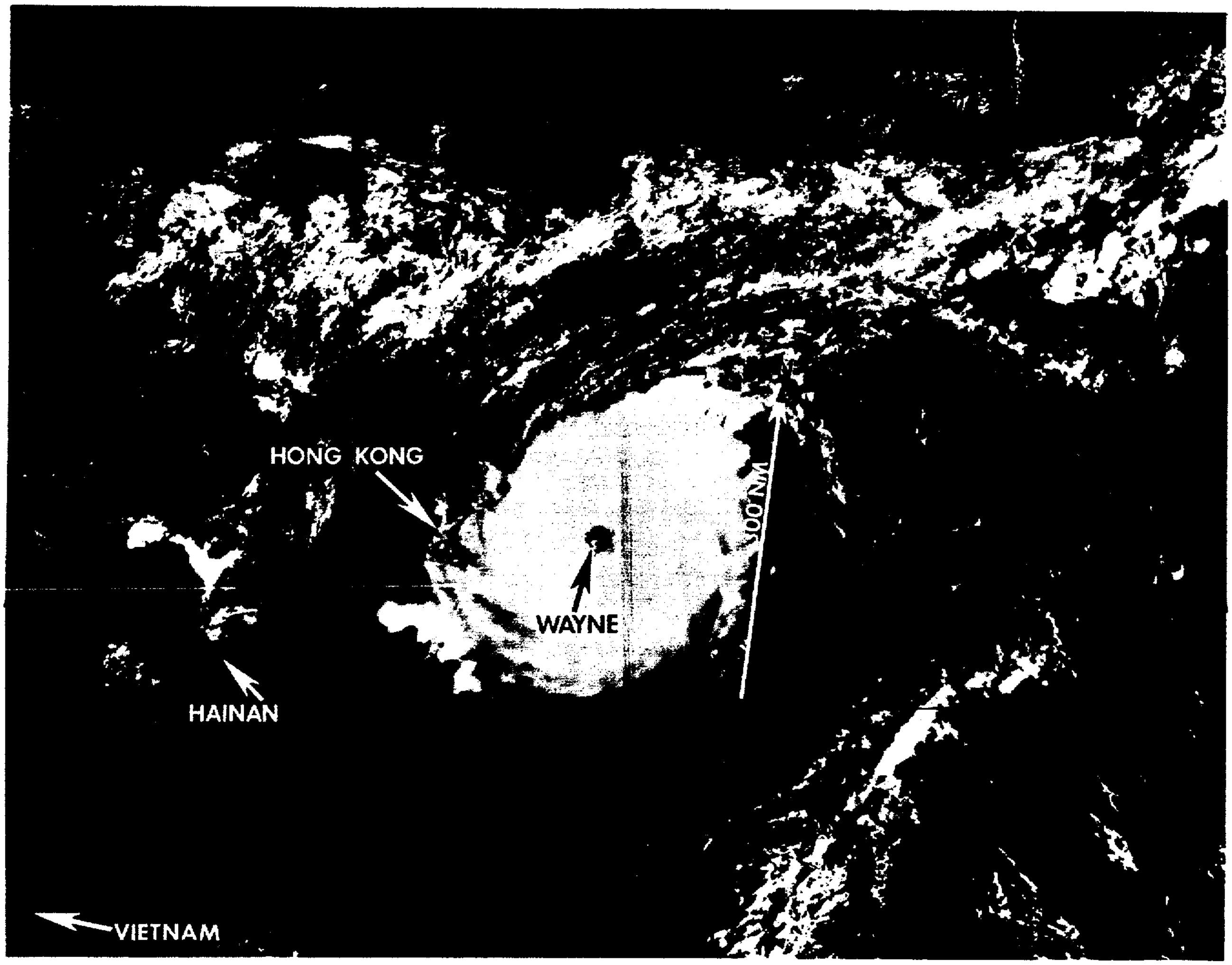


Figure 3-12-4. The eye of Typhoon Wayne. The band of cloudiness associated with the weak front, extending east-west and just to the north of the typhoon (210200Z August DMSP visual imagery).

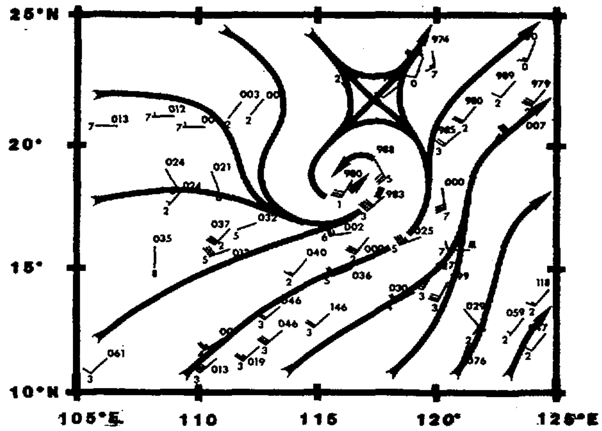


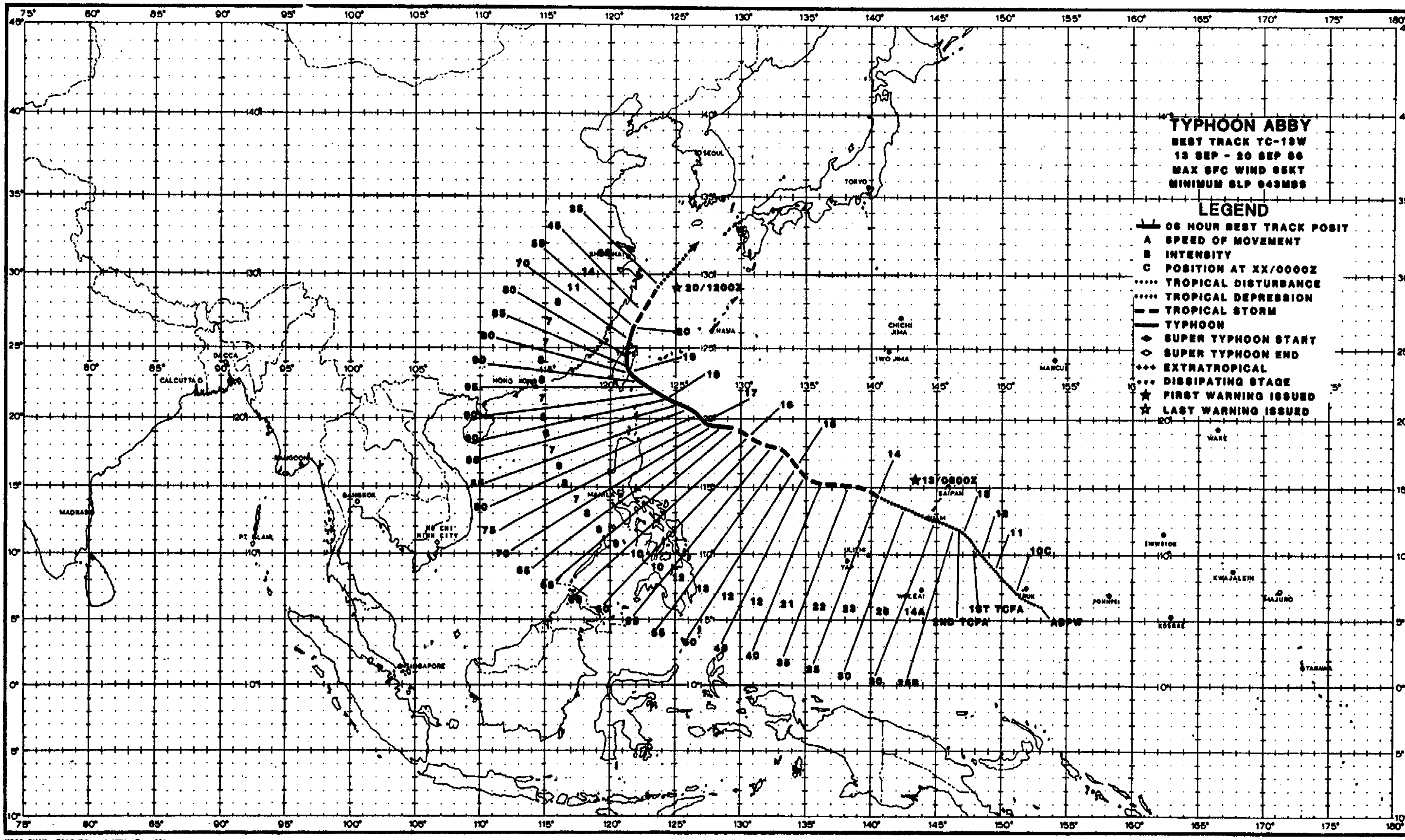
Figure 3-12-5. The 271200Z August 1986 Surface Synoptic Chart. Note the 30 kt (15 m/sec) and 40 kt (21 m/sec) ship reports associated with Wayne.

for the second time. The 271200Z surface analysis (Figure 3-12-5) showed a MSLP of 998 mb, 30 kt (15 m/sec) ship reports, and 40 kt (21 m/sec) ship reports - indications that Wayne had regenerated. These synoptic data, coupled with supporting satellite reconnaissance inputs, prompted JTWC to begin issuing warnings again on Tropical Storm Wayne at 280000Z. Wayne headed northeastward through the Luzon Strait for the second time.

By 31 August, low- to mid-level ridging built back across the East China Sea in Vera's (11W) wake. Wayne's movement toward the northeast slowed and changed toward the southwest - back through the Luzon Strait on the 2nd of September for the third time! After 301200Z, and until 051800Z, Wayne maintained typhoon intensity (Figure 3-12-6). Once through the strait, the typhoon accelerated westward. As it moved away from Luzon, Wayne reached its peak intensity of 90 kt (46 m/sec) at 040000Z. Wayne then moved south of Hong Kong, north of the island of Hainan and across the northern Gulf of Tonkin before dissipating over land over southern China. JTWC issued its final warning at 060600Z.

As a result of Typhoon Wayne, 52 people were reported killed and 97 people were reported injured in Taiwan. On Luzon, 19 people were reported killed and hundreds of people were reported injured. In Vietnam, dozens of people were reported killed in addition to the hundreds reported injured. In total, tens of thousands of people were left homeless and millions of dollars worth of damages were sustained to crops and property due to torrential rain induced flooding and high winds. In summary, Wayne was an extremely long-lived, complex, difficult to forecast "midget" typhoon that struck Taiwan twice, transited the Luzon Strait three times, caused extensive damage and loss of life, and proved to be one for the record books.

Figure 3-12-6. Wayne at typhoon intensity southeast of Taiwan as seen by the Hualien radar (WMO 46699) at 301200Z August (Photograph courtesy of the Central Weather Bureau, Taipei, Taiwan).



NOCC GUAM 3142/20 (REV 5-80)

Typhoon Abby developed in low latitudes from a broad area of convection, moved northwestward and eventually recurved around the subtropical ridge. While in its formative stage, Abby gave indications that it might develop rapidly, however, it caused little, if any, damage when it passed within 30 nm (56 km) south-southwest of Guam. Later as a typhoon, it inflicted heavy damage and loss of life on the island of Taiwan.

During the end of August and beginning of September, the monsoon trough extended eastward from its normal position along 20 degrees North Latitude between 140 and 180 degrees East Longitude. This displacement, coupled with mean pressures two millibars below normal in the monsoon trough and higher than normal pressures to the south (in the Tasman Sea), resulted in stronger surface near-equatorial westerlies from New Guinea eastward into the Gilbert Islands. This increased low-level westerly flow, along with enhanced convection, raised the potential for tropical cyclone genesis within the monsoon trough. These factors, plus low vertical wind shear (Figure 3-13-1) associated with an area of persistent convection southwest of Truk, prompted mention on the 091930Z Significant Tropical Weather Advisory (ABPW PGTW). For three days this area of cloudiness continued to develop slowly as it drifted toward the northwest. Daylight aircraft reconnaissance on the 10th, 11th and 12th of September found only broad surface troughing, minimum sea-level pressures of 1006 mb and 20 to 25 kt (10 to 13 m/sec) surface winds.

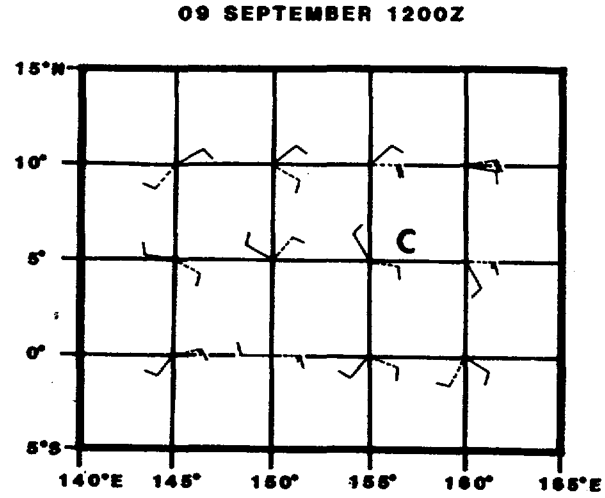


Figure 3-13-1. Differences between the 925 mb and 250 mb NVA winds on 091200Z September define an area of low vertical wind shear favorable for tropical cyclogenesis. Solid lines indicate 925 mb winds; dashed lines indicate 250 mb winds.

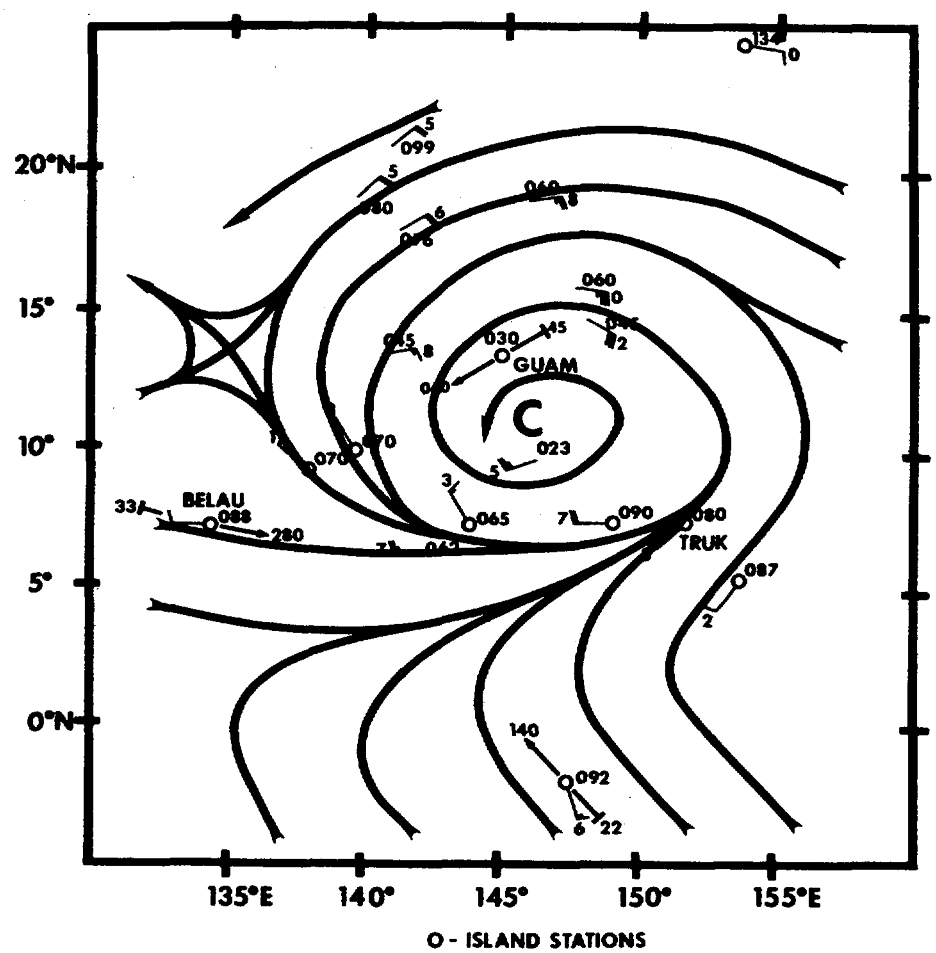


Figure 3-13-2. 130000Z September 1986 surface/gradient-level streamline analysis showing synoptic reports which prompted the first warning on Typhoon Abby.

The 130000Z surface/gradient-level streamline analysis included one 35 kt (18 m/sec) ship report, one 30 kt (15 m/sec) ship report, one 33 kt (17 m/sec) gradient-level wind report and indicated that a minimum sea-level pressure of 1002 mb was associated with the system (Figure 3-13-2). Based on this information, the first warning was issued at 130600Z, which located Tropical Depression 13W 120 nm (222 km) southeast of Guam. During this early period, Abby was a large disturbance, which lacked a persistent central dense overcast (CDO) (Figure 3-13-3). Beginning at 140600Z, however, Abby began to develop its CDO. Twelve to eighteen hours later, when the CDO feature became firmly established, Abby slowed its forward motion and intensified. As a point of interest, the band of maximum flight-level winds was displaced 70 to 120 nm (130 to 222 km) from the 700 mb center on 16 September (Figure 3-13-4).

Abby reached its maximum intensity of 95 kt (49 m/sec) at 181200Z. Twelve hours later, it swept past the east central portion of Taiwan (Figure 3-13-5) with 90 kt (46 m/sec) surface winds and torrential rains. As a result, 13 people were killed; crop and property damage were estimated at 81 million dollars.

Typhoon Abby decreased significantly in intensity following its collision with Taiwan. The upper-level circulation traveled across the island while the low-level circulation moved up the island's east coast. Without the upper-level circulation and supporting convection, the low-level vortex weakened and accelerated toward the north-northeast. At 201200Z, the final warning was issued on Abby as it dissipated over the East China Sea.

In retrospect, as Abby approached Taiwan and recurved there were some data collection problems. Aircraft reconnaissance data to support warnings was limited due to reduced aircraft availability, the proximity of the no-fly line and the rugged island topography. Determining the initial position of Abby was complicated as a result.

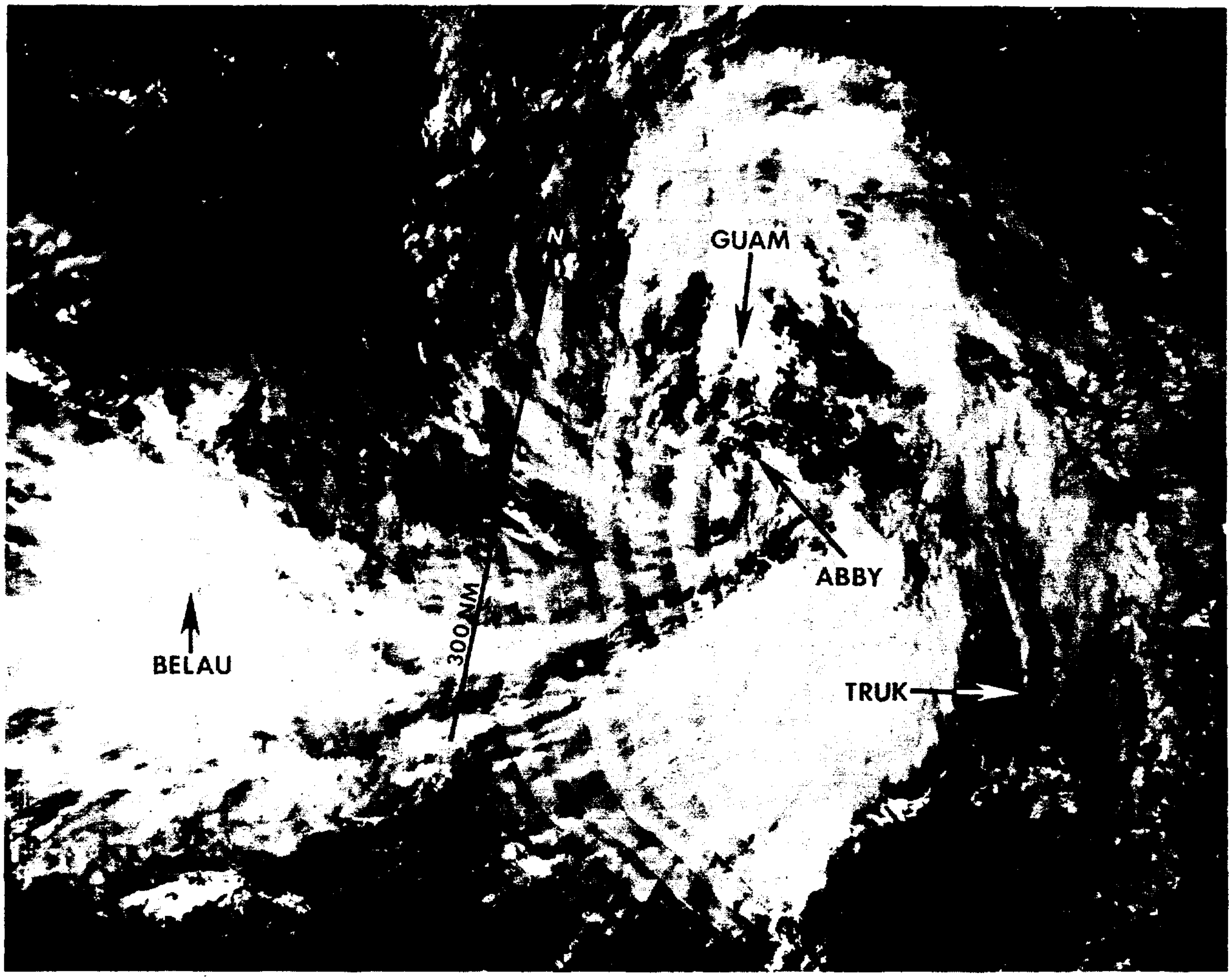


Figure 3-13-3. Tropical Depression 13W without a persistent central dense overcast (130508Z September NOAA visual imagery). The wavy lines in the imagery are due to temporary problems with the tactical sites processing equipment.

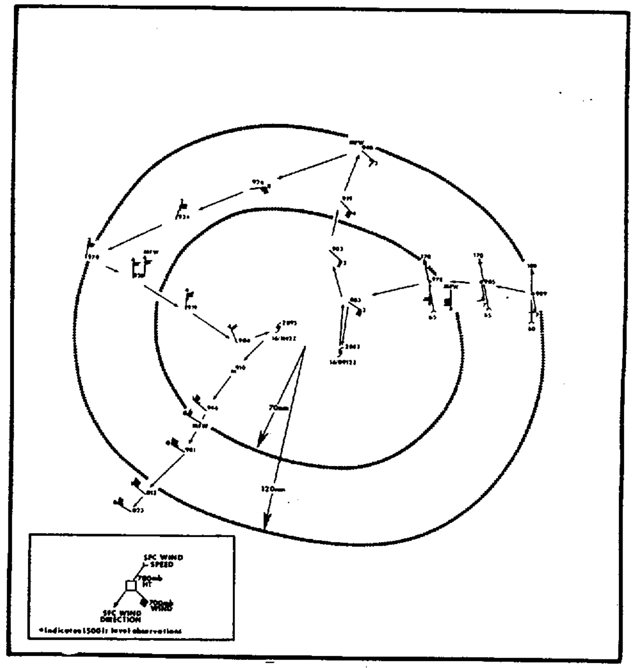


Figure 3-13-4. In-flight 700 mb winds from aircraft reconnaissance on 16 September 1986. Note the stronger winds are displaced outward from the center in a band by approximately 70 to 120 nm (130 to 222 km).

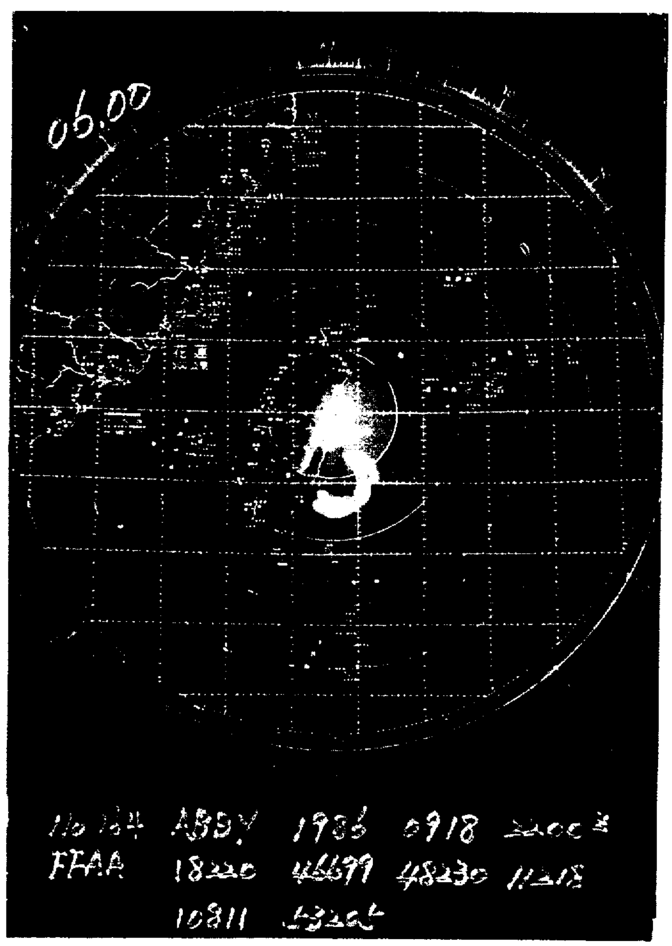
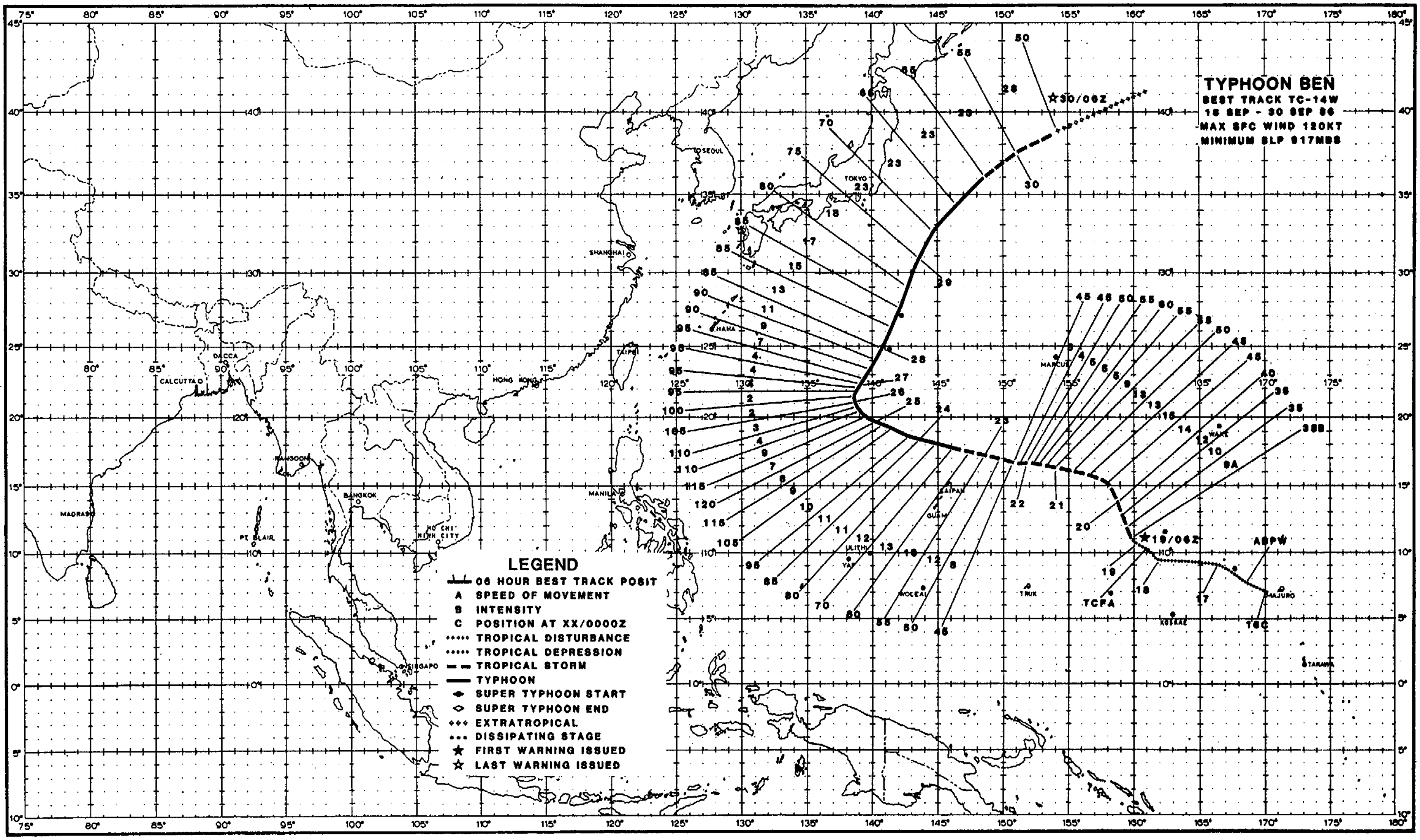


Figure 3-13-5. Radar view of Typhoon Abby as it approaches eastern Taiwan, 182300Z September (Hualien, Taiwan (WMO 46699)).



NOCC GUAM 3142/20 (NEW 5 - 80)

Typhoon Ben was the second of two tropical cyclones that reached warning status in the western North Pacific in September. Ben resulted in the loss at sea of thirteen fishermen from Saipan, who had sought shelter, as it passed by the island of Pagan in the northern Marianas. (The tragedy of the lost fishermen at Pagan was that, although the advanced warning was accurate, the captain apparently decided to leave Saipan for the northern islands anyway.) It was a long-lived typhoon with 46 warnings issued between the 19th and 30th of September.

Typhoon Ben developed from an area of enhanced convection on the 16th of September 165 nm (306 km) southeast of Kwajalein Atoll in the Marshall Islands. It was mentioned for the first time on the Significant Tropical Weather Advisory (ABPW PGTW) later that day. A Tropical Cyclone Forecast Alert was issued two days later, at 181830Z, after satellite imagery (Figures 3-14-1 and 3-14-2) indicated a rapid increase in the amount and organization of convection. The Dvorak intensity estimate was 35 kt (18 m/sec).

The first warning on Ben, as Tropical Depression 14W, was issued on the 19th, valid at 0000Z. Ben's initial warning position, which was based on satellite data, was 180 nm (333 km) north of the island of Pohnpei. Later, aircraft reconnaissance data at 190730Z resulted in a 160 nm (296 km) relocation of Ben to the northeast and upgrade from tropical depression to tropical storm intensity on the second warning.

Ben's initial forecast track was west-northwestward with a gradual intensity increase. The early forecast tracks were in close agreement with dynamical and statistical guidance. This made Ben an immediate threat to the island of Guam. However, Ben did not track as forecast, but instead moved north-northwestward until the 20th at 0600Z; after which it began a west-northwesterly track towards the northern Marianas.

Ben was forecast to reach typhoon intensity between 200600Z and 210600Z September. However, its forward movement slowed and its intensity decreased to 45 kt (23 m/sec) of maximum sustained surface winds. This decrease was due to increased vertical shear from the north-northeast. At 212124Z, the deep central convection became displaced southwestward and exposed the low-level circulation (Figure 3-14-3).

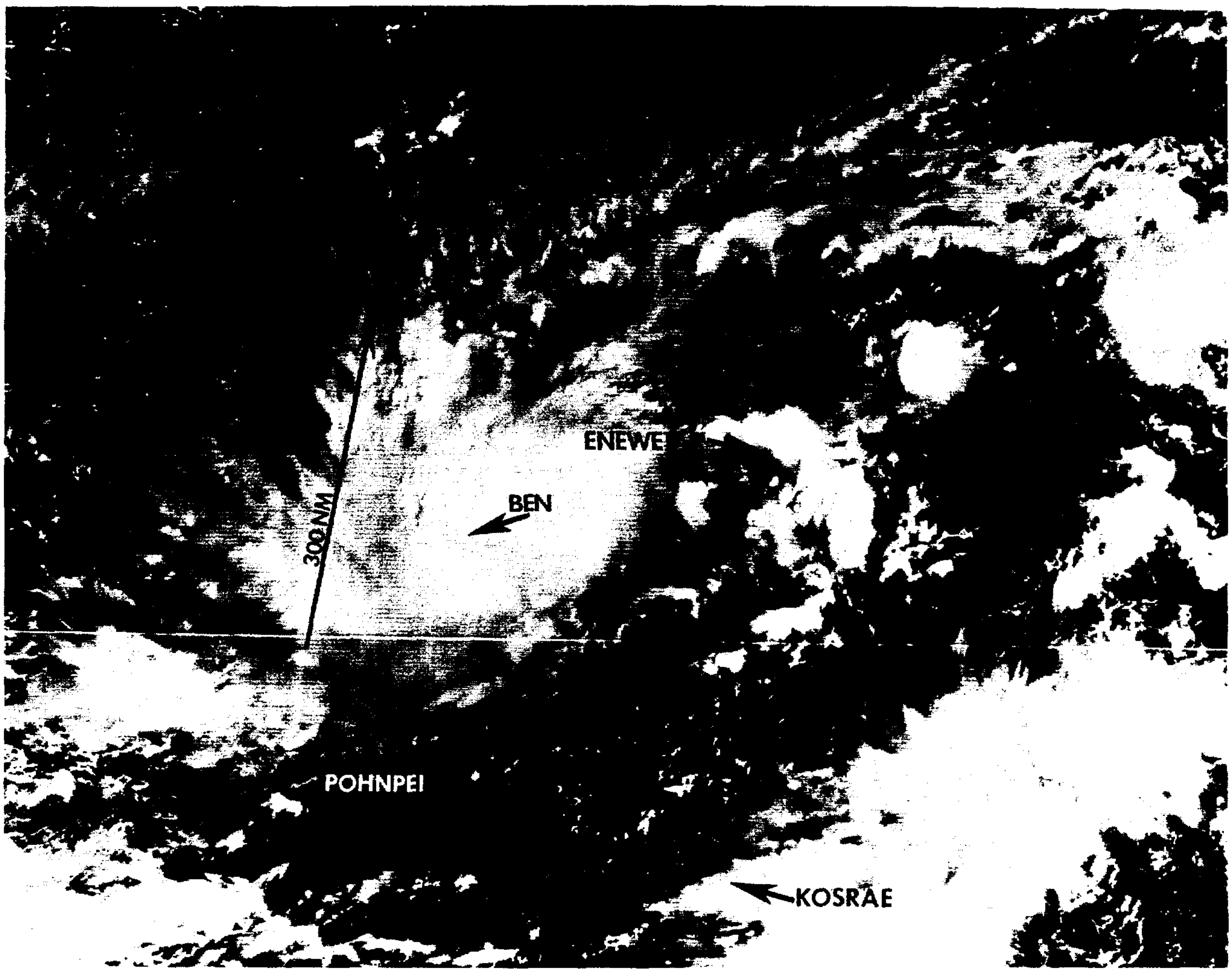


Figure 3-14-1. Typhoon Ben as a tropical disturbance (182255Z September DMSP visual imagery).

The central dense overcast had reestablished itself by 221600Z. By the 23th, Ben had increased its forward speed toward the west-northwest and intensified. It reached typhoon intensity at 230900Z just five hours before passing 20 nm (37 km) south of Pagan Island (located 270 nm (500 km) north of Guam). Ben continued to intensify through 250000Z, when its maximum sustained winds peaked at 120 kt (62 m/sec). At that time, its minimum sea-level pressure (MSLP) was 917 mb. Ben had a circular eye 40 nm (74 km) in diameter (Figure 3-14-4).

Forecasts through 250000Z indicated a gradual turn from northwestward to northward, however, Ben slowed to 2 kt (4 km/hr) by early on the 26th and drifted slowly northward into a region of increasing upper-level southwesterlies. Once Ben moved to the north of the mid-level subtropical ridge axis, the forecasts, based on a combination of dynamic and statistical aids for the track, were more accurate. Acceleration, after recurvature, was handled well by the empirical Typhoon Acceleration Prediction Technique (Weir, 1980).

As interaction with the southwesterlies aloft increased, Ben's central cloudiness became elongated north-northeast/south-southwest. At 261451Z, aircraft reconnaissance indicated that the eyewall had become ragged and open to the southwest. The MSLP had risen to 946 mb.

By 280000Z, Ben's forward speed had increased to 13 kt (24 km/hr) and its intensity had gradually decreased to 85 kt (44 m/sec). The central convection sheared away and was displaced to the northeast as the intensity decreased to 50 kt (26 m/sec). By the time the final warning was issued at 300600Z, transition to an extratropical system was complete.

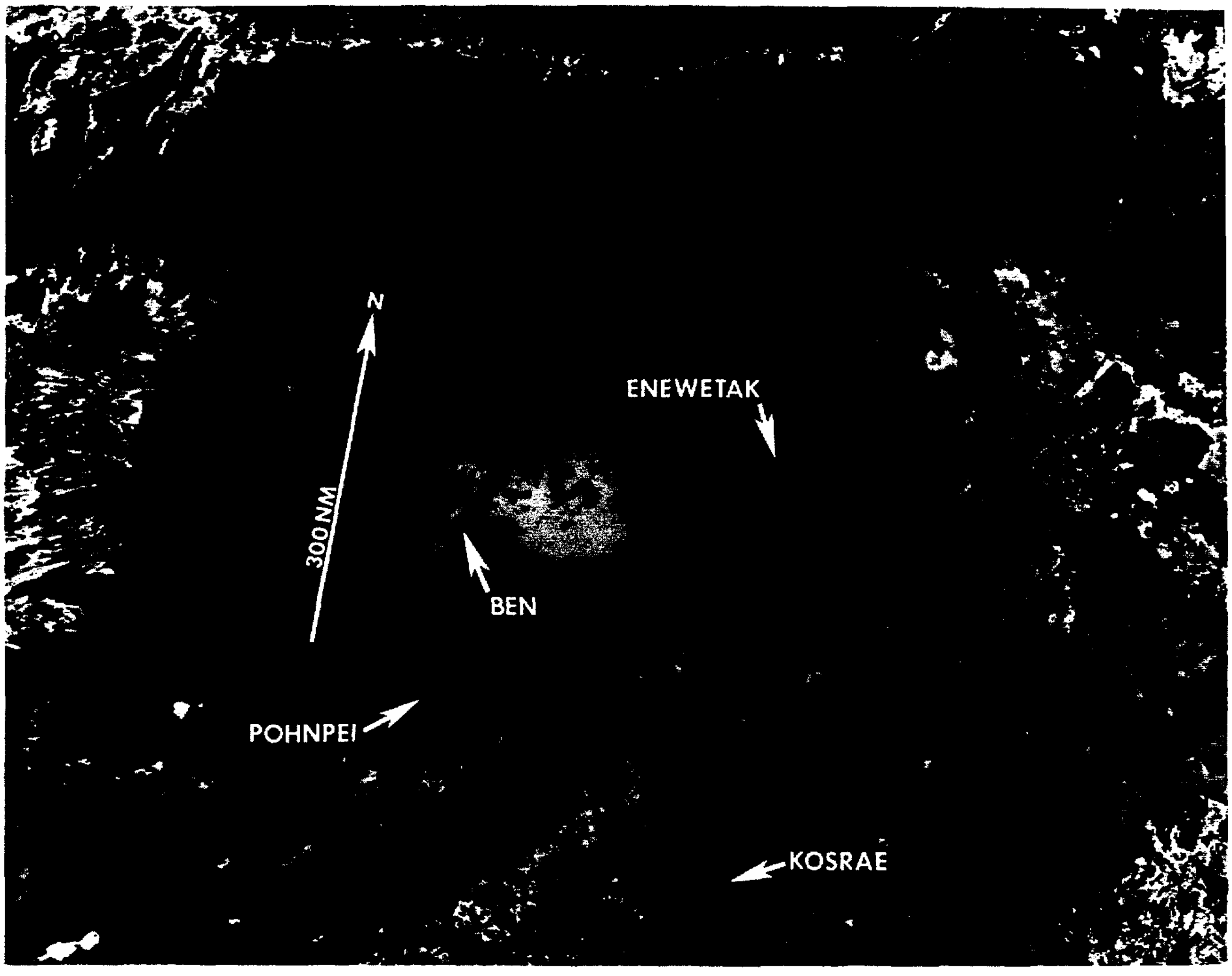


Figure 3-14-2. Enhanced infrared imagery of Ben assisted in locating the areas of vigorous convection (182255Z September DMSP infrared imagery).

Figure 3-14-3. Strong northerly upper-level flow displaces convection to the south of Ben's low-level circulation (212124Z September NOAA visual imagery).

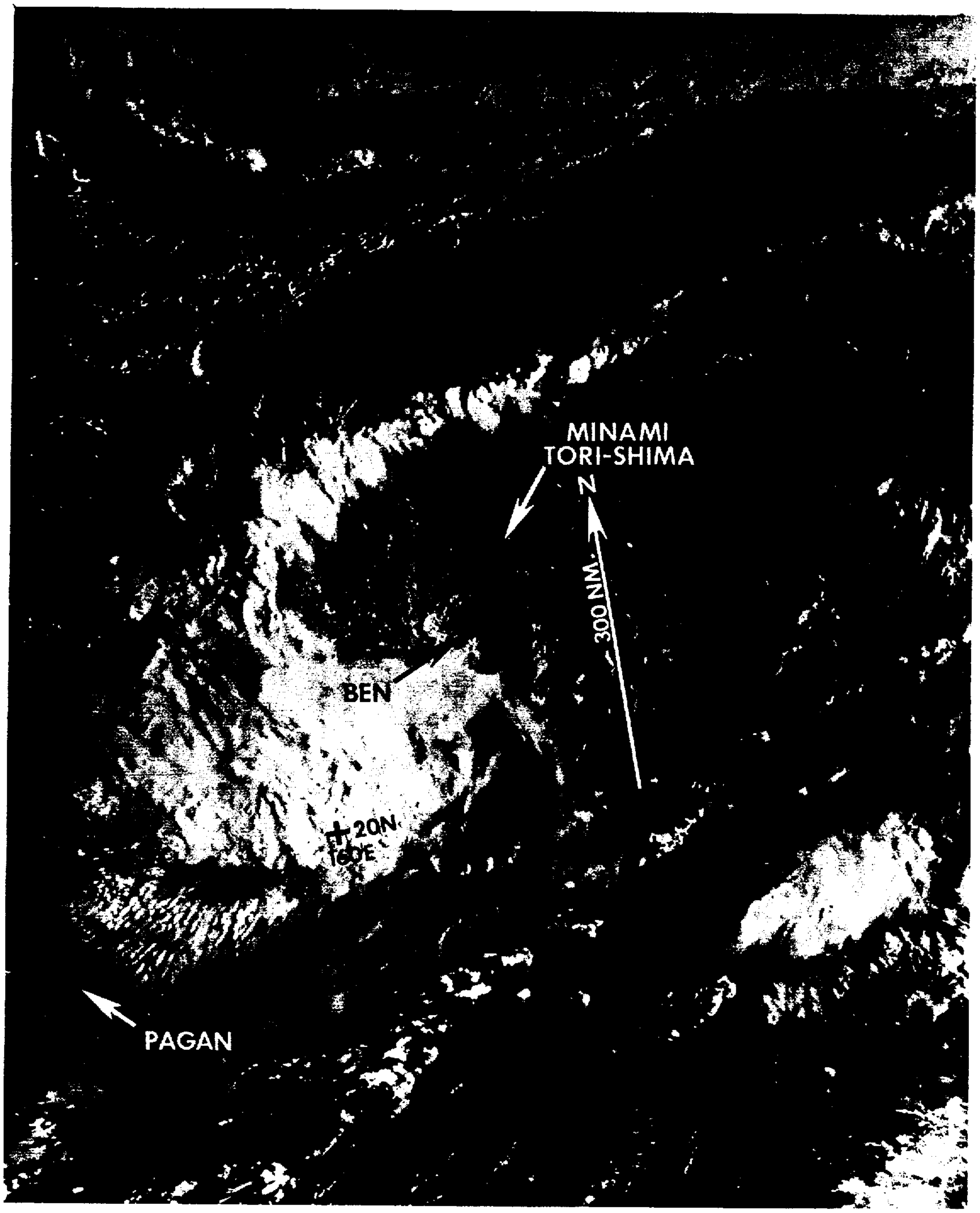
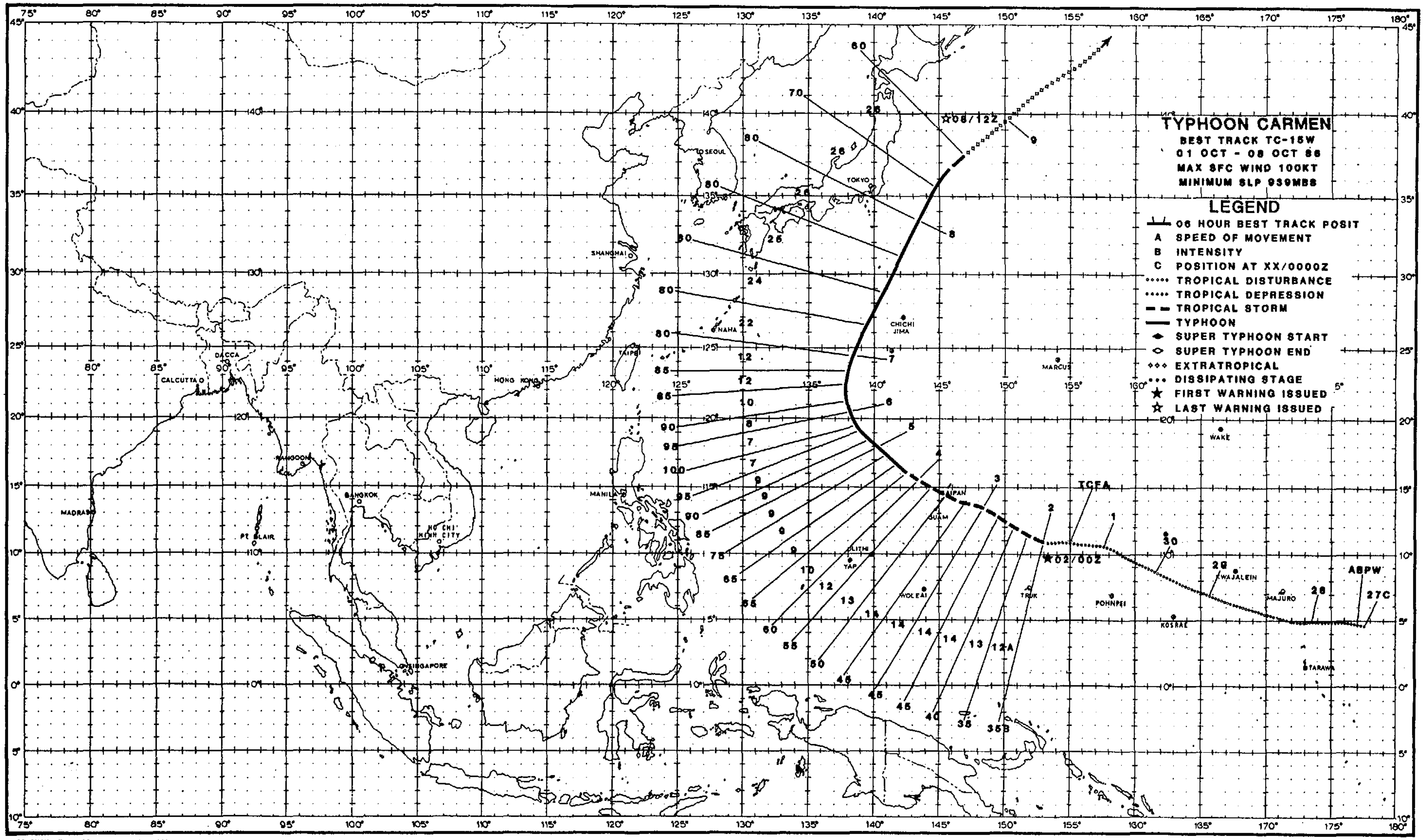


Figure 3-14-4. Two and one-half hours before Ben reached its peak intensity of 120 kt (62 m/sec). A circular eye 40 nm (74 km) in diameter is visible (242134Z September DMSP visual imagery).



NOCC GUAM 3142/20 (NEW 5 - 80)

Typhoon Carmen (15W) was the first of five significant tropical cyclones that occurred in October. Carmen followed a recurvature track that took the system between Guam and Saipan. Carmen was slow developing, but deepened rapidly prior to recurvature. The point of recurvature was 935 nm (1730 km) east of Taiwan. JTWC's forecast statistics were excellent.

Carmen spawned in an area of convergent flow associated with the near-equatorial trough east of the dateline. On 270600Z September, the disturbed area that became Carmen was first mentioned on the Significant Tropical Weather Advisory (ABPW PGTW) 350 nm (648 km) east of Majuro Atoll. The poorly organized convection was enhanced by divergent flow aloft. At 270000Z, when the surface vorticity center was first noted on satellite imagery, the minimum sea-level pressure (MSLP) was estimated to be 1009 mb, and the maximum surface winds 10 to 15 kt (5 to 8 m/sec). The tropical disturbance's organization remained poor for the next four days.

A Tropical Cyclone Formation Alert was issued on 011230Z October based on a flare-up of cloudiness detected on the satellite imagery. Because of the system's rapid development and location 330 nm (611 km) east-southeast of Guam, it presented an immediate threat to the island. The first warning for Tropical Depression 15W followed 11-hours later when satellite imagery showed continued growth. Later, aircraft reconnaissance at 020326Z fixed a low-level circulation center 480 nm (889 km) east of Guam, which was a significant displacement from the earlier satellite derived position. These data, which included a MSLP of 1001 mb, maximum 1500 ft (457 meters) winds of 45 kt (23 m/sec), and maximum surface winds of 40 kt (21 m/sec), led JTWC to relocate and upgrade Carmen to tropical storm intensity. Initially Carmen was forecast to pass south of Guam. It soon became evident that a track between the islands of Guam and Saipan was preferred.

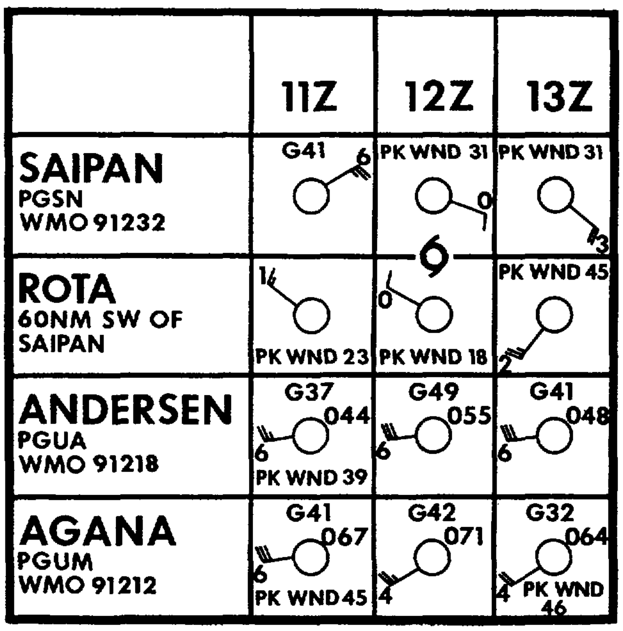


Figure 3-15-1. Synoptic data showing Carmen's passage between Saipan (WMO 91232) and the island of Rota, which is 60 nm (111 km) southwest of Saipan.

Figure 3-15-2. Winds and heavy rainshowers affect travelers on Guam on 3 October (Photo courtesy of Guam Publications, Inc.).

Carmen intensified at a slower rate than normal. This slow intensification was advantageous for the Mariana Islands. The maximum intensity at the time of passage through the Marianas was only 55 kt (28 m/sec) instead of an expected 77 kt (40 m/sec). The synoptic data (see Figure 3-15-1) reflects Carmen's presence between the islands of Rota, which is 60 nm (111 km) southwest of Saipan, and Saipan (WMO 91232) at 031200Z. Automated weather reporting stations provided the timely observations from Rota and Saipan. Maximum wind reports from Saipan were 31 kt (16 m/sec) with gusts to 41 kt (21 m/sec) at 031200Z; for Rota, 35 kt (18 m/sec) with gusts to 53 kt (27 m/sec) at 031500Z; and for Guam (Figure 3-15-2), 30 kt (15 m/sec) with gusts to 40 kt (21 m/sec) at 031155Z. Carmen did bring heavy rain, 10 to 11 inches (254 to 279 mm) for Guam, and flooding to the southern Mariana Islands, but caused little structural damage and no loss of life.

Aircraft reconnaissance at 032350Z, which reported a MSLP of 993 mb and estimated the maximum surface wind to be 65 to 70 kt (33 to 36 m/sec), led JTWC to upgrade Carmen from tropical storm to typhoon. Aircraft reconnaissance at 042355Z reported a drop in MSLP of 26 mb to 967 mb and at 051510Z reported another drop of 28 mb to a MSLP of 939 mb. This was a total decrease of 54 mb or an average of 1.4 mb/hr for 39-hours (see Figures 3-15-3, 3-15-4 and 3-15-5).

The forecasts for the recurvature of Carmen were excellent. The 72-hour forecast errors covering eight warnings (the third warning through the tenth) were less than 80 nm (148 km). One of the pieces of data that helped was a synoptic track requested and flown on 03 October from 0000Z to 1500Z. This synoptic track (see Figure 3-15-6) revealed a weakness at 500 mb in the subtropical ridge 480 nm (889 km) northwest of Guam.

Typhoon Carmen reached its maximum intensity of 100 kt (51 m/sec) with gusts to 125 kt (64 m/sec) at 051800Z. Afterward, cooler, drier air associated with a mid-latitude trough east of Japan, was entrained into the system. The aircraft mission at 052306Z reported that the eyewall had become ragged in the south through northwest segment. Satellite imagery at 061200Z confirmed Carmen was being sheared from the west by strong upper-level southwesterly flow, which caused the tropical cyclone to become elongated southwest to northeast. By that time,

Figure 3-15-3. Typhoon Carmen before rapid deepening and just after it passed Guam (040444Z October NOAA visual imagery).

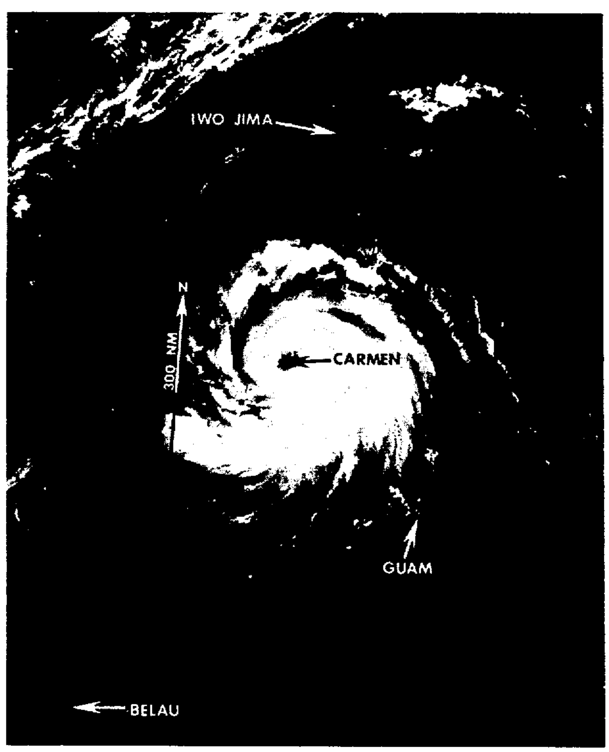


Figure 3-15-4. A mature Typhoon Carmen 19-hours after Figure 3-15-3 and rapid deepening (050013Z October DMSP visual imagery).

Carmen had already passed its point of recurvature. At 070005Z, the aircraft reconnaissance reported moderate to severe turbulence in the northwest quadrant of the system and indicated the eye was no longer present. These were indicators of extratropical transition.

Subsequently, Typhoon Carmen accelerated in forward speed to about 25 kt (13 m/sec), while maintaining an intensity of 80 kt (41 m/sec). After recurvature on October 7th, the MSLP steadily decreased and the winds remained nearly constant. At 071600Z, satellite imagery indicated Carmen had acquired subtropical characteristics and the maximum winds were 65 kt (34 m/sec). A wind maximum on the eastern portion of the trough caused Carmen to accelerate toward the northeast faster than forecast.

JTWC continued warning on Carmen until 081200Z when the system completed extratropical transition. At that time, extratropical Carmen had 60 kt (31 m/sec) maximum winds with gusts to 75 kt (39 m/sec) and was well north of the tropics.

Figure 3-15-5. Inside Typhoon Carmen's eye. This scene is from the aircraft reconnaissance mission (AF966 0715 CARMEN) at 042355Z. Compare the low cloud spiral in this figure with the remotely sensed eye in Figure 3-15-4 (Photo courtesy of Captain Susan K. Watters, USAF).

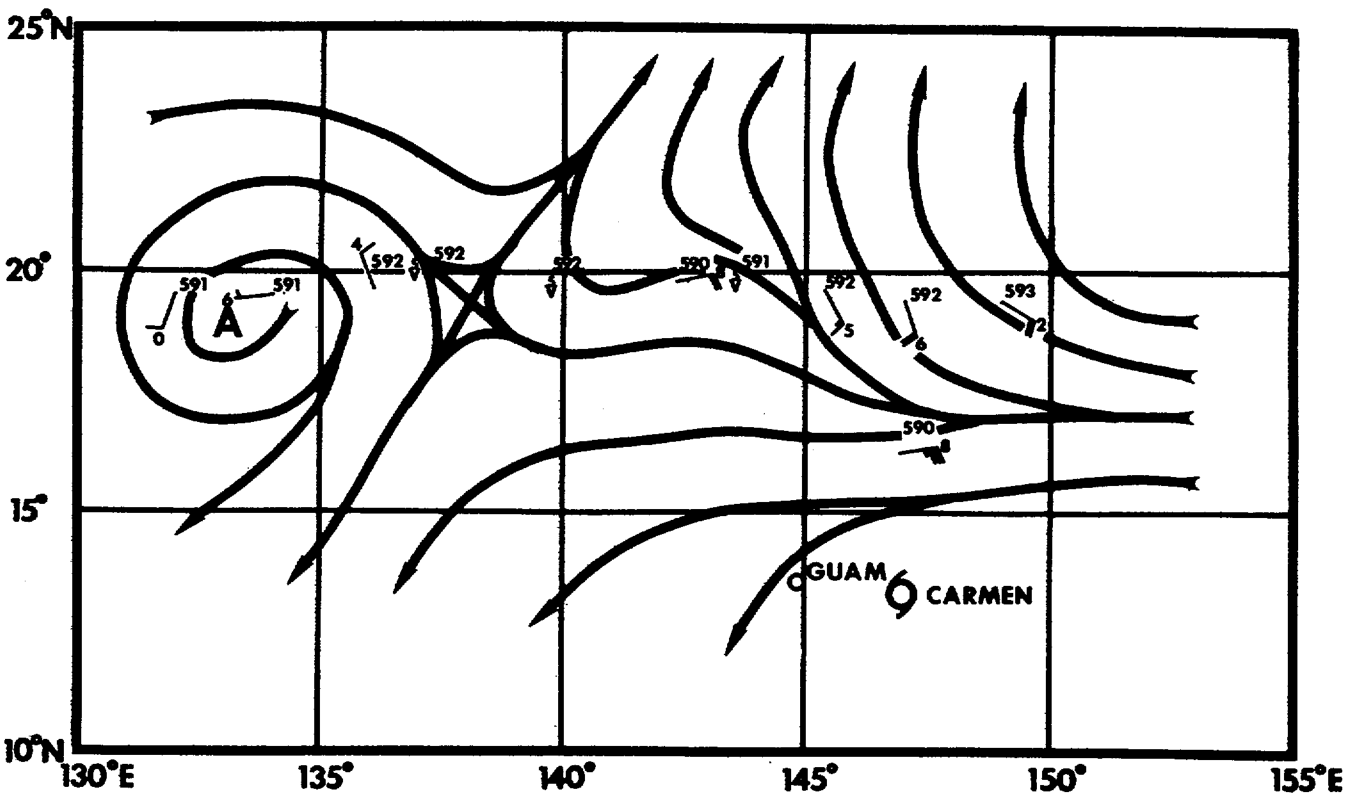


Figure 3-15-6. The synoptic track from 030000Z to 031500Z October 1986 identifies a break in the subtropical ridge.

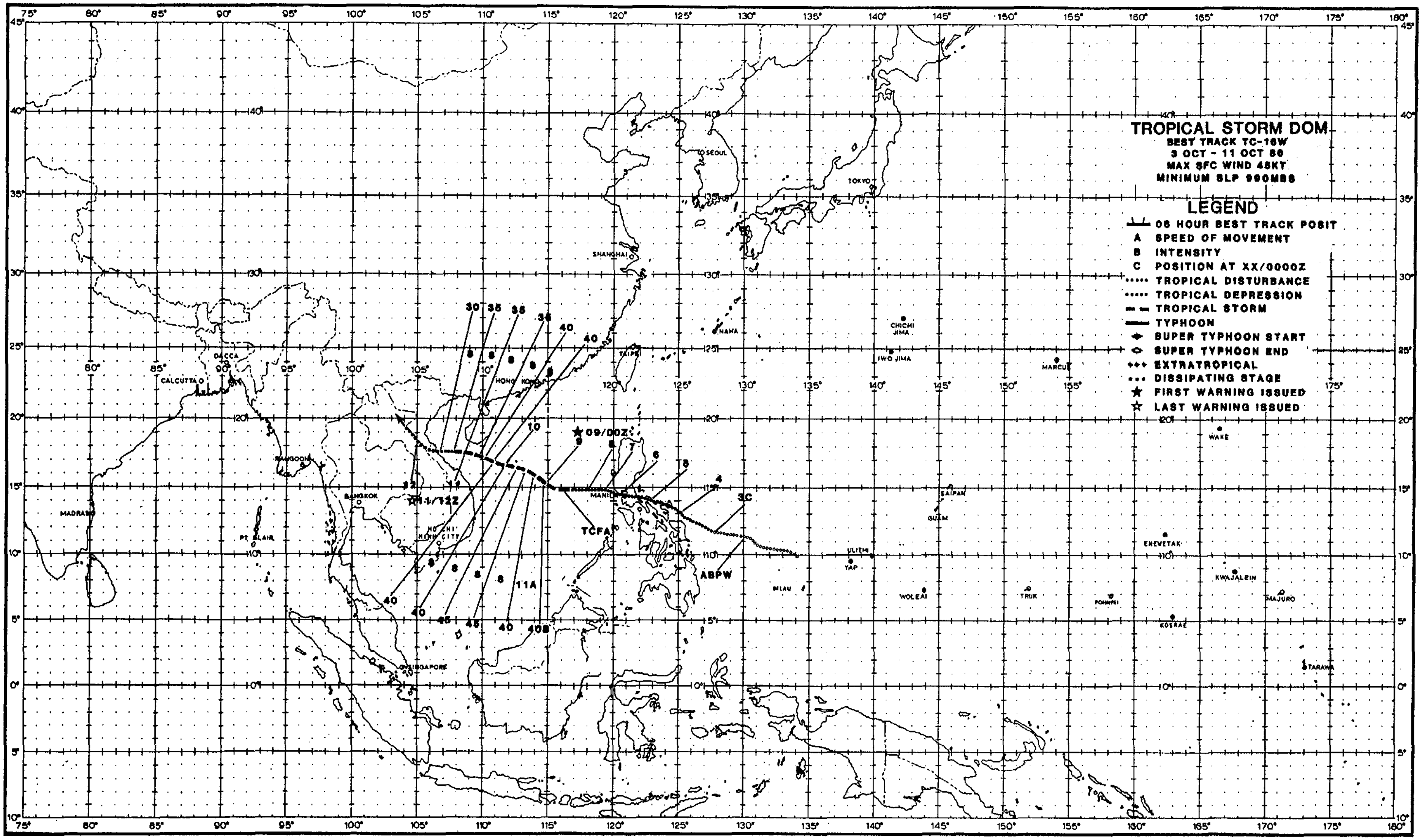
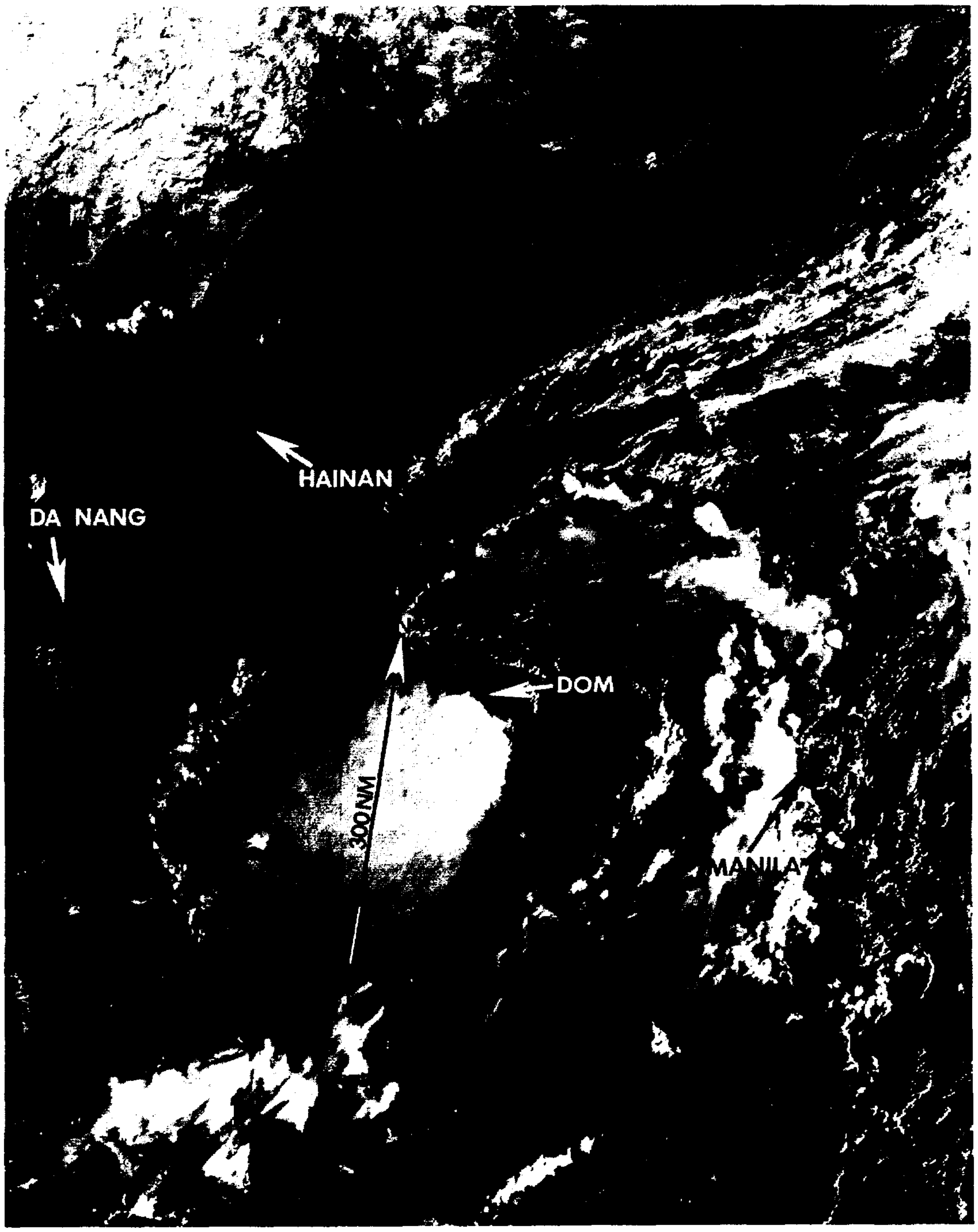
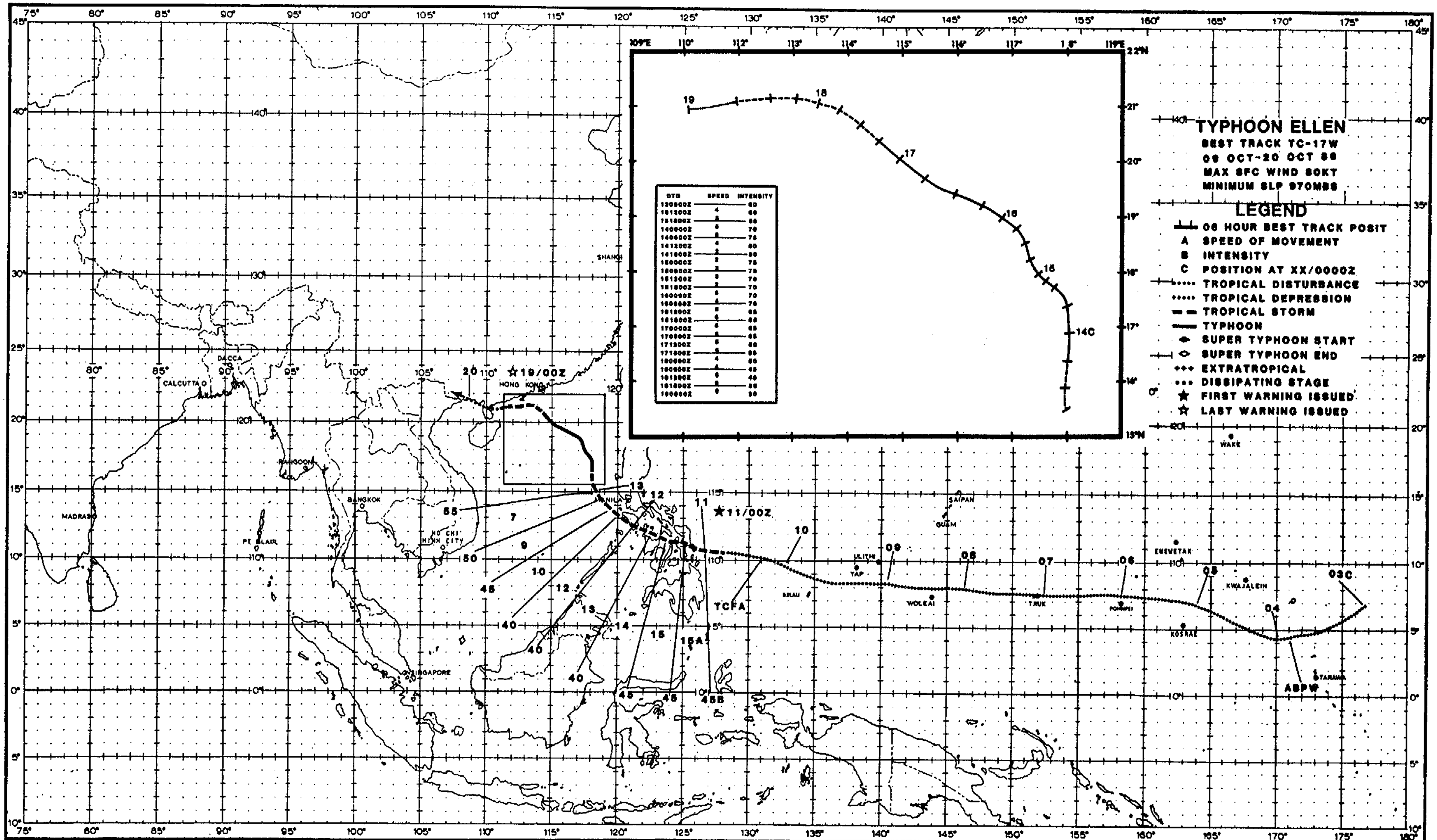

TROPICAL STORM DOM
BEST TRACK TC-16W
3 OCT - 11 OCT 86
MAX SFC WIND 45KT
MINIMUM SLP 990MBS
LEGEND
06 HOUR BEST TRACK POSIT
A SPEED OF MOVEMENT
B INTENSITY
C POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
DISSIPATING STAGE
FIRST WARNING ISSUED
LAST WARNING ISSUED
09/00Z
11/12Z
TCFA
ABPW
SEOUL
TOKYO
SHANGHAI
NAHA
TAIPEI
HONG KONG
MANILA
HO CHI MINH CITY
BANGKOK
RANGOON
CALCUTTA
DACCA
MADRAS
PT BLAIR
SINGAPORE
CHICHI JIMA
IWO JIMA
MARCUS
SAIPAN
GUAM
ULITHI
YAP
WOLEAI
TRUK
PONAPE
KOSRAE
ENEWETAK
KWAJALEIN
MAJURO
WAKE
TARAWA

Figure 3-16-1. Tropical Storm Dom slowly developed from a tropical disturbance 340 nm (630 km) east of the island of Samar in the Republic of the Philippines. It was first detected on satellite imagery on the 2nd of October and placed on the Significant Tropical Weather Advisory (ABPW PGTW) as a suspect area the same day. Dom struggled along for the next six days as it moved west-northwestward across southern Luzon producing heavy rains and flooding. The flood damage prompted the Philippine Meteorological Agency to begin warning on the system prior to JTWC. JTWC issued a Tropical Cyclone Formation Alert at 081800Z when Dom displayed increased organization and convection after entering the South China Sea. Surface winds at that time were estimated at 15 to 25 kt (7 to 12 m/sec). Dom was upgraded to tropical storm intensity on the first warning at 090300Z. The warning was based on aircraft reconnaissance reports of 50 kt (26 m/sec) estimated maximum surface winds and a minimum sea-level pressure of 1002 mb. A well-established ridge located north of Dom provided strong mid- to upper-level northeasterly flow caused Dom's convection to be sheared to the west-southwest of the low-level circulation center. Later, this shear, when combined with the increasing interaction with the rugged terrain of central Vietnam, caused Dom to weaken and dissipate. The last warning on Dom was issued by JTWC for 111200Z. The satellite picture shows Dom just prior to the issuance of the first warning (090215Z October DMSP visual imagery).





NOCC GUAM 3142/20 (NEW 5 - 80)

Typhoon Ellen was the third cyclone of five that developed in the month of October. It followed close on the heels of Typhoon Carmen (15W) and Tropical Storm Dom (16W). Ellen proved to be a difficult system to forecast, particularly when it encountered weak steering in the South China Sea. The system traveled over 4000 nm (7408 km) from its inception on the 3rd of October 250 nm (463 km) east of the Majuro Atoll in the Marshall Islands to dissipation sixteen days later along the border of southern China and Vietnam.

As Ellen moved westward through the Marshalls, the Significant Tropical Weather Advisory (ABPW PGTW) was reissued late on the 3rd of October, at 1800Z. The disturbance in the monsoon trough had shown signs of improved convective organization on the satellite imagery.

Ellen finally developed into a tropical depression as it passed 120 nm (222 km) south of the island of Ulithi in the Caroline Islands on 9 October. Twenty-four hours later, JTWC issued a Tropical Cyclone Formation Alert when the disturbance again showed an increase in organization. The initial aircraft reconnaissance investigative mission found only a weak circulation in a broad low-pressure trough and estimated surface winds of 10 to 20 kt (5 to 10 m/sec).

By the following morning, Ellen had changed significantly. The second aircraft reconnaissance mission at 110122Z reported a minimum sea-level pressure of 992 mb with estimated surface winds of 45 kt (23 m/sec). JTWC immediately issued its first warning on Tropical Storm Ellen, valid at 110000Z (see Figure 3-17-1).

Shortly after its development into a tropical storm, Ellen moved through the the central Philippine Islands. Only a modest weakening to 40 kt (21 m/sec) resulted during the 24-hours it took to make the passage.

Upon entering the South China Sea on the morning of the 12th, Ellen turned northward into a region of weak steering current and slowed in forward speed. At that point, most of the statistical and dynamic forecast guidance predicted the tropical cyclone

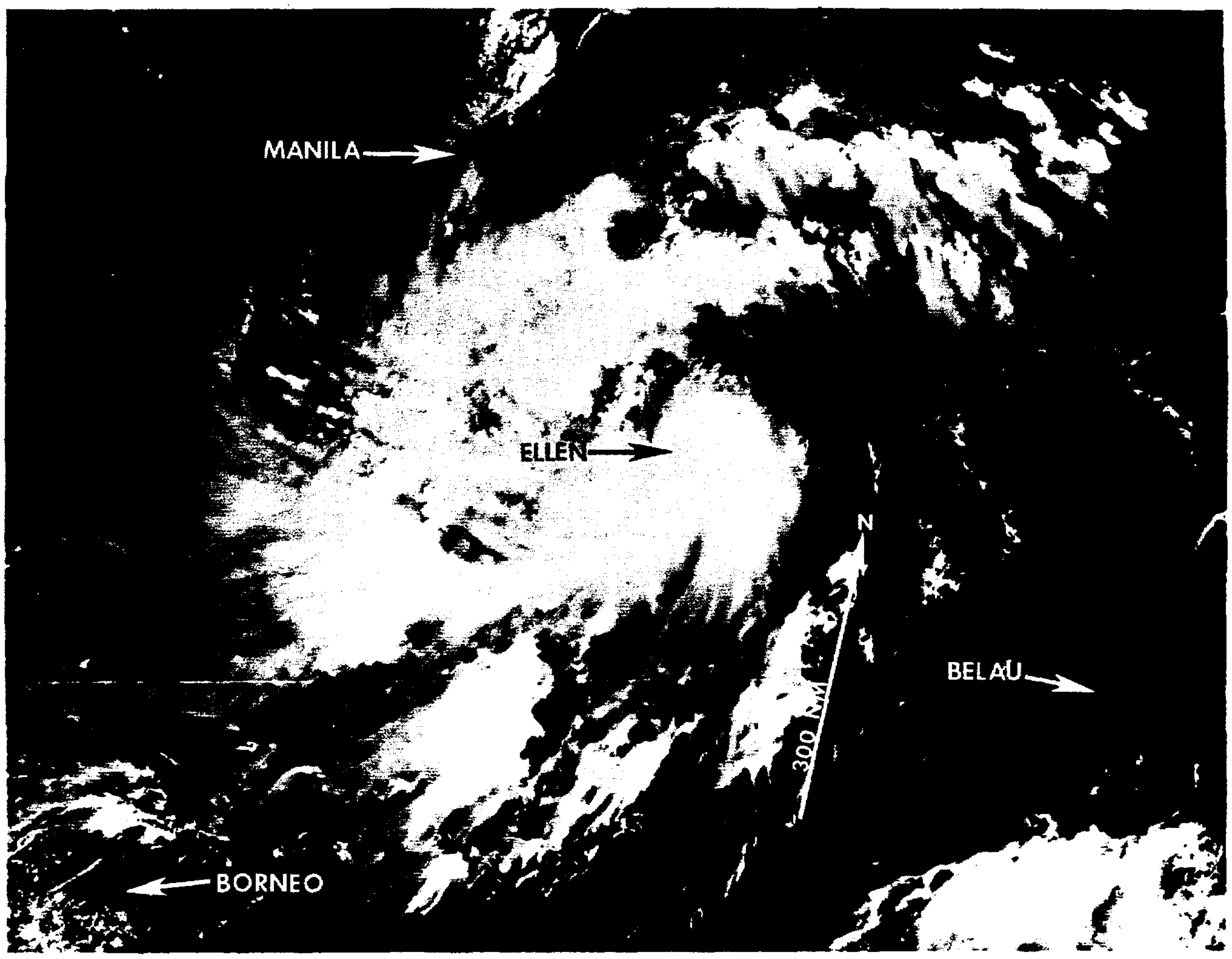


Figure 3-17-1. Tropical Storm Ellen at the time of the second aircraft reconnaissance mission that found 45 kt (23 m/sec) surface winds and a minimum sea-level pressure of 992 mb (110134Z October DMSP visual imagery).

would recurve. This was the forecast philosophy that was followed. Later the One-way Interactive Tropical Cyclone Model (OTCM) changed to a more northwesterly, and eventually, westerly track. JTWC stayed with the recurvature forecast until the 16th when the Typhoon made a definite turn toward the west. Aircraft reconnaissance data provided this critical information. The three hourly movement between the intermediate and on-time vortex fix positions confirmed that Ellen was headed northwest and not northeast. In retrospect, the low-level surge from the northeast across the Yellow Sea, Taiwan, and later, the south coast of China pressured Ellen northwestward.

After reaching a peak intensity of 80 kt (41 m/sec) on the 14th (Figure 3-17-2), the vertical shear from the westerlies remained too weak to shear away the central convection and Ellen maintained tropical storm intensity almost until landfall northeast of the island of Hainan. Figure 3-11-3 provides a radar view of the rainbands as the system passed south of Hong Kong on the 18th. There were no reports received of heavy damage or loss of life attributed to Ellen.

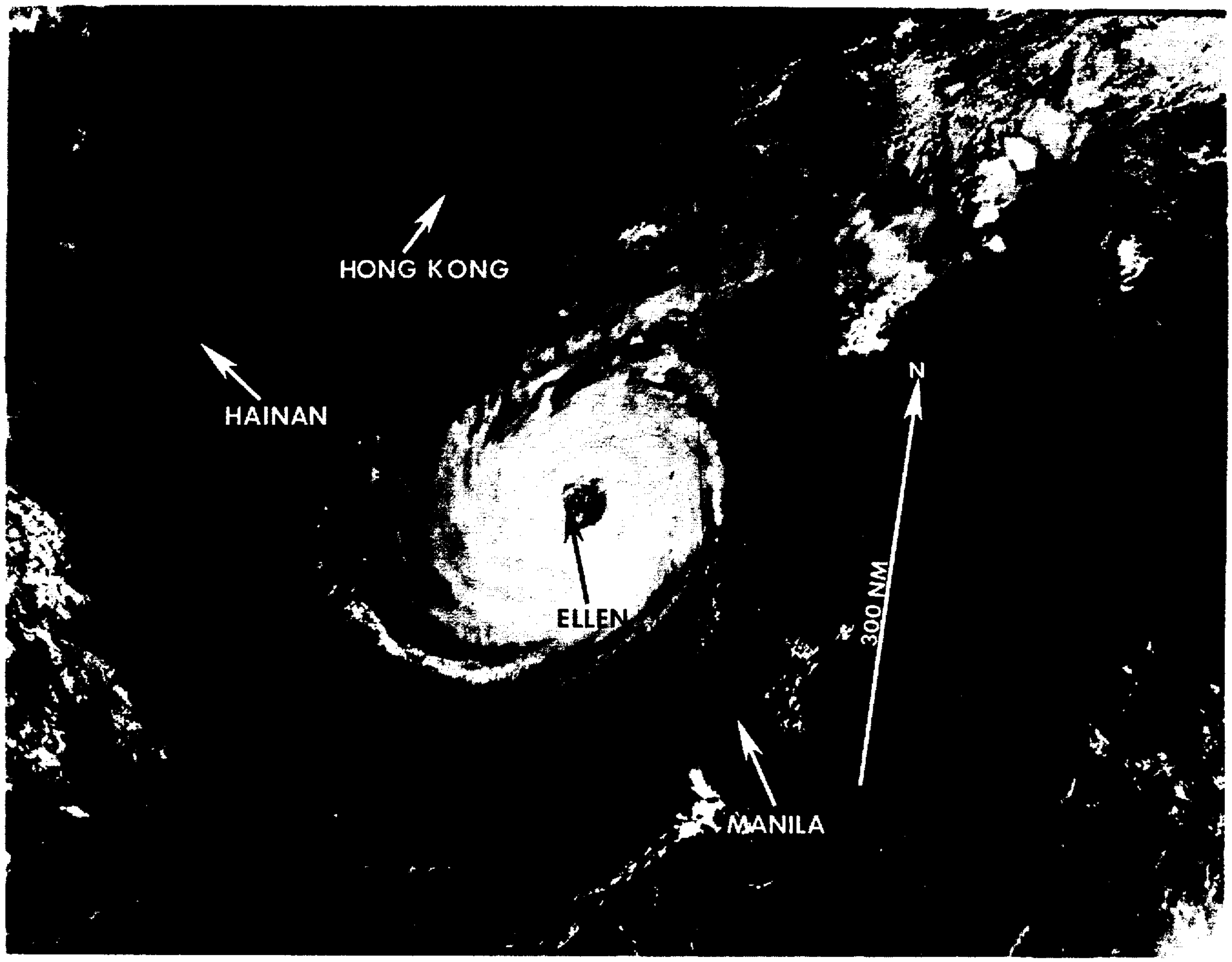
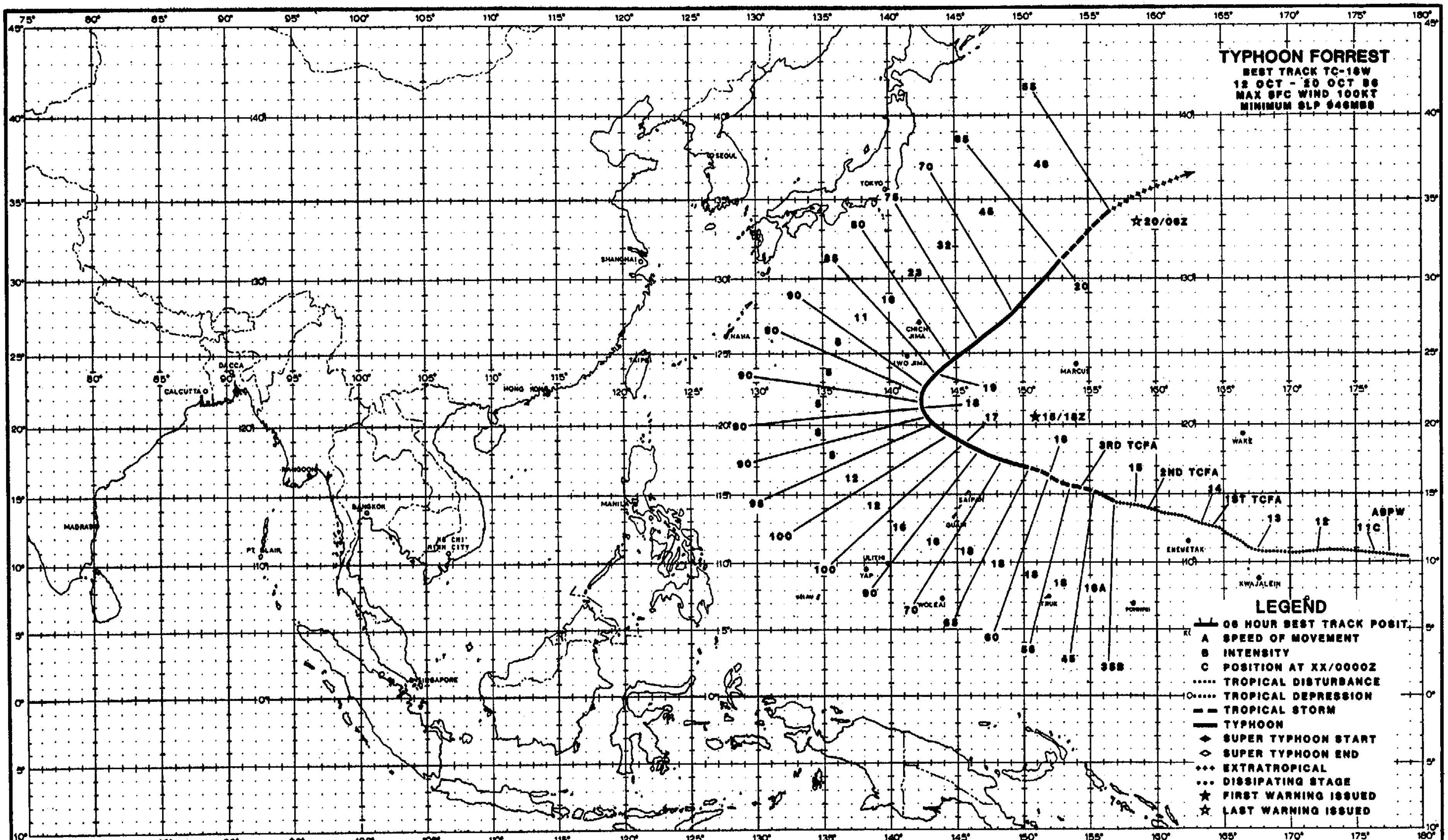


Figure 3-17-2. Weak vertical wind shear over the South China Sea enabled Ellen to intensify into a typhoon. Its large eye is visible to the west of the island of Luzon (150153Z October DMSP visual imagery).

Figure 3-17-3. A digital radar picture of Tropical Storm Ellen as it passed south of Hong Kong on the 18th of October at 0640Z (Picture provided courtesy of the Hong Kong Royal Observatory).



NOCC GUAM 3142/20 (NEW 5-80)

Typhoon Forrest was the second tropical cyclone to begin east of the dateline and move westward into the western North Pacific. Forrest was a classic recurver and a small, compact system. The track and intensities were well forecast with the exception of the intensities being a little low through the first half of Forrest's life. An interesting point to note about this system is that the upper-level vortex appeared to develop first and then built downward to the surface. Post-analysis of synoptic and aircraft reconnaissance data indicates the stronger upper- and mid-level winds did not begin to reach the surface until after the 14th of October.

On 9 October, personnel at Detachment 1, 1st Weather Wing, Satellite Operations first detected Forrest on satellite imagery as an area of poorly organized convection in the trade wind trough 600 nm (1111 km) east of the Marshall Islands. Over the next 18-hours the convection began to slowly increase in organization. Once across the dateline, it was first discussed on the Significant Tropical Weather Advisory (ABPW PGTW) at 100600Z. At that stage, the amount of convection began to decrease, but a small cyclonic vorticity center remained. Over the next 48-hours, Forrest remained in a region where the upper-level environment was unfavorable for development. As a result, it remained poorly organized and continued moving west-northwestward. Sparse synoptic data indicated the minimum sea-level pressure (MSLP) was approximately 1008 mb and the maximum sustained surface winds were 10 to 20 kt (5 to 10 m/sec).

The orientation of low-level clouds on the visual satellite imagery at 120000Z revealed a broad circulation center in the western quadrant of deep convection located 320 nm (593 km) east of the Bikini Atoll in the Marshall Island Group. The intensity was estimated to be 25 kt (13 m/sec). Later, at 121800Z, Forrest demonstrated continued growth. This prompted reissuance of the ABPW PGTW at 122000Z to upgrade Forrest's potential for development to fair. This trend towards increased organization (Figure 3-18-1) continued and resulted in a Tropical Cyclone Formation Alert (TCFA) at 132000Z. The first aircraft reconnaissance investigative mission flown into the disturbance on the 14th of October found multiple low-level circulation centers, a MSLP of 1008 mb, maximum winds of 10 to 25 kt (5 to 13 m/sec) near the vortices and 30 kt (15 m/sec) displaced to the north. The TCFA was reissued at 142000Z, since supporting data did not, as yet, necessitate a warning.

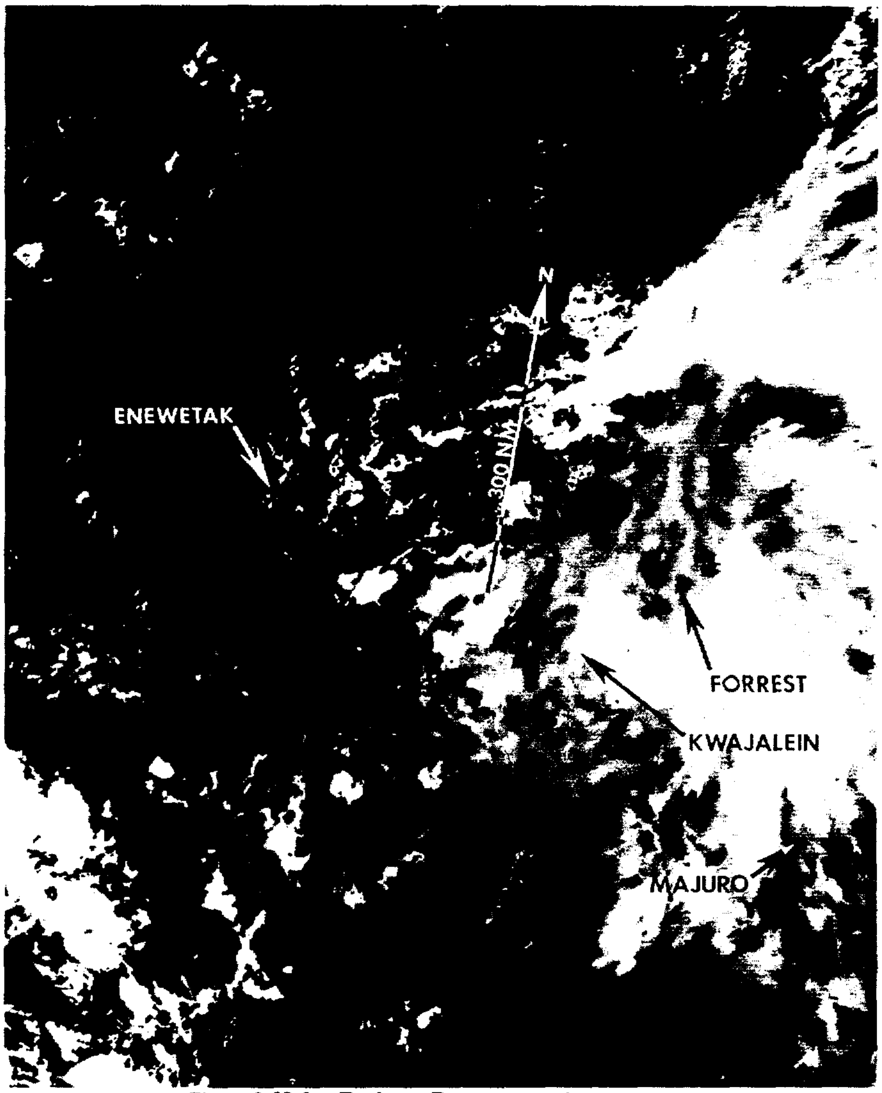


Figure 3-18-1. Typhoon Forrest organizing over the Marshall Islands (122311Z October DMSP visual imagery).

Aircraft reconnaissance on the 15th found a single circulation center; the MSLP had dropped to 1002 mb and maximum winds were 25 kt (13 m/sec). The (Dvorak) satellite intensity estimate at 151600Z of 45 kt (23 m/sec) prompted the first warning. The warning at 151800Z for Tropical Depression 18W, however, only mentioned maximum sustained winds of 30 kt (15 m/sec). The lower intensity on the warning was caused by the Typhoon Duty Officer placing more weight on the earlier aircraft reconnaissance information than the Dvorak analysis of infrared satellite imagery. Subsequent aircraft reconnaissance at 152126Z, however, proved otherwise. They reported maximum winds to be 55 kt (28 m/sec) with a MSLP of 988 mb and a closed, but thin, eyewall. At 160009Z, the aircraft observed 80 kt (41 m/sec). Figure 3-18-2 shows the stronger winds in the north semicircle of Forrest indicative of the tighter pressure gradient between the low pressure center and the subtropical ridge. The 160000Z warning upgraded Forrest from tropical depression to typhoon intensity with maximum sustained surface winds of 65 kt (33 m/sec). In retrospect, the initial warning was too conservative and the forecasters had waited too long for the aircraft reconnaissance to confirm the strong development indicated by the satellite data.

While moving northwestward at 16 to 18 kt (30 to 33 km/hr) over the next 24-hours, Forrest rapidly deepened. Nighttime aircraft reconnaissance on the 16th indicated Forrest had continued to deepen rapidly as the 700 mb heights fell 70 meters in less than three hours. Dvorak intensity estimate on satellite imagery at 161600Z indicated Forrest contained winds of 102 kt (53 m/sec). By 162105Z the 700 mb heights had dropped by 219 meters from 2840 meters to 2621 meters. The MSLP was 946 mb. Satellite imagery and aircraft intensities were in agreement, that Forrest had deepened rapidly over a very short time period. Forrest peaked at its maximum intensity of 100 kt (51 m/sec) at 170000Z (Figure 3-18-3). Two hours before this peak

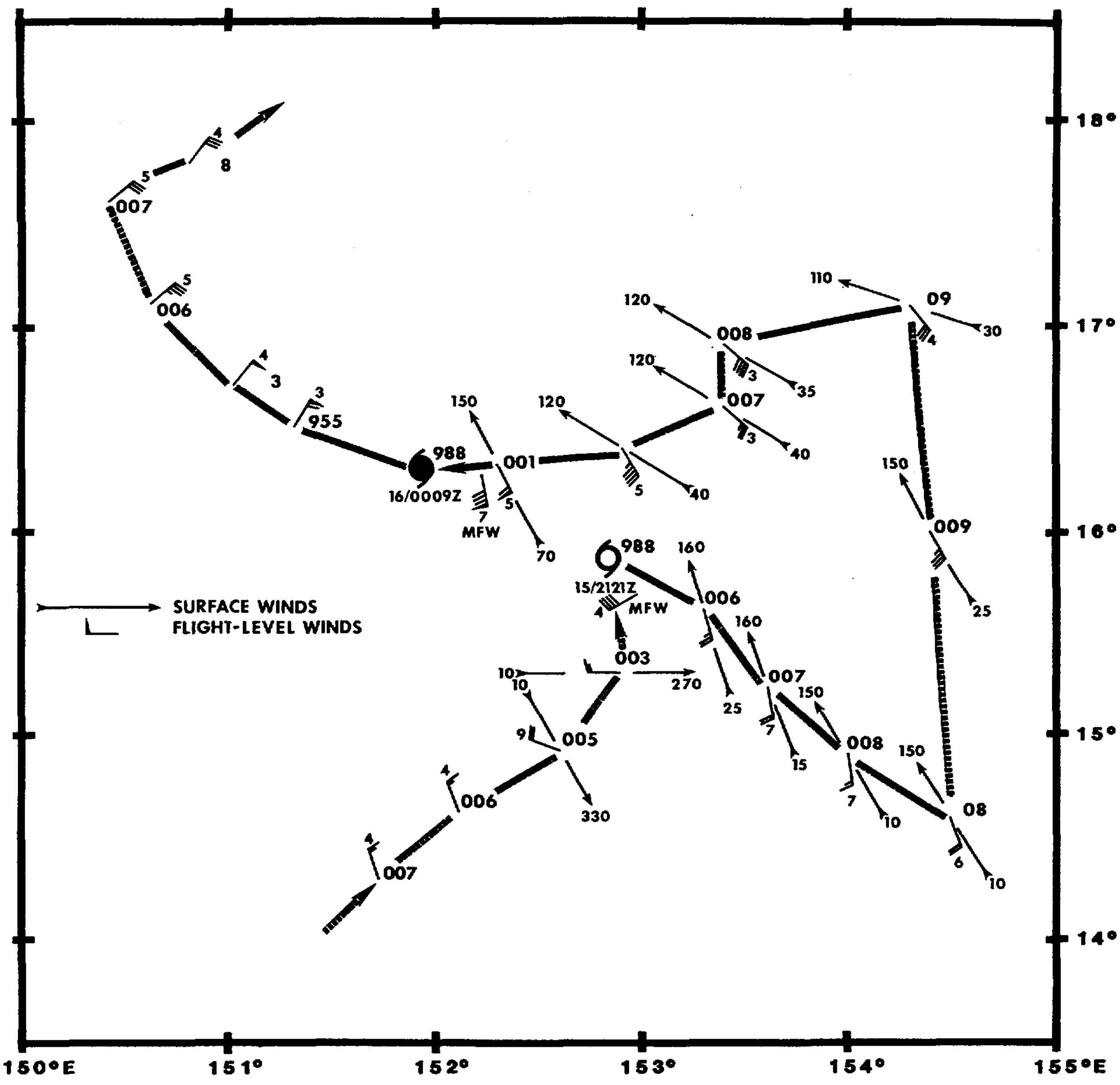


Figure 3-18-2. Plot of aircraft reconnaissance date from 152126Z to 160009Z October showing higher wind speeds to the north and east of the cyclone center. "MFW" represents the maximum observed flight-level winds and "MSW" represents the maximum observed surface winds.

Figure 3-18-3. Typhoon Forrest at maximum intensity of 100 kt (51 m/sec) with a small eye. With the sun low in the east, the cloud top topography is striking (162029Z October DMSP visual imagery).

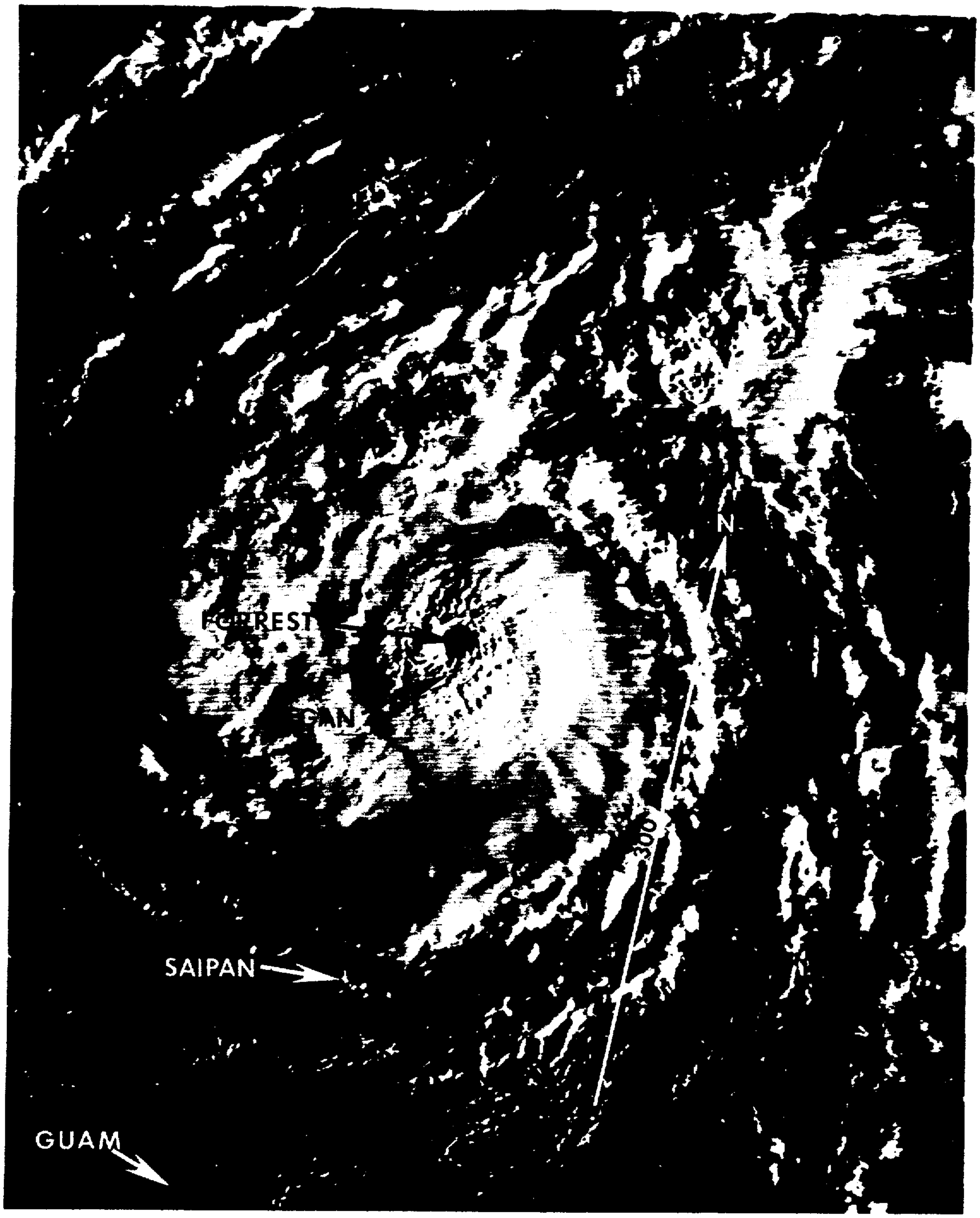
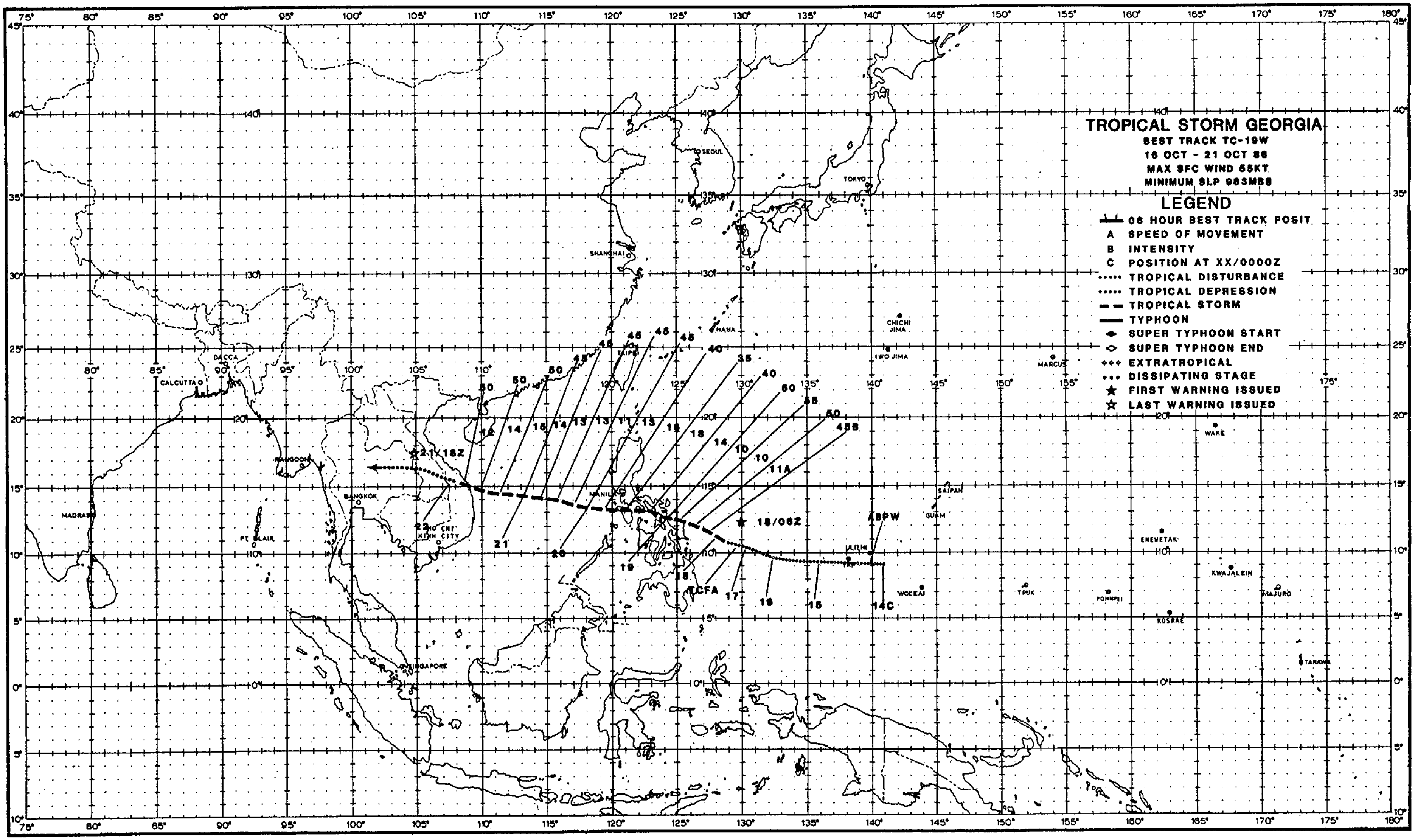


Figure 3-18-4. The thin cirrus clouds in the west semicircle indicate the beginning of the end for Forrest as it was becoming influenced by the stronger mid- to upper-level westerly flow. A short time later, Forrest began to move rapidly northeastward (180536Z October NOAA infrared imagery).

intensity, the island of Agrihan (located in the northern Marianas 270 nm (500 km) north of Guam) bore the brunt of Typhoon Forrest as it passed 10 nm (19 km) to the south. Fortunately, the island's 25 residents received no injuries even though only one building was left standing and two-way communications were destroyed. On the 21st of October, the Navy and Coast Guard joined forces and airlifted 1000 pounds of canned food, medical supplies and a two-way radio to the islanders.

At maximum intensity and just prior to recurvature, Forrest started elongating southwest to northeast and slowed to 5 kt (9 km/hr). JTWC had been expecting Forrest to recurve due to the break in the ridge since the first warnings on the system. The dynamic forecast aids were also in good agreement in this regard. The One-Way Interactive Tropical Cyclone Model (OTCM) provided the best guidance for speed and the Nested Tropical Cyclone Model (NTCM) had the best handle on direction.

Over the next 30-hours, Forrest began to very gradually weaken as it moved slowly around the western end of the subtropical ridge and started moving northeastward. Figure 3-18-4 shows Forrest's outflow restricted to the west due to the increasing westerlies aloft. By 191200Z, the system was beginning to accelerate northeastward at 23 kt (43 km/hr). Forrest completed transition to an extratropical cyclone and the final warning, indicating 55 kt (28 m/sec) intensity, was issued at 200600Z.



NOCC GUAM 3142/20 (NEW 5 - 80)

Typhoons Ellen (17W) and Forrest (18W) were already in progress, when Tropical Storm Georgia formed in the monsoon trough east of the Philippine Islands. The convective activity in the trough began to increase on the 14th of October, however it did not consolidate until the 18th.

First mention of Georgia as a tropical disturbance was on the Significant Tropical Weather Advisory (ABPW PGTW) of 140600Z. For the next four days, the large area of convection remained disorganized. By 17 October, satellite imagery (at 0300Z) indicated increased convective curvature and the (Dvorak) intensity estimate increased to 25 kt (13 m/sec). Aircraft reconnaissance later in the day closed off a weak, broad circulation center in the Philippine Sea 345 nm (639 km) northwest of Belau at 170655Z. A Tropical Cyclone Formation Alert was issued at 170821Z based on these data.

The (Dvorak) analysis of satellite imagery at 180052Z estimated a maximum wind of 30 kt (15 m/sec) (Figure 3-19-1). Aircraft reconnaissance in the area at 180543Z estimated surface winds of 45 kt (23 m/sec) with a minimum sea-level pressure of 991 mb. Based on the information provided by the aircraft reconnaissance crew, the first warning followed for Tropical Storm Georgia, valid at 180600Z.

At 181800Z, Georgia struck the central Philippine Islands with maximum winds of 55 kt (28 m/sec). The tropical cyclone weakened to 35 kt (18 m/sec) during the 16-hours it took to traverse the rugged central Philippine Islands. During this time, Georgia was forecast to remain south of the ridge and

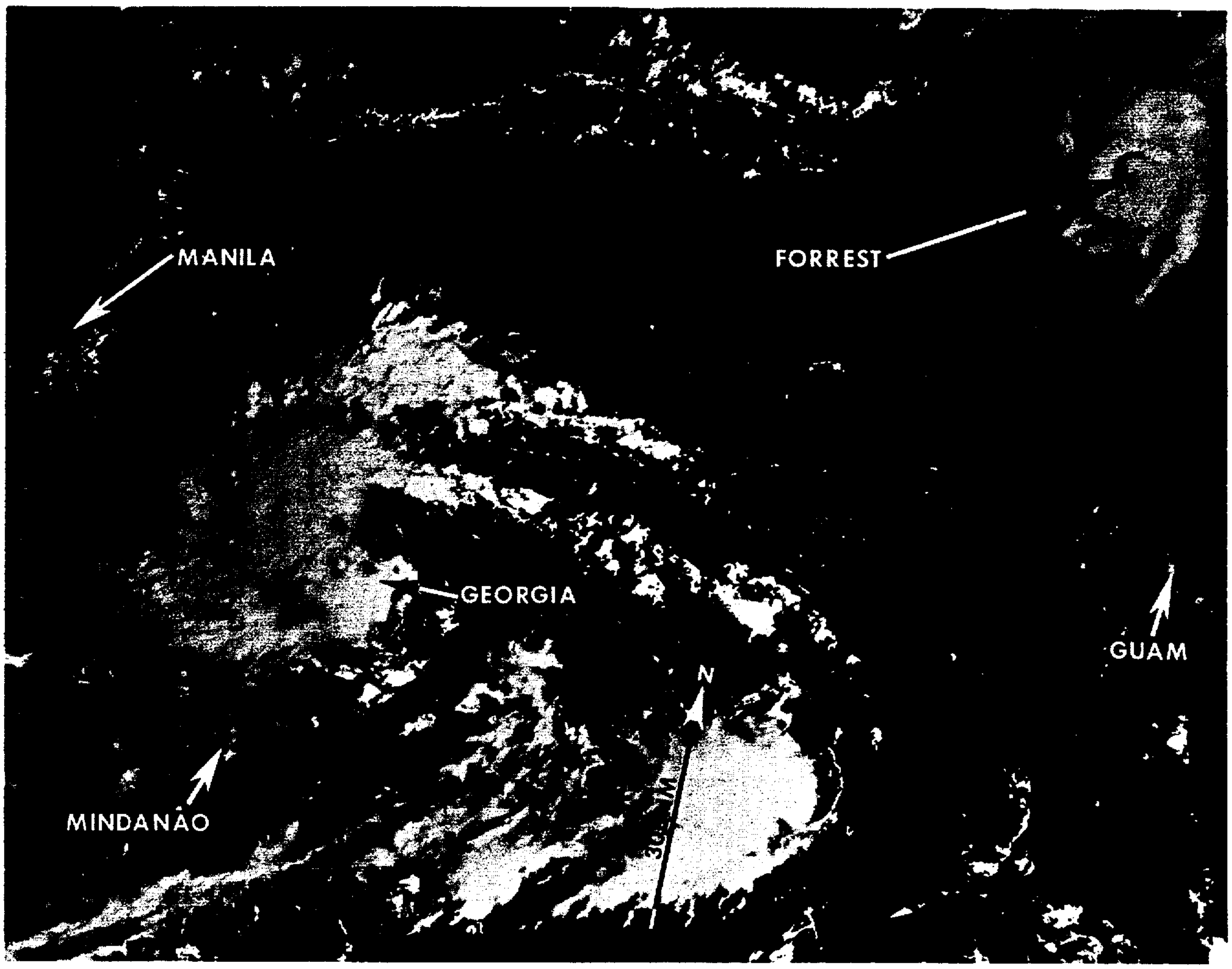


Figure 3-19-1. Georgia with (Dvorak) estimated winds of 30 kt (15 m/sec). Georgia was part of a multiple tropical cyclone outbreak that occurred in mid-October. Typhoon Forrest (18W) is located to the northeast of Tropical Storm Georgia on this satellite image. Typhoon Ellen (17W) was in the northern South China Sea and not visible on this pass (100052Z October DMSP visual imagery).

then move northwestward toward the island of Hainan. The forecast was in close agreement with the forecast aids for 180000Z through 181800Z which paralleled the low- to mid-level steering flow to the northwest. However, mid-level pressure surface heights rose across the northern South China Sea in the wake of Typhoon Ellen (17W), which had moved westward along the southern coast of mainland China. The 200000Z warning reflected a change in forecast philosophy and the track became more westerly with landfall in central Vietnam.

Upon entering the South China Sea, Georgia began to slowly reintensify. The final aircraft fix mission flew into Georgia on the 21st. On that flight, the reconnaissance aircraft reported severe turbulence in the convection surrounding Georgia's center (Figure 3-19-2). For the 12-hours prior to making landfall, Georgia's winds reached 50 kt (26 m/sec). The final warning was issued for Tropical Storm Georgia at 211800Z as the system made landfall and interacted with the rugged Annamitique mountains of central Vietnam.

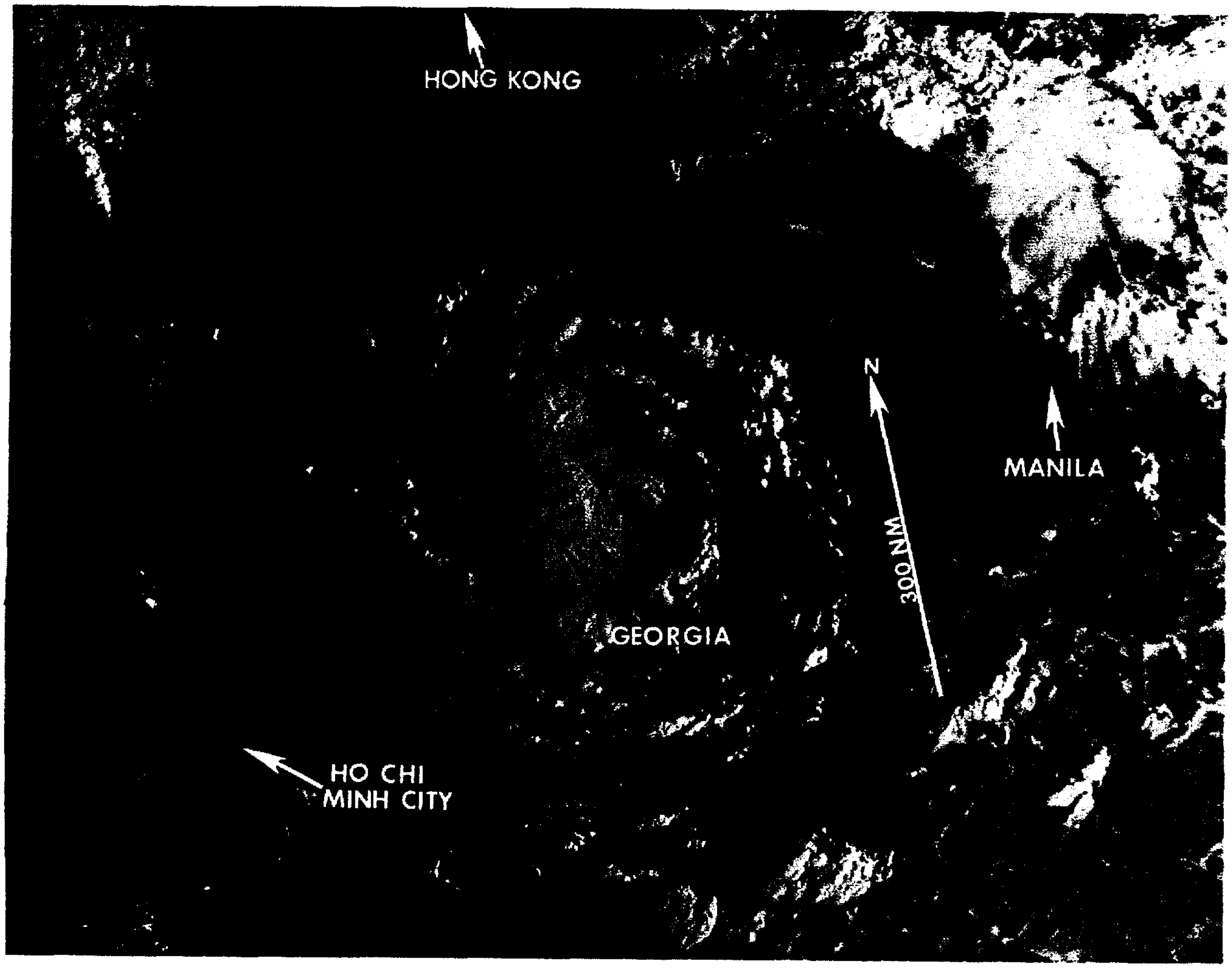


Figure 3-19-2. Tropical Storm Georgia after reintensifying in the South China Sea. The system made landfall 18-hours later and dissipated over the rugged mountains of Vietnam (210018Z October NOAA visual imagery).

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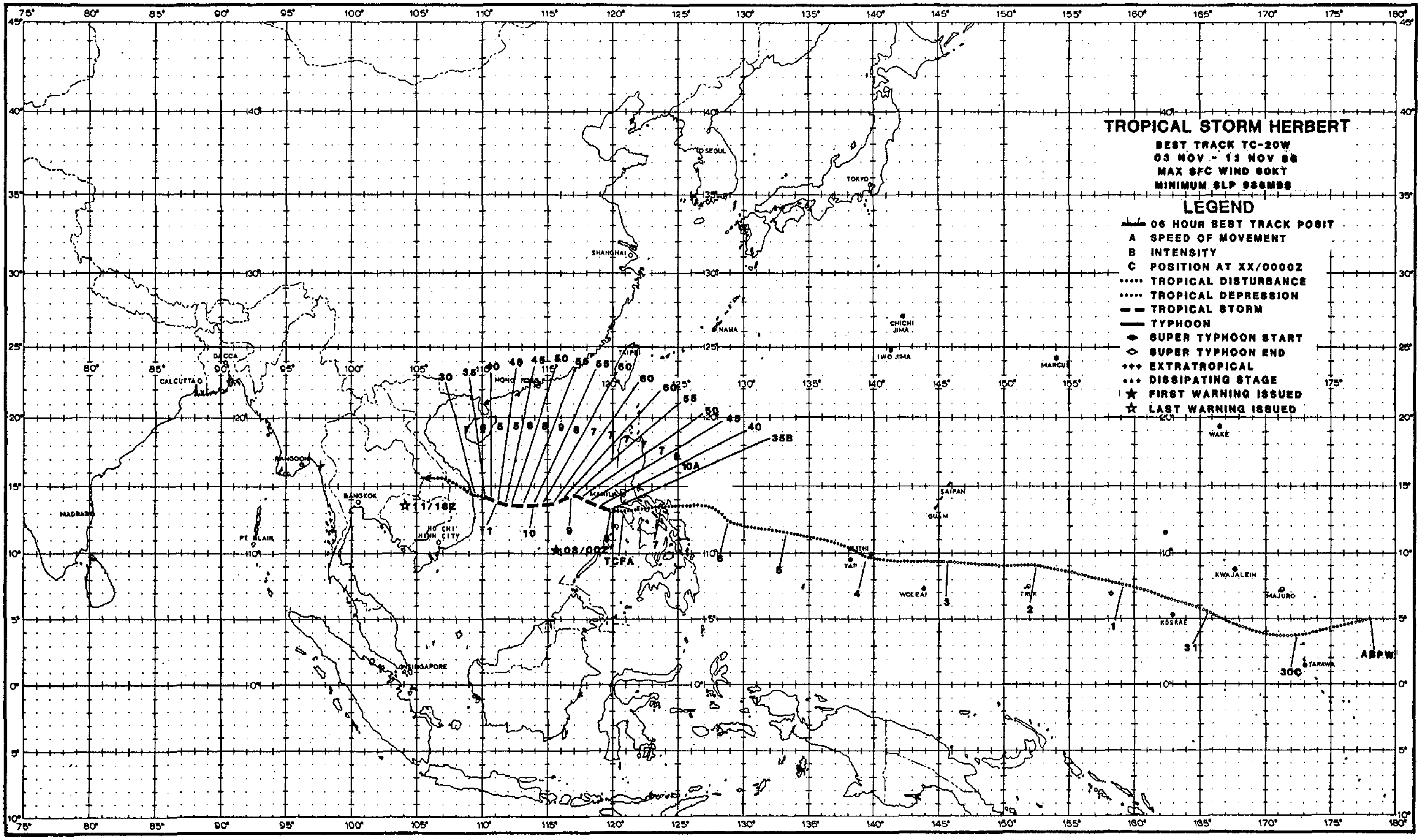


NOCC GUAM 3142/20 (NEW 5-80)

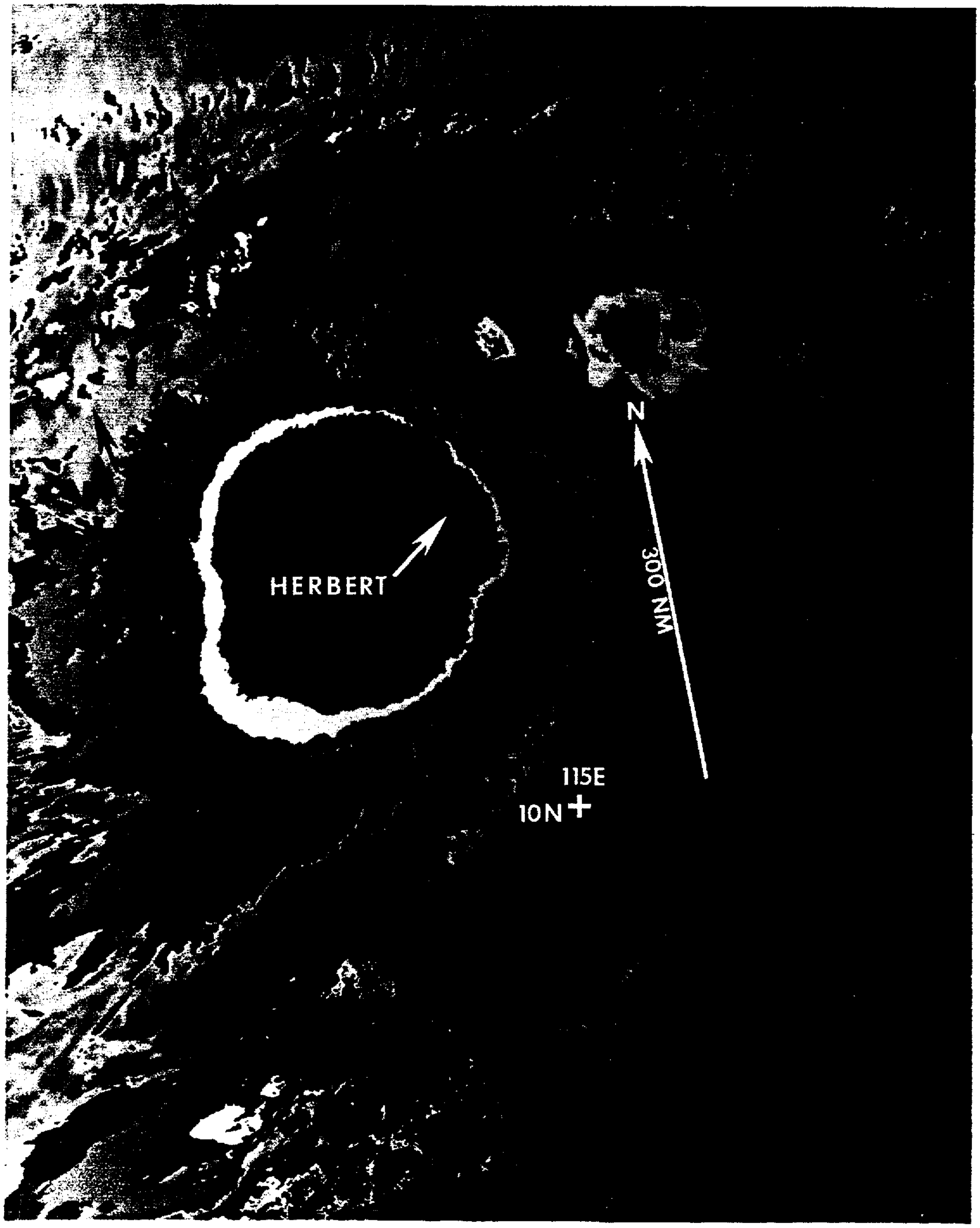
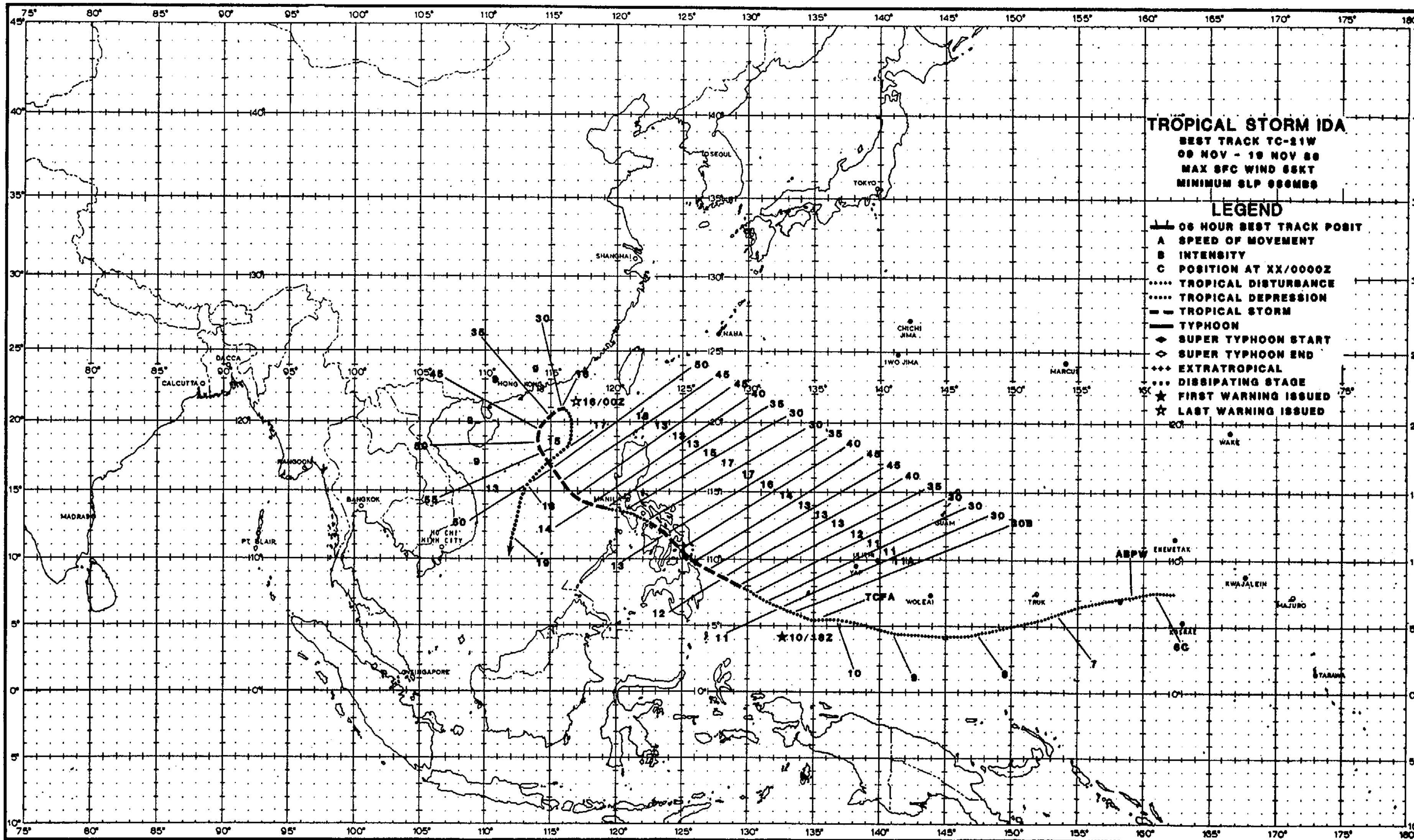


Figure 3-20-1. Herbert, as a tropical disturbance, tracked from east of the dateline across the western North Pacific, Philippine Sea and into the central Philippine Islands before reaching tropical storm intensity. The Significant Tropical Weather Advisory (ABPW PGTW) referred to this disturbance for a period of ten days (290600Z October to 070600Z November). The above NOAA imagery shows Tropical Storm Herbert near its maximum intensity of 60 kt (31 m/sec). On this specially enhanced infrared image note the small warm spot in the central dense overcast which is the eye. In the South China Sea, the strongest winds associated with Herbert persisted in the northeastern semicircle due to interaction with the northeast monsoonal flow from Asia. (092344Z November NOAA infrared imagery).



NOCC GUAM 3142/20 (NEW 5 - 80)

Tropical Storm Ida was the second of four tropical cyclones to develop during the month of November. This tropical cyclone presented unique forecast problems for JTWC as it interacted with strong northeasterly low-level flow near the coast of China.

Ida was first detected as a tropical disturbance in the near-equatorial trough on 6 November. Satellite and synoptic data indicated an upper-level anticyclone was present, but only a weak circulation existed near the surface. It was mentioned on the 060600Z Significant Tropical Weather Advisory (ABPW PGTW). By 9 November, the upper-level circulation was located near an area of broad-scale westerly flow approximately 500 nm (926 km) south of Guam. Tropical Storm Herbert (20W) and Typhoon Joe (22W) also developed in this same genesis area during the first half of the month. The excess cyclonic vorticity created by easterly winds south of the subtropical ridge and westerly winds near the equator enhanced development of the low-level circulation over the next 24-hours. Satellite imagery at 100129Z revealed a partially exposed low-level circulation center (Figure 3-21-1), prompting the issuance of a Tropical Cyclone Formation Alert, valid at 100600Z. Intense convection developed in the northeast quadrant during the evening hours of the 10th. The first warning on Ida, valid at 101800Z, was based on a satellite analysis of 35 kt (18 m/sec) winds using the Dvorak technique. Synoptic data indicated that Tropical Storm Ida lost its upper-level anticyclone, the main synoptic feature of its development, shortly after the first warning was issued. Aircraft reconnaissance flown on the morning of the 11th found a minimum sea-level pressure (MSLP) of 1004 mb, or the equivalent of 21 kt (11 m/sec) on the Atkinson-Holliday wind/pressure relationship.

In retrospect, the first warning may have been

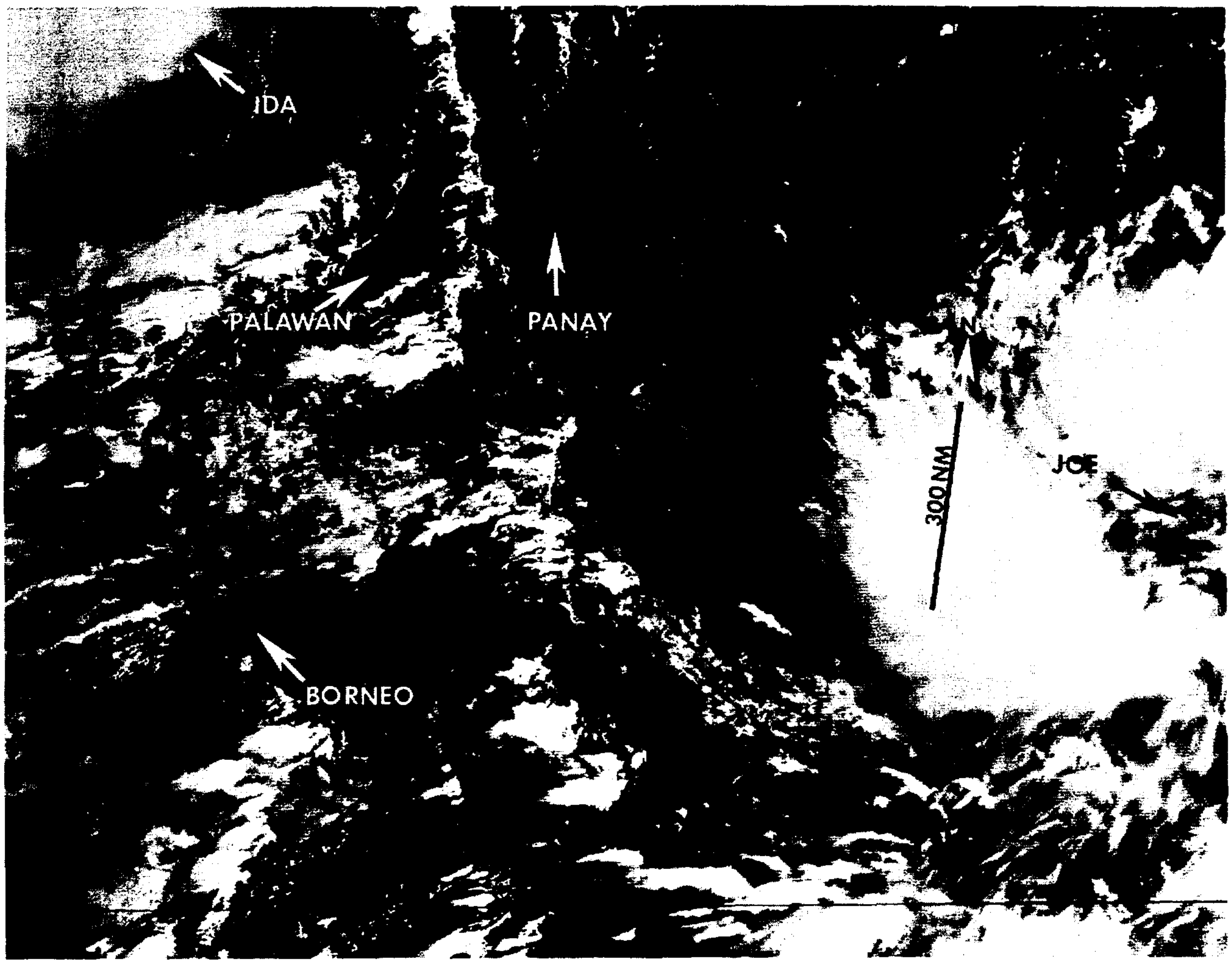


Figure 3-21-1. Tropical Storm Ida in the formative stage of development. Convective bands in the northern and western quadrants describe the upper-level anticyclone outflow that exists over the tropical disturbance (100129Z November DMSP visual imagery).

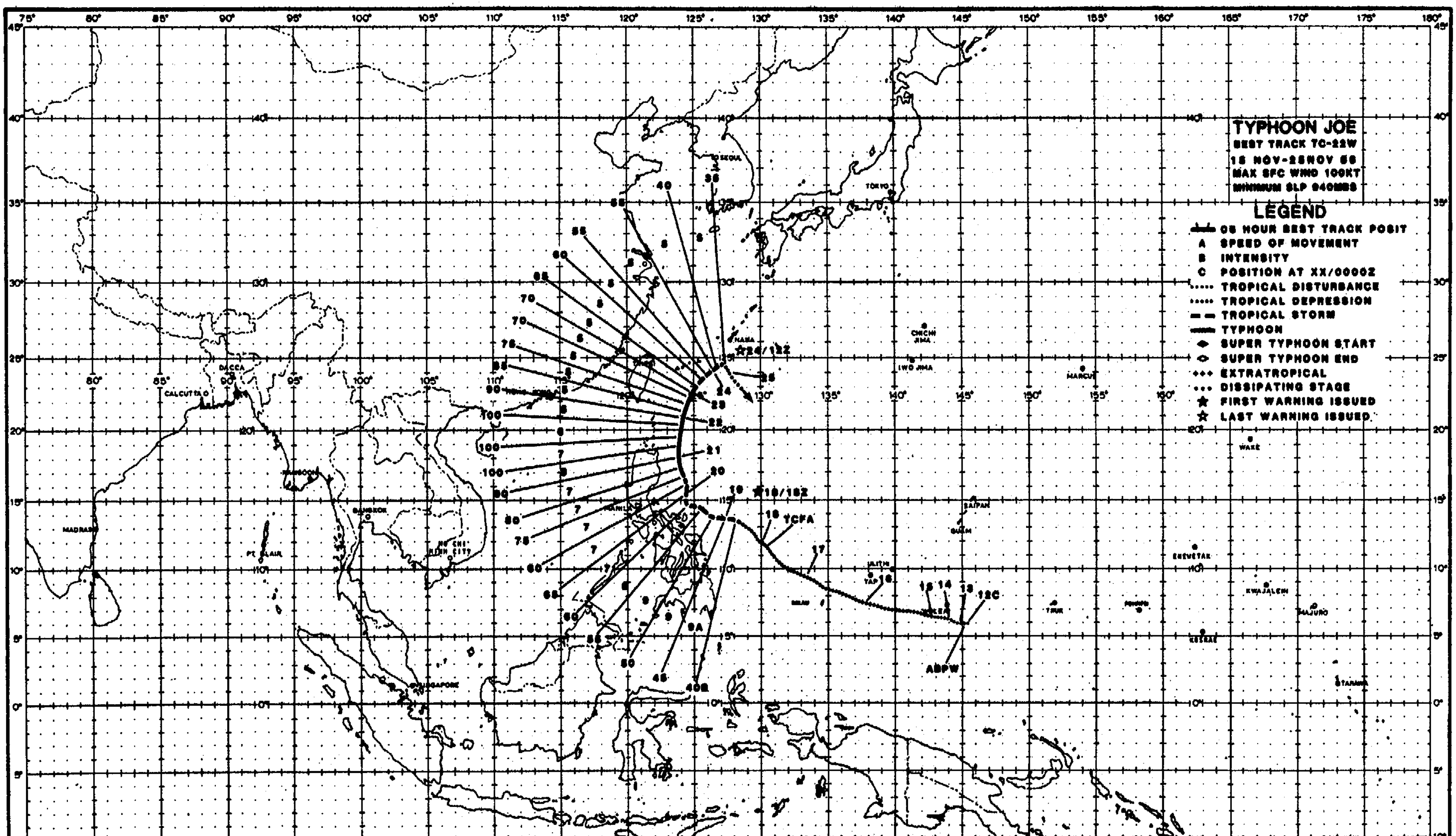
issued prematurely without enough data from synoptic and aircraft reconnaissance data to support an upgrade to tropical storm intensity. The initial warning was based on satellite analysis of a rapidly developing cloud system, which later proved to be inaccurate.

Tropical Storm Ida gradually intensified as it approached the Philippine Islands. Aircraft reconnaissance at 120223Z found a MSLP of 990 mb, or a drop of 14 mb in 24-hours. Ida accelerated as it traversed the Philippines and weakened slightly due to orographic effects. It followed nearly the identical track through the islands as Tropical Storm Herbert (20W) just six days earlier. Ida regained tropical storm intensity shortly after entering the South China Sea and reached its peak intensity of 55 kt (28 m/sec) early on the 15th (see Figure 3-21-2).

At this point Ida was influenced by the northeast monsoon winds off of mainland China. The One-Way Interactive Tropical Cyclone Model (OTCM) indicated the cyclone would continue its northward track for approximately 24-hours. JTWC forecasts followed this prognostic reasoning. Post-storm analysis indicated that Ida attempted to recurve around the subtropical ridge as the upper-level circulation sheared off to the northeast. However, the low-level circulation drifted eastward in apparent opposition to the surface wind flow. The cold air feeding into Ida caused it to undergo rapid extratropical transition. Also, the cold air behind the mid-level trough just north of Tropical Storm Ida merged with the warm air advected northward by the tropical cyclone, leading to the strengthening of the frontal boundary off the China coast. Ida became embedded in this frontal boundary. The final warning was issued at 160217Z. No loss of life or significant property damage was attributed to Ida.

The low-level eddy, which was the remnant of Ida, separated from the frontal boundary on 17 November and drifted southwestward in the South China Sea with the gradient-level flow. It persisted as a vortex on visual satellite imagery until 19 November.

Figure 3-21-2. Tropical Storm Ida near maximum intensity in the South China Sea (150129Z November DMSP visual imagery).


TYPHOON JOE
BEST TRACK TC-22W
18 NOV-25NOV 86
MAX SFC WIND 100KT
MINIMUM SLP 940MBS
LEGEND
06 HOUR BEST TRACK POSIT
A SPEED OF MOVEMENT
B INTENSITY
C POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
DISSIPATING STAGE
FIRST WARNING ISSUED
LAST WARNING ISSUED.
TCFA
ABPW

Typhoon Joe was the third of four tropical cyclones to reach warning status in the month of November. As a tropical disturbance, Joe became evident on satellite imagery on the 12th. JTWC mentioned it for the first time on the Significant Tropical Weather Advisory (ABPW PGTW) when it appeared as an area of enhanced convective activity 425 nm (787 km) south of Guam at 120600Z. The amount of convection and organization (Figure 3-22-1) increased very slowly as it moved west-northwestward. Synoptic data during this period indicated a weak low-level cyclonic circulation. Upper-level data indicated divergent flow aloft. The central convection began to consolidate and a Tropical Cyclone Formation Alert (TCFA) was issued at 172251Z. Satellite intensity analysis shortly after the TCFA issuance indicated surface winds of 35 kt (18 m/sec).

The initial aircraft vortex fix mission at 0213Z on the 18th located a 30 kt (15 m/sec) low-level circulation. The extrapolated minimum sea-level pressure (MSLP) was 1005 mb, which normally supports less than 30 kt (15 m/sec) winds (Atkinson and Holliday, 1978). By 181800Z, however, satellite imagery indicated increased development and the first warning was issued on Tropical Depression 22W. A circular eye 15 nm (28 km) in diameter was first observed by aircraft reconnaissance at 190046Z. Some elongation north-northeast/south-southwest was apparent on satellite imagery by 191800Z as Joe began to interact with a mid-latitude trough passing to the north. Three hours later, aircraft reconnaissance reported that Joe's eye had become elliptical and the MSLP had decreased to 976 mb. Typhoon intensity was reached between 191800Z and 200000Z as Joe began to

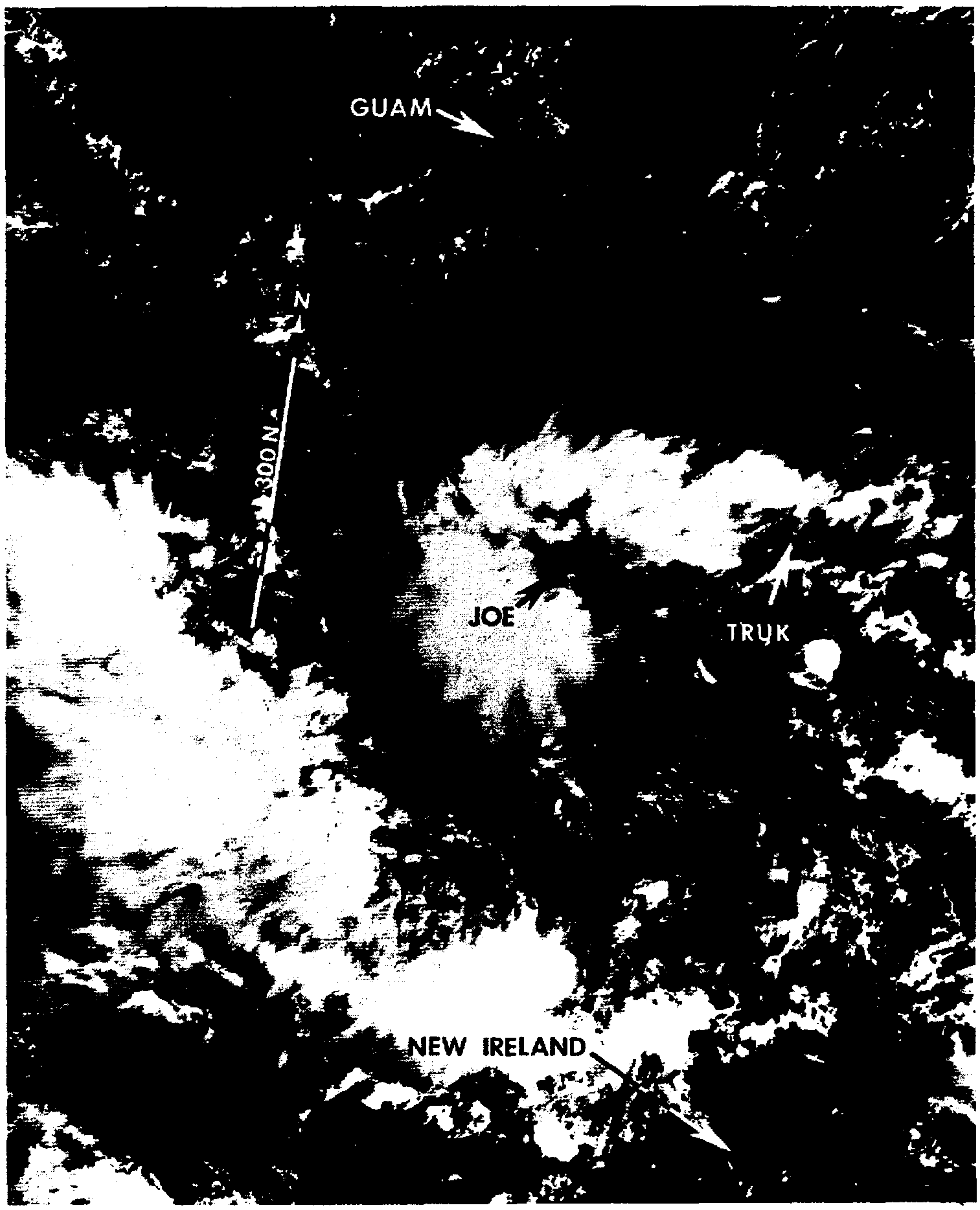


Figure 3-22-1. Typhoon Joe as an area of enhanced convection south of Guam (140008Z November DMSP visual imagery).

move northward around the periphery of the subtropical ridge to its east (Figure 3-22-2).

The first warning (181800Z) forecast Joe to move northwestward, just over the northeast corner of the island of Luzon in the Republic of the Philippines. The second through fifth warnings (from 190000Z to 191800Z) forecast a more westward track for Joe. These forecasts relied heavily on the dynamic guidance of the One-way Interactive Tropical Cyclone Model (OTCM) which indicated west-northwestward

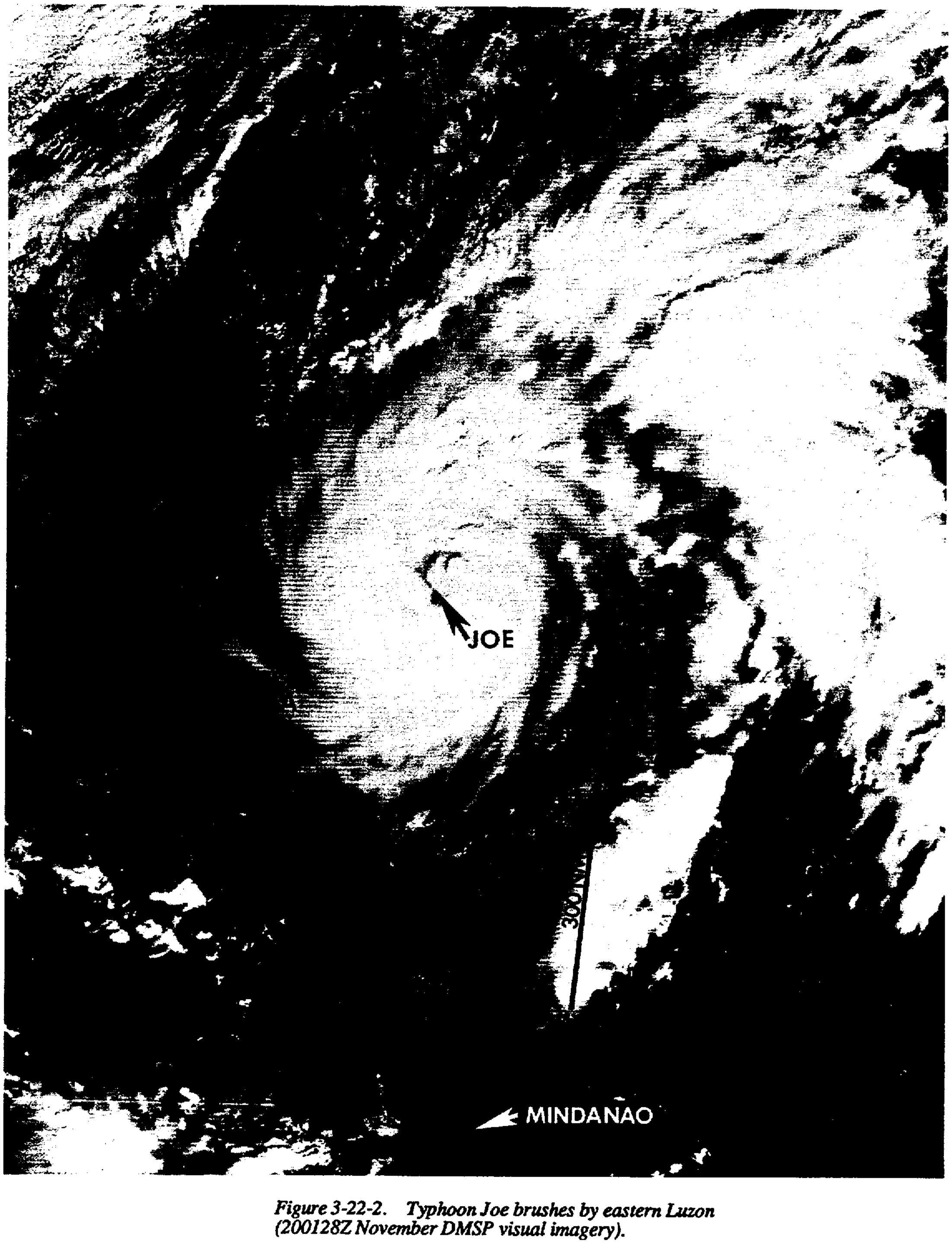


Figure 3-22-2. Typhoon Joe brushes by eastern Luzon (200128Z November DMSP visual imagery).

movement of Joe across central Luzon. However, the OTCM persisted in forecasting westward movement as late as 231200Z, three days after Joe had assumed a northerly track. This could possibly have been due to the model's inability to adequately handle the interactions between the typhoon and the strong northeasterly low-level flow from Asia. JTWC broke with the faulty OTCM guidance after the fifth warning and correctly forecast recurvature.

A ragged eye first became visible on satellite imagery at 0128Z on 20 November. Typhoon Joe continued to intensify, even as the strength of the mid- to upper-level southwesterly flow increased aloft. Joe continued to intensify and reached a peak of 100 kt (51 m/sec) maximum sustained surface winds at 210600Z.

As Joe continued to move northward around the western end of the subtropical ridge, the vertical shear on the system increased. The result was Joe's upper-level outflow became displaced to the northeast of the low-level leaving the exposed low-level circulation behind. The final warning was issued at 241200Z, since Joe no longer retained any persistent central convection. Only the residual low-level circulation persisted and was still evident on imagery through 242318Z (Figure 3-22-3).

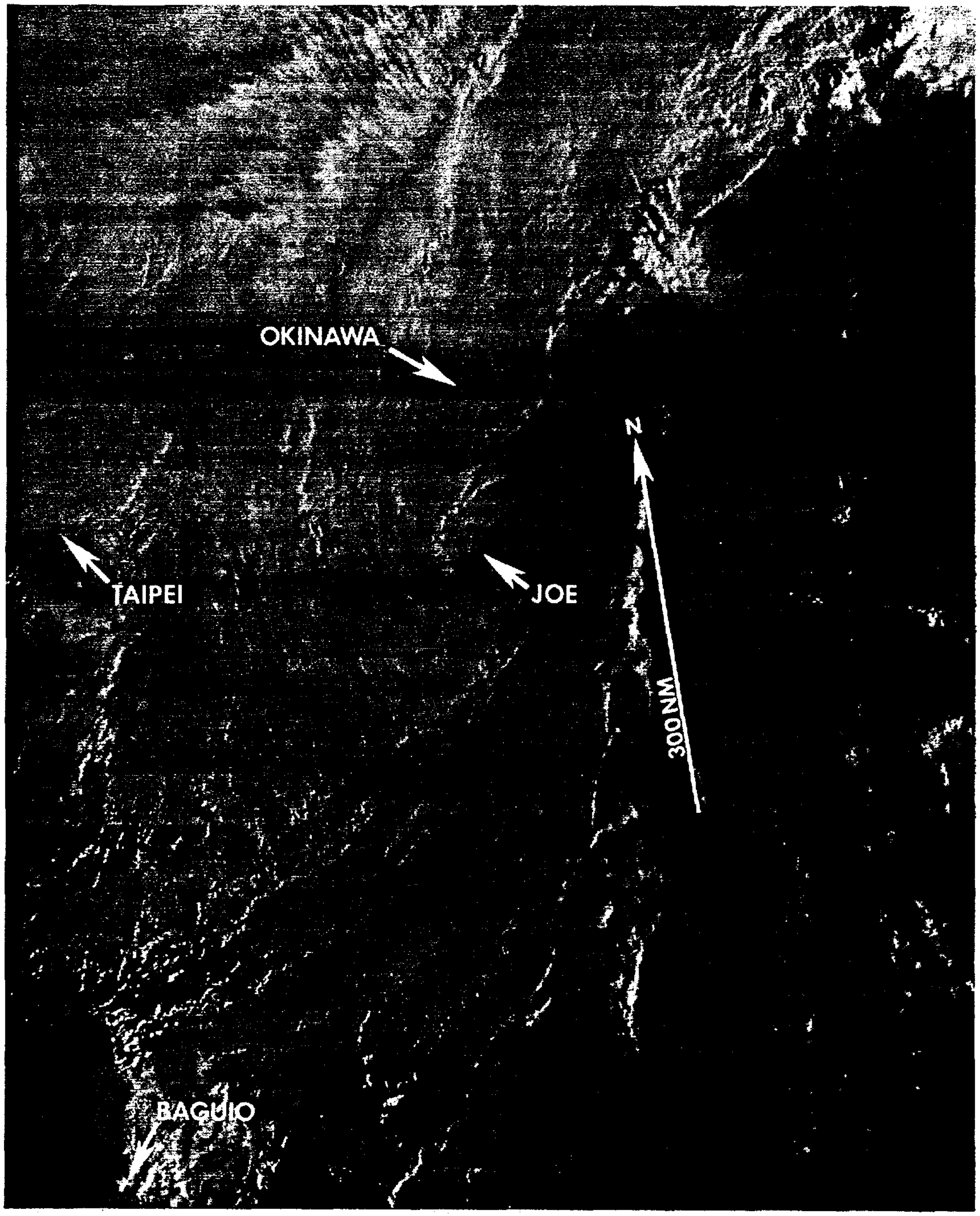
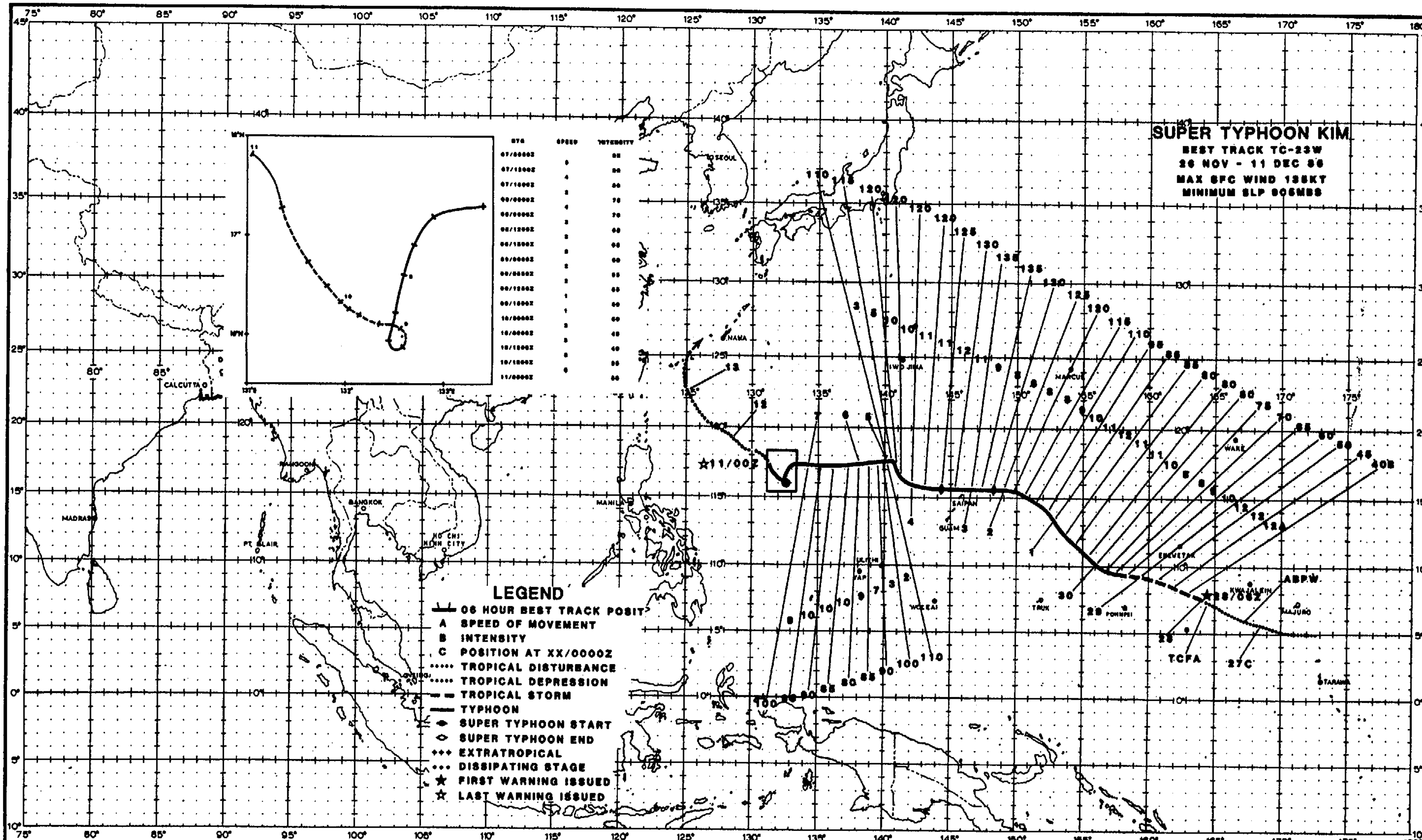


Figure 3-22-3. By 24 November, a residual low- level circulation was all that remained of Joe (242318Z November NOAA Visual imagery).



NOCC GUAM 3142/20 (NEW 5 - 80)

Super Typhoon Kim was a "midget" tropical cyclone that produced sustained winds of 135 kt (69 m/sec) with gusts to 165 kt (85 m/sec) and attained a minimum sea-level pressure (MSLP) of 905 mb. It was the fourth significant tropical cyclone that began in November, and was the first of four significant tropical cyclones in the month of December. Kim was the third super typhoon of the year and the first December super typhoon in twenty-two years since Super Typhoon Opal (December 1964). Fifty-two warnings were issued on Kim - more than any other tropical cyclone in 1986 except for Typhoons Vera (11W) and Wayne (12W). Thirty aircraft reconnaissance missions were flown on Kim, the most for any tropical cyclone in 1986. Included in these missions were five synoptic tracks and 45 center fixes. The information provided by the aerial reconnaissance platform was quite essential as Kim presented JTWC with track forecast problems at three different times.

Kim began, innocently enough, as a broad poorly organized area of convection near the dateline on the 26th of November. When convection persisted for 24-hours, JTWC first mentioned it on the Significant Tropical Weather Advisory (ABPW PGTW) at 270600Z. Maximum sustained winds were estimated at 10 to 20 kt (5 to 10 m/sec) and the MSLP was estimated at 1006 mb. Over the next 15-hours, outflow and convection increased significantly. Upper-level outflow was unrestricted in all quadrants and an upper-level anticyclone became well-established over the surface circulation center. The MSLP was estimated at 1005 mb. For these reasons JTWC issued a Tropical Cyclone Formation Alert (TCFA) at 272130Z, when the system was located about 360 nm (667 km) east of Pohnpei. Just nine hours later, at 280600Z, JTWC issued the first warning on Tropical Depression 23W based on a (Dvorak) intensity estimate of 35 kt (18 m/sec). At 281200Z, JTWC upgraded Tropical Depression 23W to Tropical Storm Kim based on continued intensification.

At 290126Z, the first aircraft reconnaissance mission closed off the surface circulation center 145 nm (269 km) north-northeast of Pohnpei. The Aerial Reconnaissance Weather Officer reported that an elliptical eye was beginning to form, which was open to the northwest. This first penetration found maximum 700 mb winds of 65 kt (33 m/sec) and a 700 mb height of 2921 meters, which corresponds to an MSLP of about 980 mb. The second penetration, 90 minutes later, reported maximum surface winds of 80 to 85 kt (41 to 44 m/sec). The 290600Z warning upgraded Kim to typhoon status.

From 261800Z through 291200Z (warning number 6), Kim tracked toward the west-northwest following a basic under-the-ridge scenario. At 291800Z, the eastward movement of a mid-latitude trough weakened the subtropical ridge. This caused Kim to move northwestward. The weakness in the ridge was misinterpreted by JTWC as a "break" in the ridge. At 010000Z, JTWC altered Kim's forecast track from an under-the-ridge scenario to a through-the-ridge scenario based on this break. Kim's track changed from anticyclonic to cyclonic, as Kim continued to track toward the northwest. As Kim reached the inflection point, it began to intensify at a rate slightly greater than expected from the normal Dvorak curve of one "T-number" per day. Kim's intensity increased from 85 kt (44 m/sec) at 010000Z to 135 kt (69 m/sec) by 022100Z.

The first, of three, major track forecasting problems arose when aircraft reconnaissance at 021105Z verified prior satellite imagery indications that Kim was moving westward. The mid-level ridge to the north strengthened as the low- to mid-level trough moved off to the east. Because of the significant forecast track change on Kim, an abbreviated warning message was sent out at 022100Z, since Kim immediately became a threat to Saipan.

At about 030400Z, Super Typhoon Kim, with its peak winds of 135 kt (69 m/sec), passed about 18 nm (33 km) to the north of Saipan. Kim inflicted

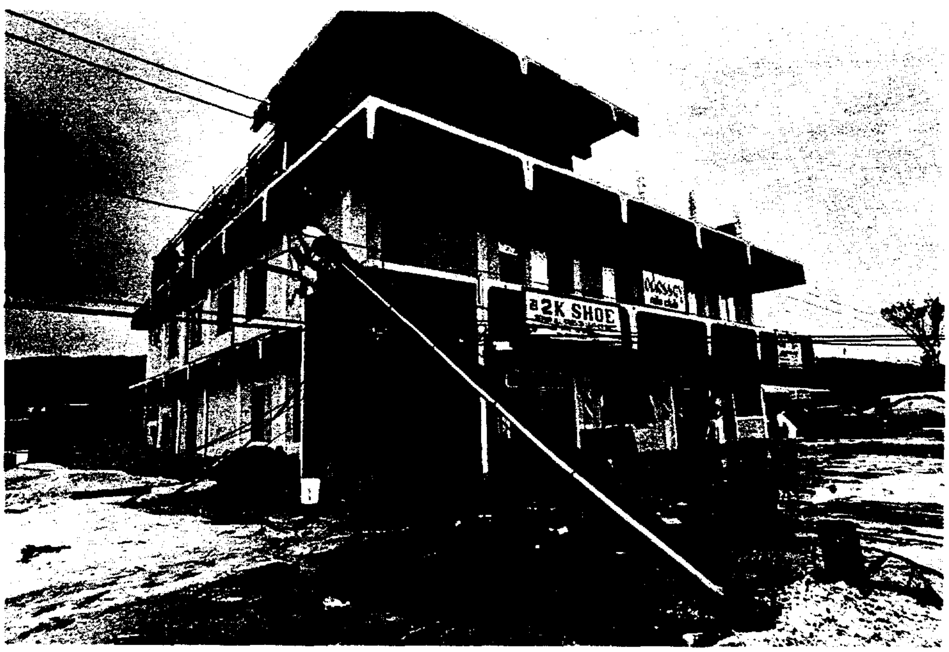


Figure 3-23-1. One of the many downed telephone poles leans against a shoe store in Garapan, the major city of Saipan, in the aftermath of Kim (Photo provided courtesy of Guam Publications, Inc.).

substantial damage to Saipan, leaving the entire island without electricity and water. An estimated one-third of all power poles were down (see Figure 3-23-1), hundreds of people were left homeless, 14 people were injured, mainly due to flying glass, and one (heart attack) fatality was reported. Damages (Figure 3-23-2) were estimated at about 15 million dollars by the Governor of Saipan. A team of U.S. Navy Construction Battalion personnel (Seabees), engineers from the U.S. Navy Public Works Center (Guam) and electrical generators were sent to Saipan to get the island's essential power system back on-line.

Kim continued tracking westward until 040000Z (Figure 3-23-3). Afterward, it began moving northwestward. This presented the second major forecasting problem with Kim. JTWC had followed the One-Way Interactive Tropical Cyclone Model (OTCM) guidance and repeatedly forecast recurvature. A synoptic track flown between 040500Z and 041200Z indicated a "break" in the subtropical ridge approximately 135 nm (250 km) southwest of Iwo Jima. The forecast looked good, but for the second time an unforecasted major directional change in the track occurred. Once again, this was not a "break" in the ridge, but merely a weakness that would cause the tropical cyclone to take a "step" toward the northwest and then return to a the westward track; as the mid-latitude trough moved north and then east of the system.

At 071200Z, Kim abruptly changed track and began moving toward the south along the leading edge of a modifying polar air mass moving off the Asian landmass. At the same time, the entrainment of cold air and increased vertical shear started to weaken the tropical cyclone. Aircraft reconnaissance at 081542Z, 082130Z and 090000Z documented this trend and Kim was subsequently downgraded to tropical storm intensity at 090000Z. By 090600Z, Kim's intensity was down to 55 kt (28 m/sec), and forty-two hours later, at 110000Z, to 30 kt (15 m/sec). After three days of erratic movement, Kim was further downgraded to a tropical depression. The final warning was issued at 110000Z as the system dissipated over water. The remains of Kim tracked west-northwestward and dissipated over the Philippine Sea 300 nm (556 km) east of the island of Luzon.

Figure 3-23-2. Many structures were extensively damaged by wind and water (Photo courtesy of Guam Publications, Inc.).

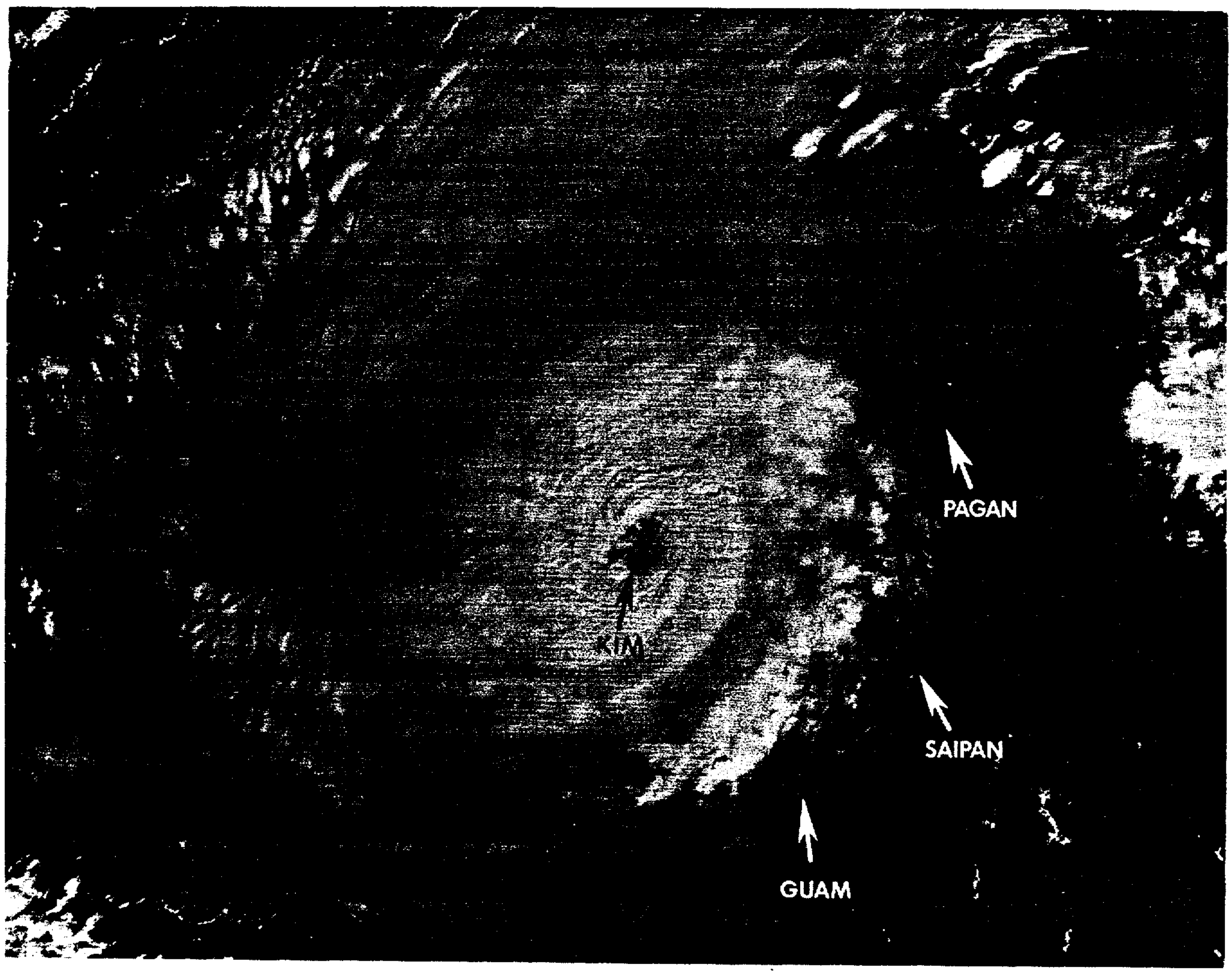
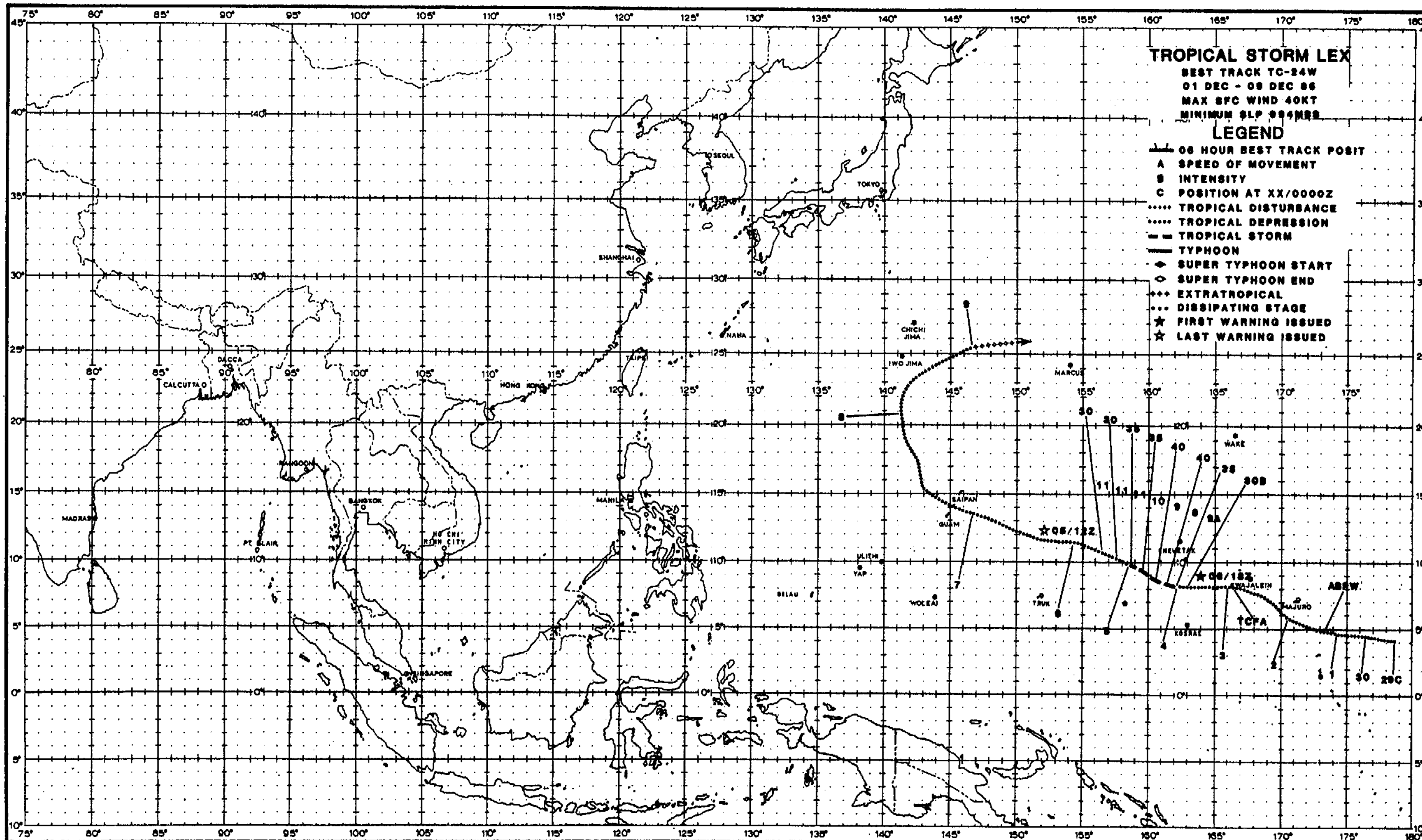


Figure 3-23-3. A day after damaging Saipan, Super Typhoon Kim was still on a westward track (040004Z December DMSP visual imagery).



NOCC GUAM 3142/20 (NEW 5 - 80)

Tropical Storm Lex was the first of three significant tropical cyclones to develop in the month of December. Initially, Lex developed rapidly in the wake of Super Typhoon Kim (23W) and presented a threat to Guam. Significant further development was inhibited by Kim (23W) and a mid-latitude trough, although a brief flare-up of convection occurred just before Lex passed through the southern Marianas.

Lex first appeared as a small mass of convection about 300 nm (556 km) to the east-southeast of the Kwajalein Atoll in the Marshall Islands at 301200Z November. The convection rapidly increased. Upper-level organization and low-level inflow also increased over the next 18-hours. For these reasons, Lex was initially placed on the Significant Tropical Weather Advisory (ABPW PGTW) at 010600Z December.

The tropical disturbance continued to show potential for development and at 022345Z, it became the subject of a Tropical Cyclone Formation Alert (TCFA). The convection became more centralized, prompting JTWC to issue the first warning on Tropical Depression 24W at 031800Z. Upper-level organization continued to improve, as satellite imagery indicated good banding features to the north and south. Increased satellite (Dvorak) intensity estimates resulted in an upgrade from Tropical Depression 24W to Tropical Storm Lex at 040000Z on the second warning.

Lex was first fixed by aircraft reconnaissance at 040537Z. The Aerial Reconnaissance Weather Officer reported surface winds of near 45 kt (23 m/sec), and fixed the surface center further to the east of the previous (040000Z) warning position, which was based on satellite data, and 85 nm (157 km) east of the 040600Z forecast position. This led JTWC to relocate Lex's position on the 040600Z warning.

Although forecast to reach typhoon intensity within 48-hours, it had already attained its peak intensity by 040600Z. The combination of an eastward moving trough and the proximity of Kim (23W) to the northwest, greatly inhibited Lex's upper-level outflow.

Aircraft reconnaissance indicated a tilt toward the west between the surface center and the upper-level center and a possible secondary center about 30 nm (56 km) to the northwest of Lex. As evidenced in visual satellite imagery at 042344Z (Figure 3-24-1), Guam was between Super Typhoon Kim (23W) (to the northwest) and Tropical Storm Lex. Lex continued to decrease in convection and organization. A nighttime aircraft reconnaissance fix mission scheduled for 051200Z found 700 mb westerlies throughout the area and no sign of a closed circulation. For these reasons, Tropical Storm Lex

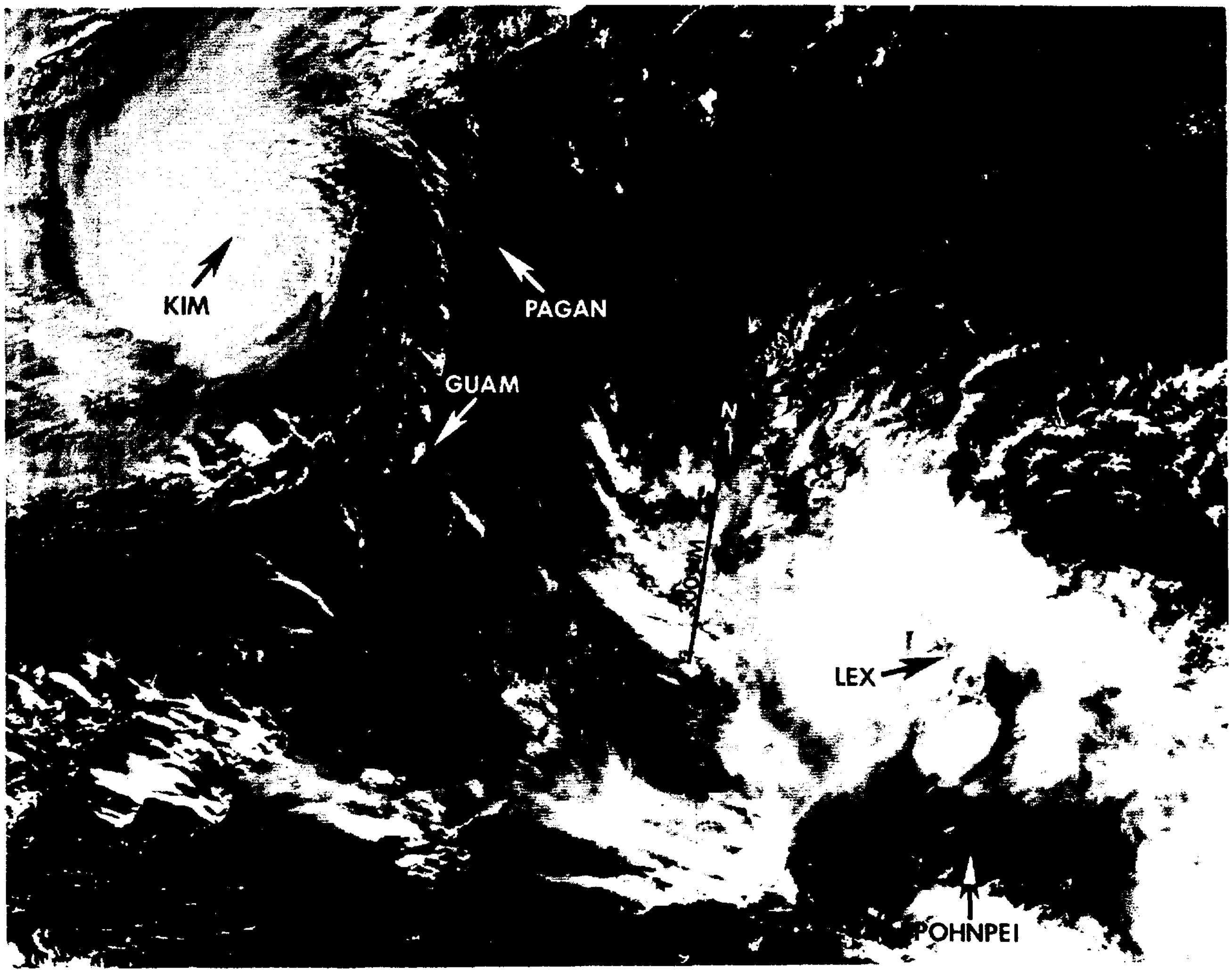


Figure 3-24-1. Visual satellite imagery showing Super Typhoon Kim (23W) and Tropical Storm Lex. The island of Guam is in the region between the two tropical cyclones (042344Z December DMSP visual imagery).

was downgraded to Tropical Depression 24W, and the final warning (number 8) was issued at 051200Z.

JTWC continued to monitor the remnants of Lex. Because of the sudden flare-up of central cold cover (Dvorak, 1984) cloud viewed on the satellite infrared imagery (Figure 3-24-2), Lex again was the subject of a TCFA (062300Z) about 80 nm (148 km) east-southeast of Guam. Due to the proximity to Guam, the prospect of sudden deepening and the uncertainty concerning what was really out there, JTWC diverted a WC-130 aircraft from a fix mission, that was in progress on Kim (23W), to fly an investigative profile on Lex. The results were that Lex's low-level circulation could not be closed off and warnings were not resumed. The weak disturbance moved rapidly by at 28 kt (52 km/hr) and passed directly over the island of Rota located 40 nm (74 km) north-northeast of Guam. Mid- to upper-level shear over the system was strong and the upper-level outflow remained restricted by Super Typhoon Kim (23W). JTWC cancelled the TCFA at 071500Z. The remains of Lex then moved northwestward until 080000Z, then curved northeastward and transitioned to an extratropical system.

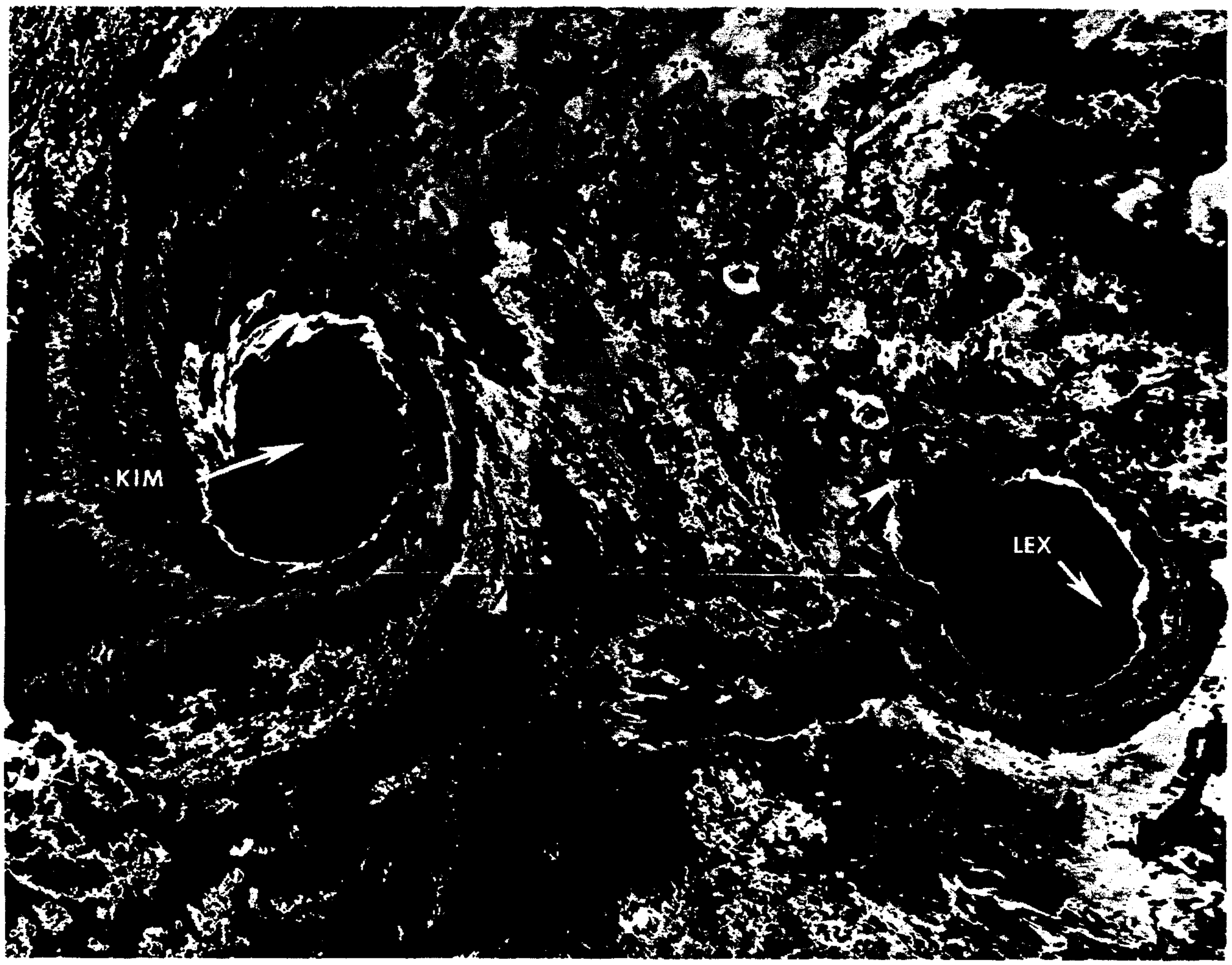
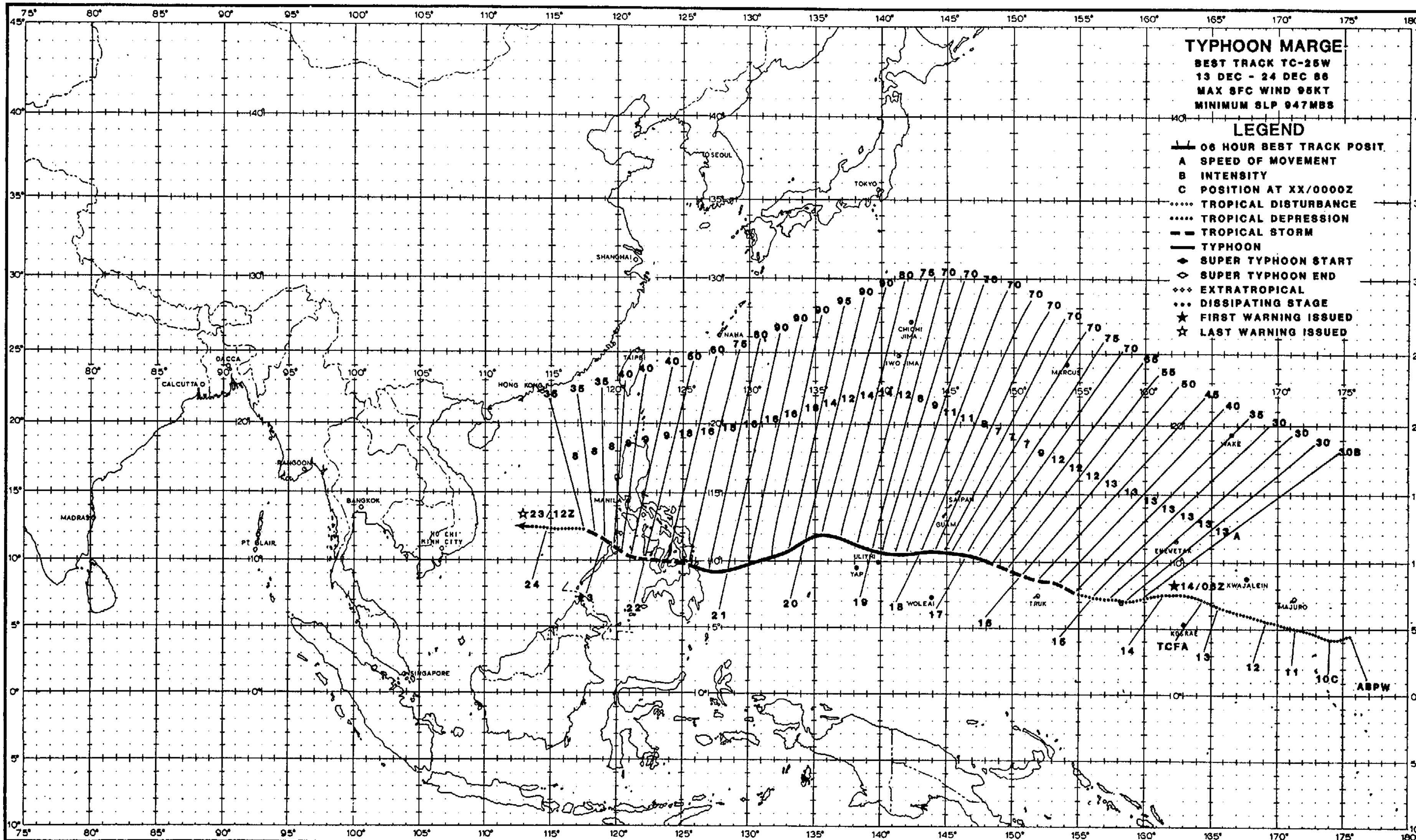


Figure 3-24-2. Enhanced infrared image for the Dvorak intensity estimation technique of the disturbance (Lex) and Kim (23W) at typhoon intensity. At first glance, the cloud signatures look similar. However, the distinction between the transitory flare-up of the central cold cover (Dvorak, 1984) over Lex and the persistent central dense overcast and eye of Kim (23W) is crucial for proper intensity analysis (061758Z December NOAA infrared imagery).



NOCC GUAM 3142/20 (NEW 5 - 80)

Typhoon Marge was a mid-December tropical cyclone that originated in the near-equatorial trough at low latitudes just east of the Marshall Islands. Slow to develop, Typhoon Marge presented a couple of unique forecasting problems which included some unexpected movement in the Philippine Sea.

Referenced for the first time on the Significant Tropical Weather Advisory (ABPW PGTW) on 9 December, the first warning wasn't issued until 140600Z December. During the intervening time, Marge drifted slowly toward the northwest as a large area of disorganized convection. The first Tropical Cyclone Formation Alert valid at 130330Z was based on satellite (Dvorak) intensity estimates of 20 to 30 kt (10 to 15 m/sec) winds and decreasing sea-level pressure. The first warning followed on the 14th and was based on satellite imagery which indicated an increase in convection and upper-level organization. From the 15th through the 16th, Marge's mean track was west-northwestward as the forecasts followed the under-the-ridge scenario.

Based on the Dvorak analysis of satellite imagery at 150300Z, indicating a maximum wind of 35 kt (18 m/sec), Tropical Depression 25W was upgraded to tropical storm intensity (see Figure 3-25-1). The

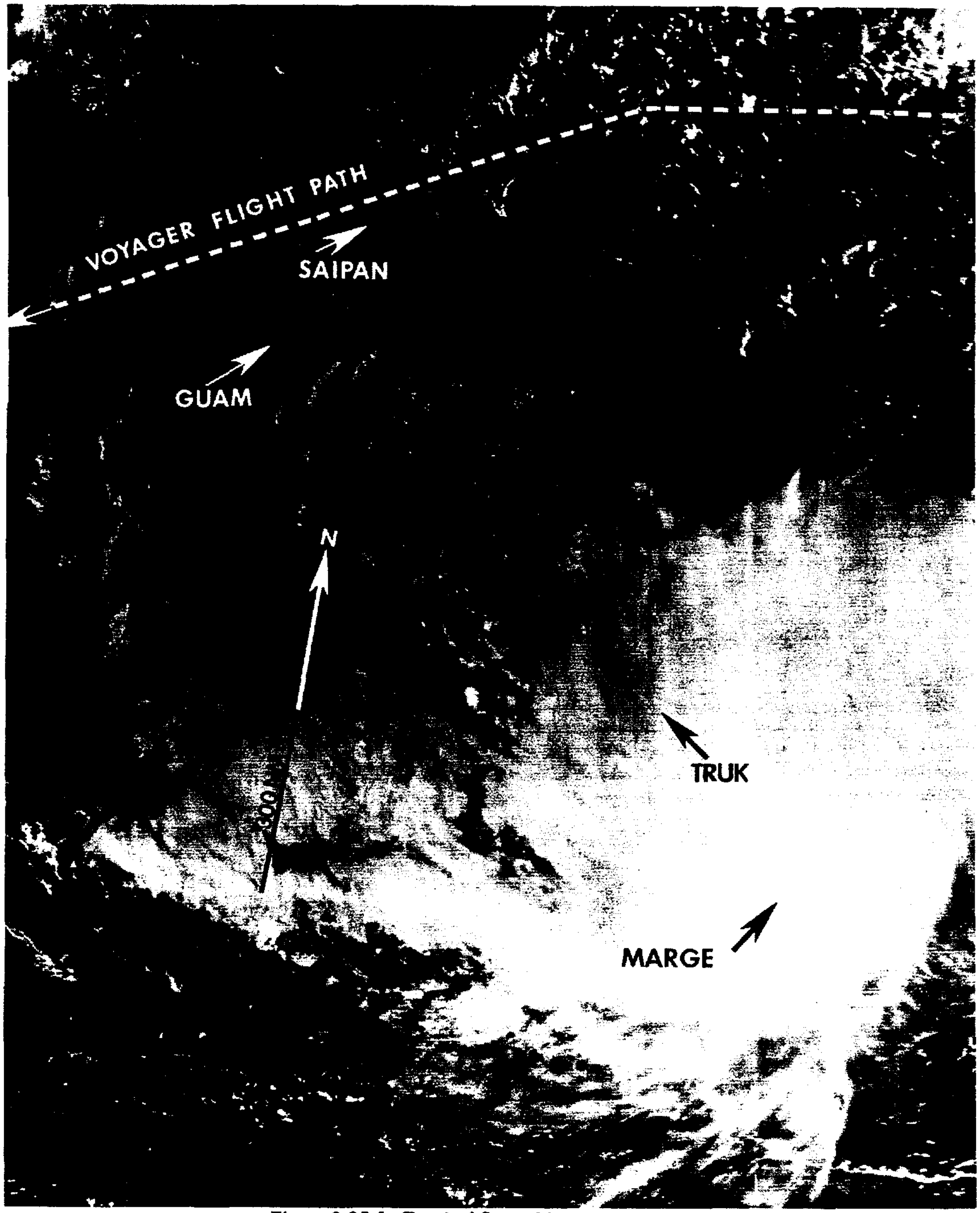


Figure 3-25-1. Tropical Storm Marge passed south of Guam just nine hours before Voyager left on the start of its record-setting flight (150517Z December NOAA visual imagery).

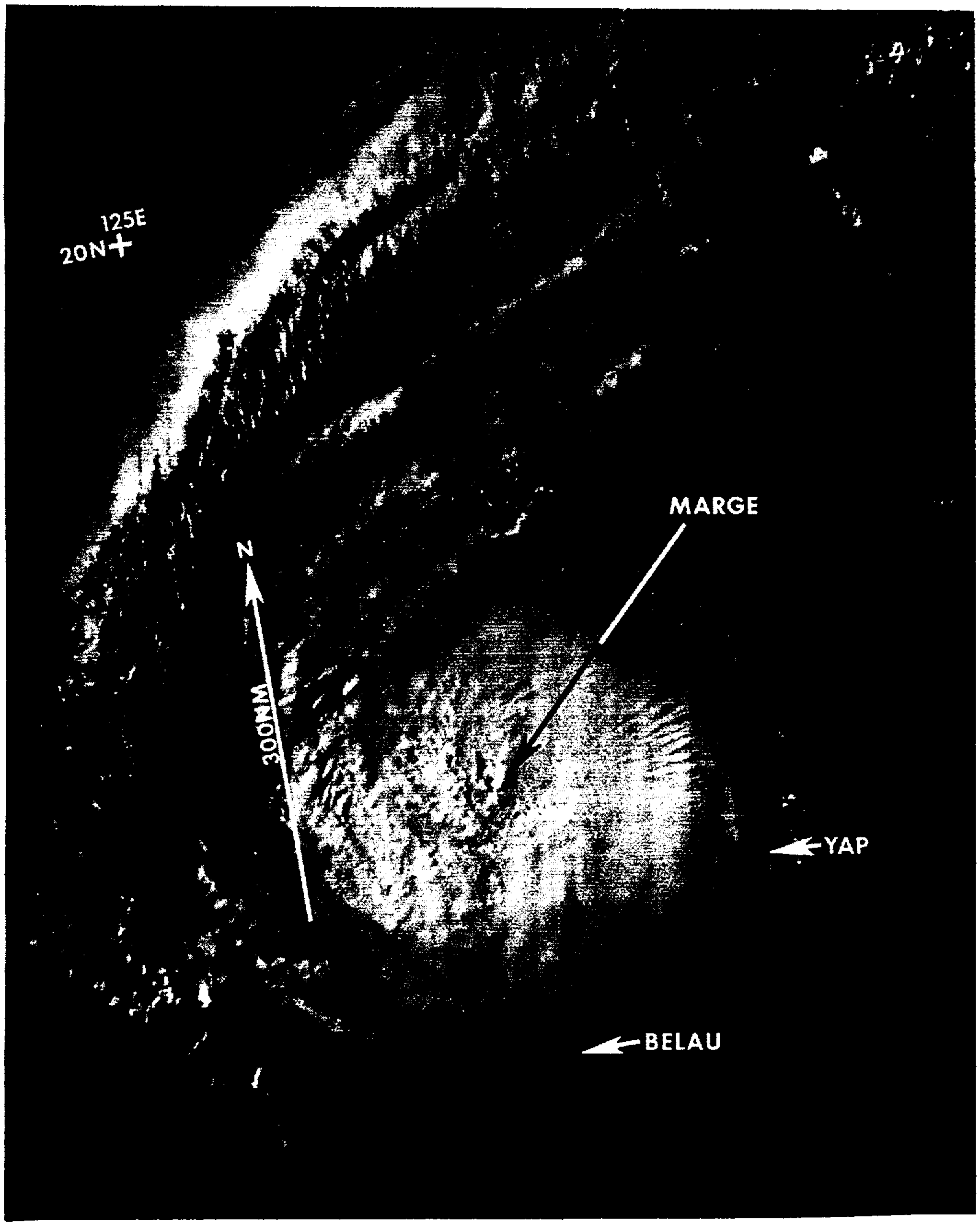


Figure 3-25-2. Marge six hours prior to reaching maximum intensity (192236Z December NOAA visual imagery).

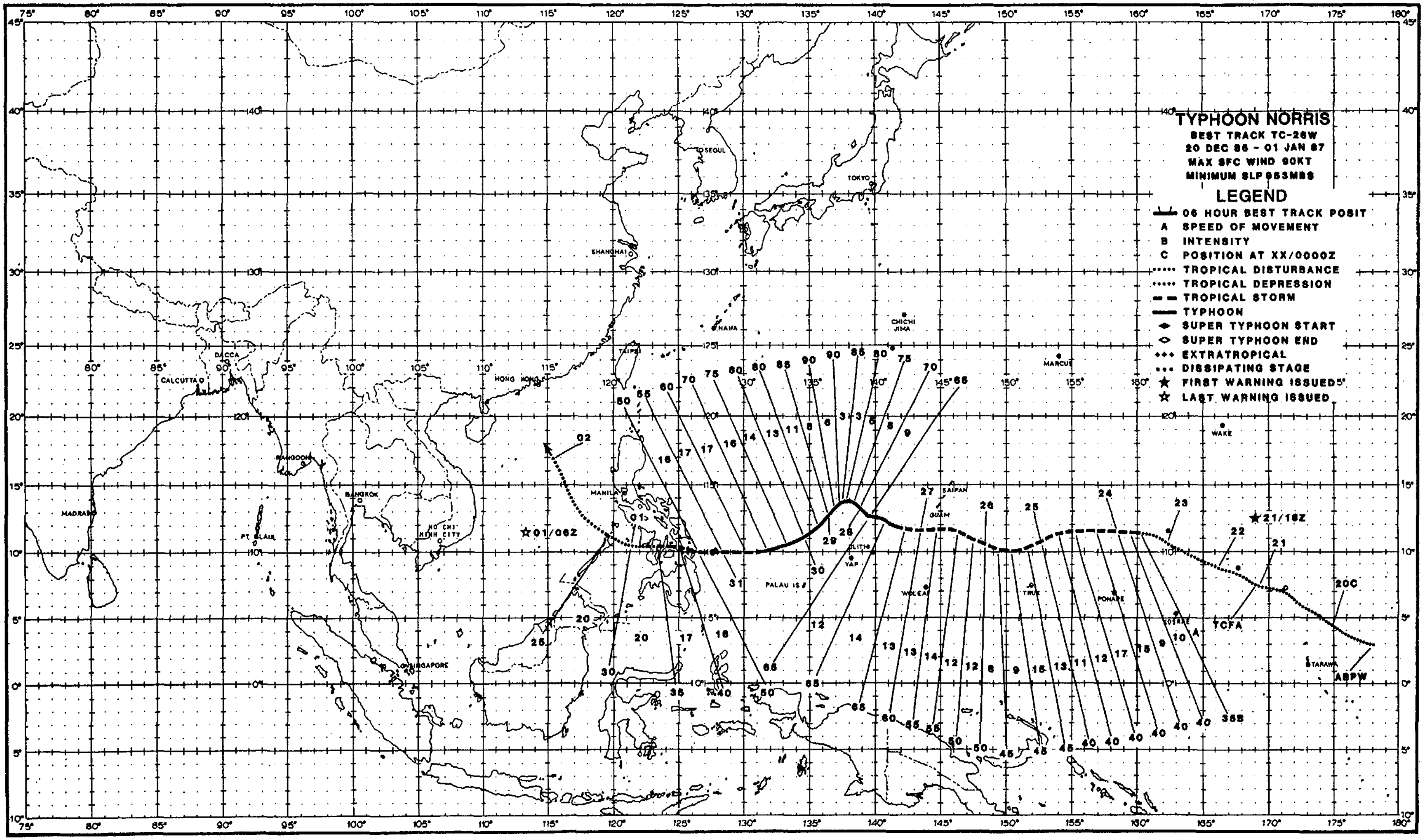
first aircraft reconnaissance mission on the 15th found a minimum sea-level pressure (MSLP) of only 1000 mb, 30 kt (15 m/sec) winds and did not close off a circulation. The next aircraft mission early on the 16th located a vortex with a MSLP of 996 mb and maximum surface winds of 60 kt (31 m/sec). The 161200Z warning upgraded the system to a typhoon.

The first forecast problem with Marge arose at 170000Z, when satellite fixes and aircraft reconnaissance observations began indicating that Marge was no longer moving as forecast toward the west-northwest, but in a more westerly direction. The computer prognostic guidance persisted with the now incorrect west-northwest movement. From 170000Z to 181800Z Marge moved due westward along the edge of the modifying polar air and passed 160 nm (296 km) south of Guam. No evacuations or significant damage to the island occurred.

The next forecast problem arose at 200000Z as Marge began slipping toward the west-southwest. JTWC's initial response was to consider the southward movement as a short-term event and the forecasts reflected this philosophy. This proved to be in error as Marge was forced further southwestward by a strong surge of polar air from the Asian landmass. Marge's unforecast movement in the Philippine Sea caused considerable concern for shipping. For example, the USS Proteus (AS 19) passed within 60 nm (111 km) of the center of Typhoon Marge, circled around its southwest quadrant and experienced winds of 50 kt (26 m/sec) at 210430Z. There was minimal damage to the ship and no personnel were injured. At that time Marge's maximum winds near the center were 80 kt (41 m/sec) and had decreased from a maximum of 95 kt (49 m/sec) earlier at 200600Z (see Figure 3-25-2).

After entering the Philippine Islands, the system weakened and changed course towards the northwest. It then tracked into the South China Sea and dissipated over water.

During Marge's lifetime, aviation history was being made. The Voyager, a light-weight, graphite fiber-bodied aircraft, piloted by Burt Rutan and Jeana Yeager, departed Edwards Air Force Base, California, on 15 December at 1402Z (14 December at 11:02 A.M. EST) in a record-setting attempt to circle the globe on a single tank of fuel. Initially, the flight plan routed Voyager south of the equator, passing just north of Australia on the Pacific portion of the journey. However, a very active monsoon trough present in the western North Pacific at this time forced a change in plans. Following coordination with JTWC, Voyager was rerouted north of the Mariana Islands. While it winged its way west, Marge continued to intensify. Although, at one point it appeared the Voyager might have to terminate its mission, the low-level inflow winds into Marge's center actually aided in the flight. Despite some moderate turbulence, as a consequence of flying between two of Marge's spiral bands to pick up increased tail winds of 35 kt (65 km/hr), Voyager was able to reduce fuel consumption and speed onward to complete a successful mission.



NOCC GUAM 3142/20 (NEW 5 - 80)

The final typhoon of 1986, Typhoon Norris, began as Typhoon Marge (25W) was moving through the Caroline Islands and south of Guam. Norris was first detected as a weak low-level circulation in the near-equatorial trough south of the Marshall Islands on 17 December. Initially, an anticyclone aloft at low latitudes near the dateline aided the development of Norris by providing a favorable low-shear environment.

First carried on the Significant Tropical Weather Advisory (ABPW PGTW) on 19 December at 0600Z, the disturbance drifted northwestward while its organization and convection remained minimal. On 20 December, the organization began to improve and at 210300Z, a Tropical Cyclone Formation Alert was issued.

The first warning was issued on 21 December at 1200Z on Tropical Depression 26W when Dvorak analysis of satellite reconnaissance indicated 30 kt (15 m/sec) winds were present (see Figure 3-26-1).

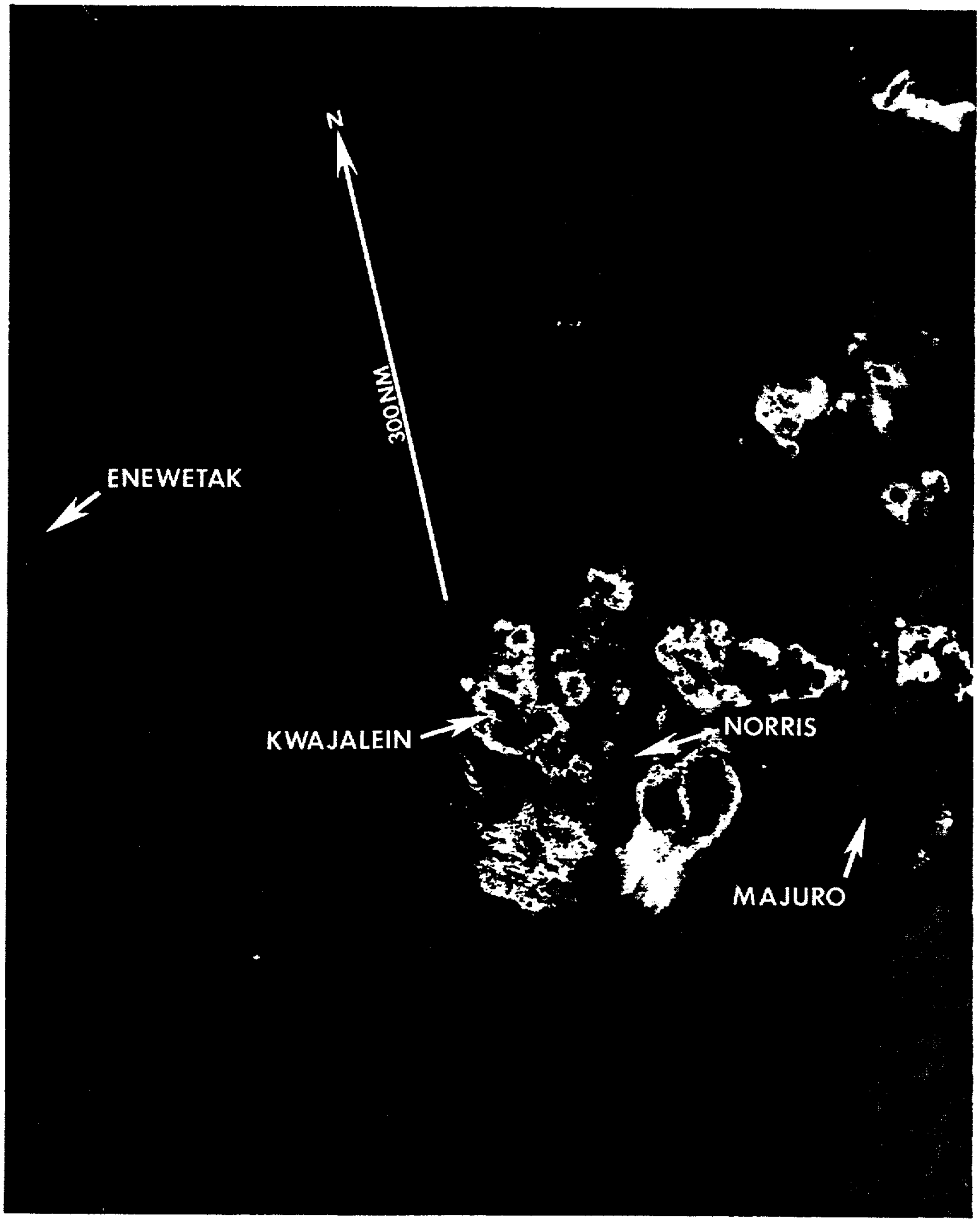


Figure 3-26-1: This enhanced infrared (EIR) image of the tropical disturbance, which ultimately became Typhoon Norris, shows it embedded in the near-equatorial trough (210756Z December DMSP infrared imagery).

Satellite imagery on 22 December revealed an exposed low-level circulation center with the convection displaced approximately 60 nm (111 km) to the west (Figure 3-26-2). Aircraft reconnaissance on the morning of 23 December located the low-level vortex. The Aerial Reconnaissance Weather Officer (ARWO) reported winds of 35 kt (18 m/sec) and a minimum sea-level pressure (MSLP) of 999 mb, which resulted in the upgrade to Tropical Storm Norris (26W) on the 230000Z warning.

From the time Norris began forming in the near-equatorial trough, the system moved steadily toward the northwest following the forecast under-the-ridge scenario. The movement toward the northwest was also influenced by the passage of a mid-latitude trough. On 23 December, the mid-latitude trough had moved to the east of the system and the subtropical ridge began to rebuild. Norris responded and moved westward. In addition, the low-level circulation center had just started to move under the convection (see Figure 3-26-3).

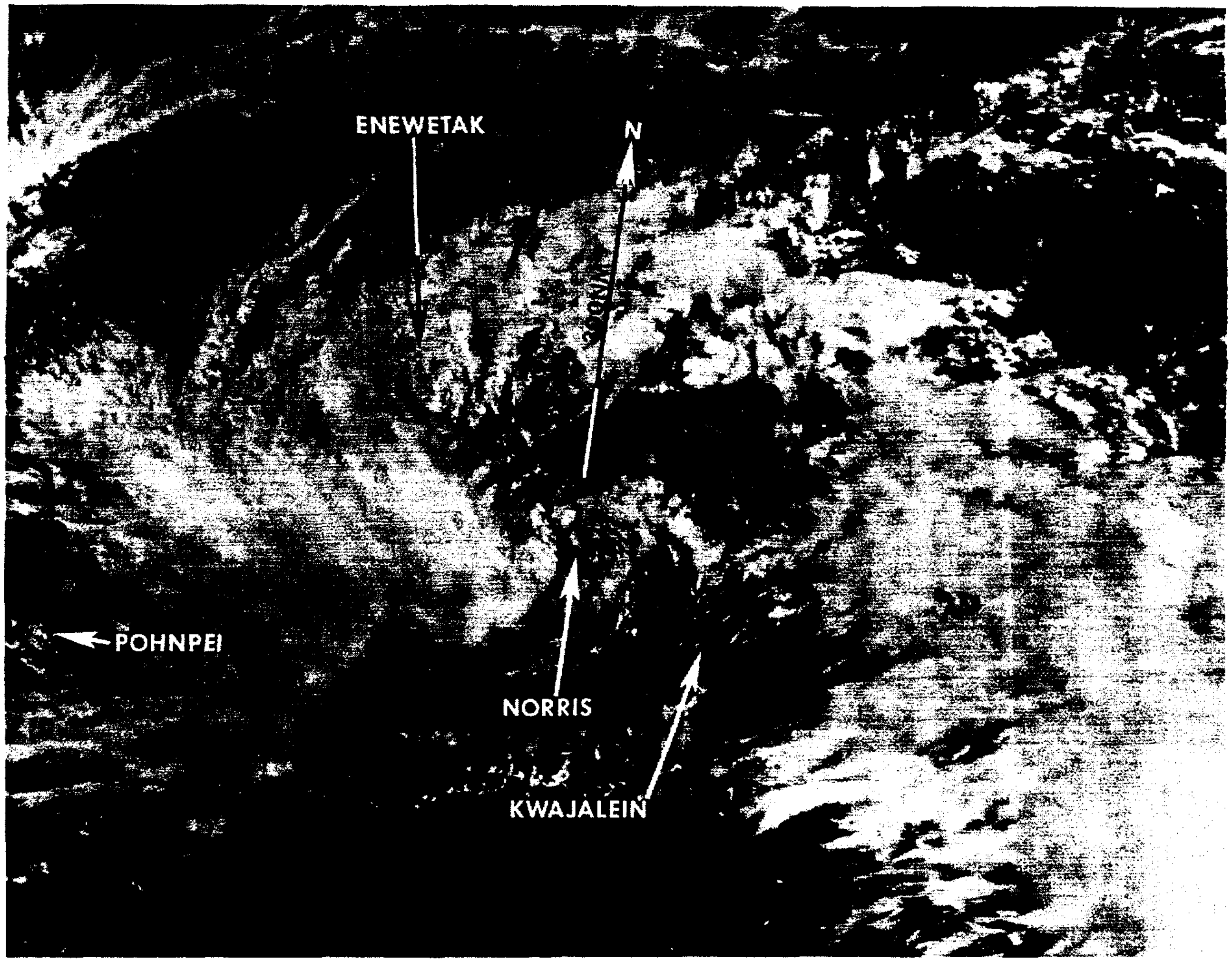


Figure 3-26-2: Vertical shear continues to force the convection towards the west of the low-level circulation center (220400Z December NOAA visual imagery).

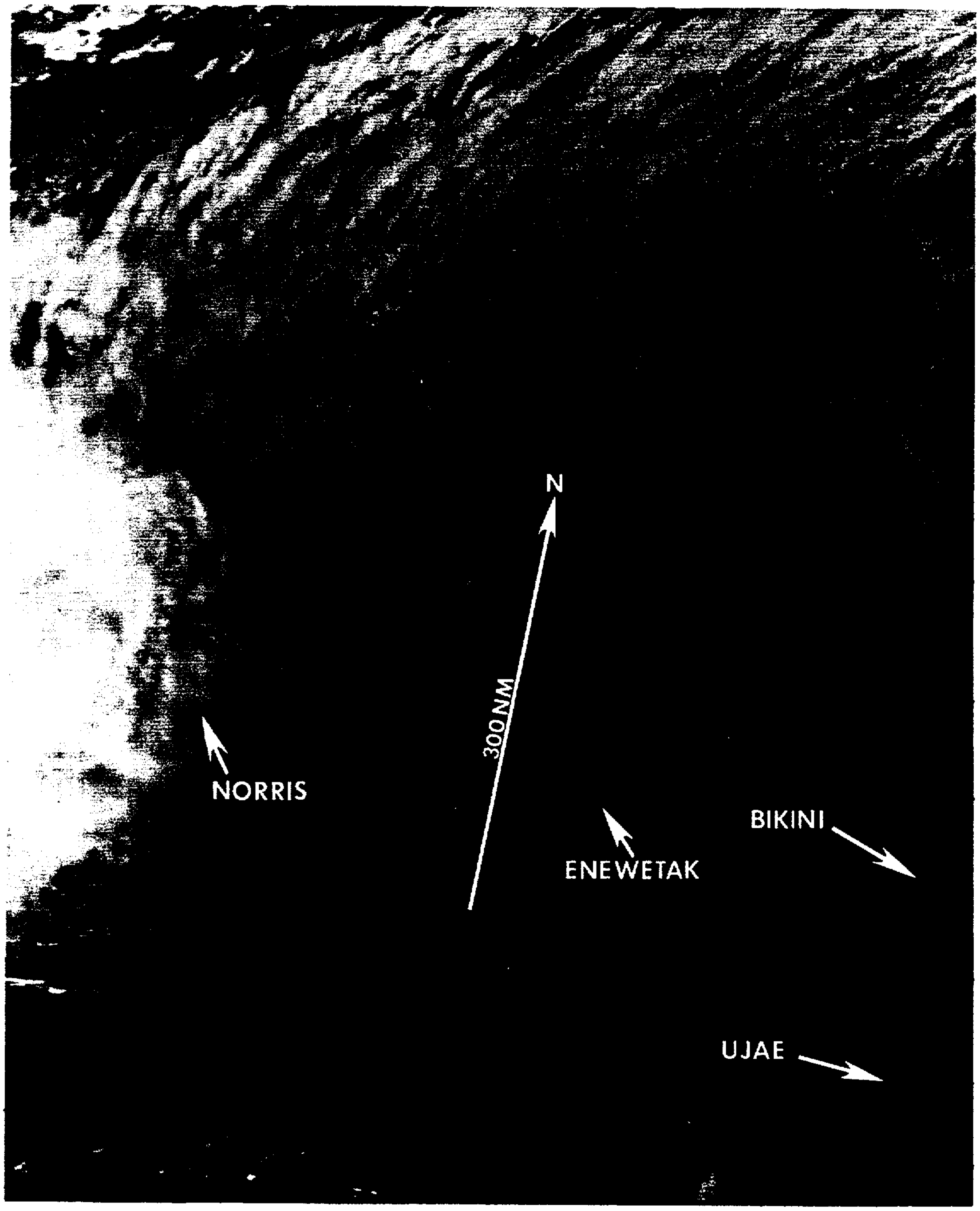


Figure 3-26-3. Tropical Storm Norris still struggling to get organized. The low-level circulation center is beginning to move under the convection (240338Z December NOAA visual imagery).

As the ridge continued to build, Norris began moving away from the forecast track and towards the west-southwest on Christmas Day (Figure 3-26-4). The forecast guidance from the dynamic One-Way Interactive Tropical Cyclone Model (OTCM) and persistence was for westward movement. Within 12-hours the southwestward drift stopped and Norris once again began moving toward the west-northwest. Aircraft reconnaissance on 25 December found the first indications of a developing elliptical-shaped eye.

As Norris moved towards the west-northwest, the system continued to intensify. Winds of typhoon intensity were forecast. Due to a mid-latitude frontal system moving off the Asian mainland, expected adjustment of the subtropical ridge, and an anticipated track change, officials in the southern Marianas braced for the worst. However, aircraft reconnaissance at approximately 261200Z found the movement more westward than west-northwestward. Over the next 12-hours residents of the southern Marianas Islands continued to wait and hope that Norris would miss them. Norris slipped by to the south, passing within 100 nm (185 km) of Guam. Guam experienced 50 kt (26 m/sec) winds and localized flooding, but damage was minimal.

After by-passing Guam and once again moving west-northwestward, Norris continued to develop (see Figure 3-26-5). Based on Dvorak intensity analysis of 65 kt (34 m/sec), Tropical Storm Norris was

Figure 3-26-4: Norris matures and moves toward the west-southwest on Christmas Day (250509Z December NOAA visual imagery).

Figure 3-26-5: Tropical Storm Norris, just prior to its being upgraded to a typhoon (270041Z December DMSP visual imagery).

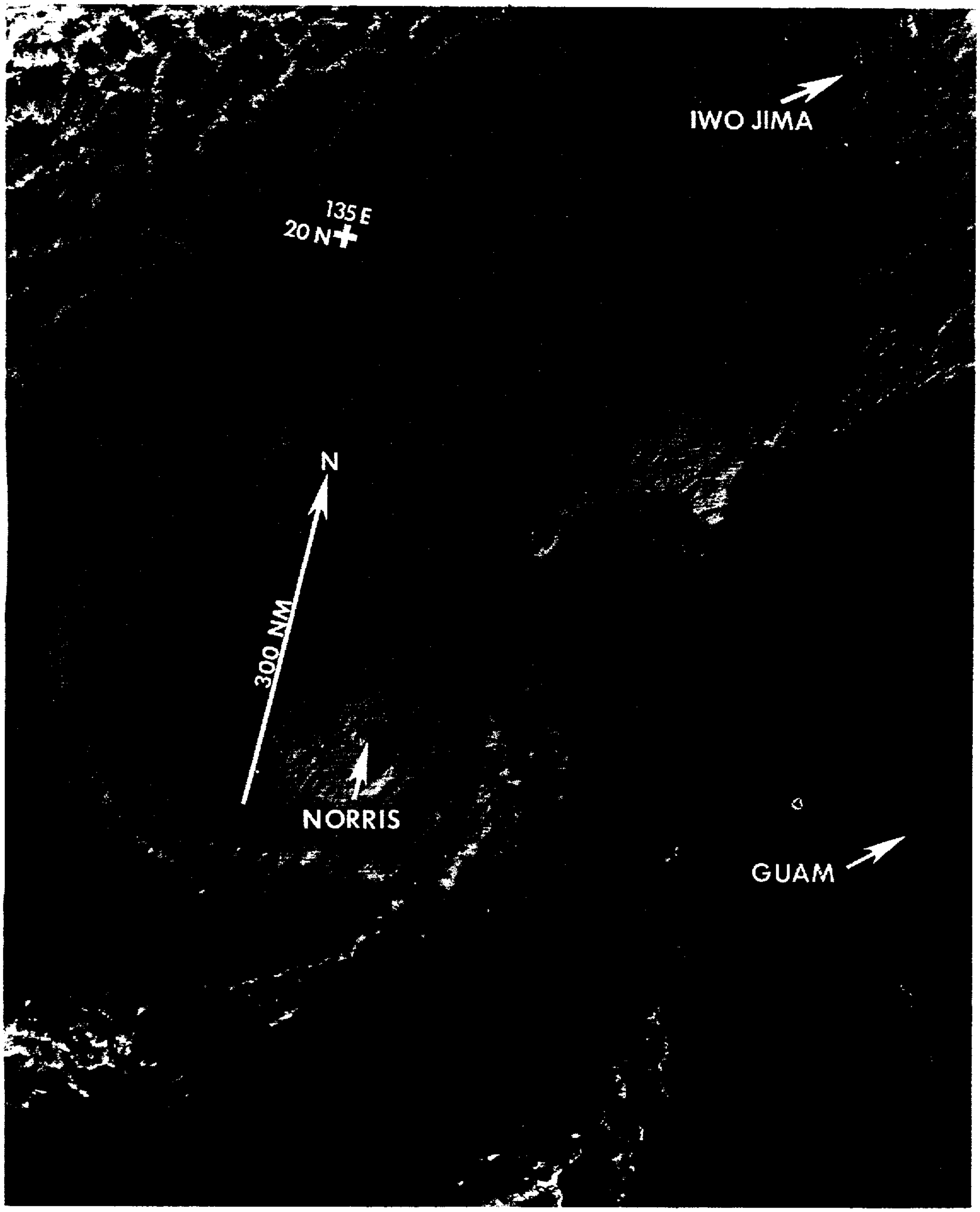


Figure 3-26-6. Typhoon Norris at maximum intensity. The forecast track, until this time, indicated that Norris would recurve and become extratropical (290000Z December DMSP visual imagery).

upgraded to Typhoon Norris at 270600Z. Aircraft reconnaissance at 271101Z reported an eye and a MSLP of 984 mb.

Norris continued moving northwestward toward the weakness in the ridge induced by the passage of a mid-latitude trough moving off the Asian mainland. Previous forecasts had indicated continued movement toward the west-northwest; however, as the mid-latitude trough moved further south and east, Norris' forecast track, starting with the 280600Z warning, was altered to indicate recurvature and extratropical transition.

By 290000Z, the trough moved east and Norris reached maximum intensity (see Figure 3-26-6). The ARWO on the reconnaissance fix mission earlier, at 282103Z, observed 89 kt (46 m/sec) maximum surface winds and a MSLP of 953 mb. Norris, which was caught along the edge of the modifying polar air and northwesterly flow in the Philippine Sea, abruptly changed course and moved southward for 36-hours. Once again the southwesterly course was not forecast or addressed beforehand by the OTCM guidance.

At 301200Z, Norris' track changed to due west as it headed towards the central Philippine Islands (see Figure 3-26-7). After being downgraded to tropical storm intensity at 301800Z, Norris moved into the South China Sea and continued to weaken. By 010300Z January, Norris was further downgraded to a tropical depression. By that time, strong upper-level southeasterly flow had exposed the low-level circulation center. Norris dissipated over water in the South China Sea on January 2nd.

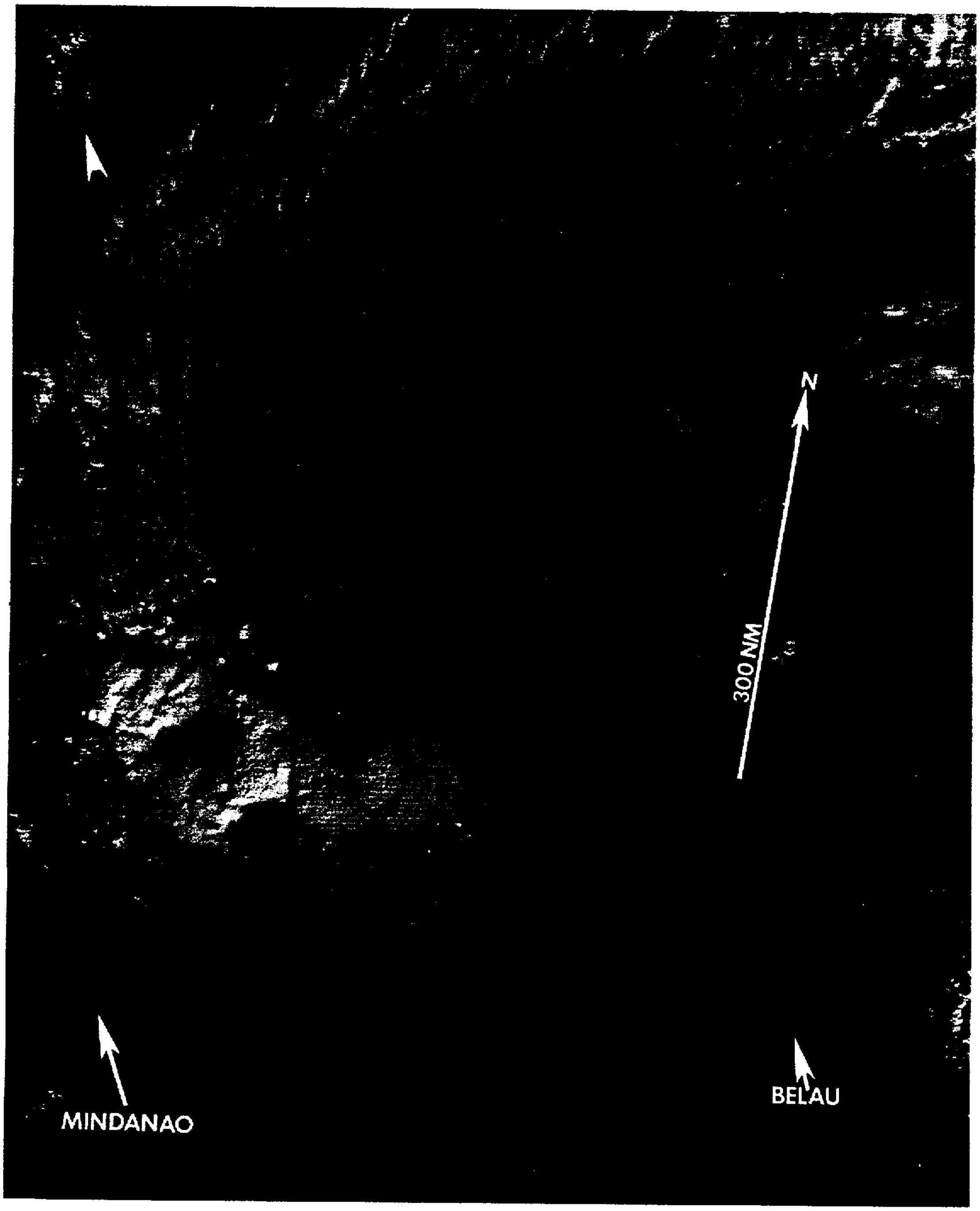


Figure 3-26-7: Tropical Storm Norris approaching the Philippine Islands (310101Z December DMSP visual imagery).

3. NORTH INDIAN OCEAN TROPICAL CYCLONES

Tropical cyclone activity in the North Indian Ocean was slightly below normal. Three significant tropical cyclones, all of tropical storm intensity, developed as compared to the climatological mean of four. These systems occurred in the spring and fall transition seasons, which normally encompasses the peak of the activity. Tables 3-5 and 3-6 provide a summary of information for 1986 and comparison with earlier years.

TABLE 3-5.

NORTH INDIAN OCEAN
1986 SIGNIFICANT TROPICAL CYCLONES

TROPICAL CYCLONE	PERIOD OF WARNING	CALENDAR DAYS OF WARNING	NUMBER OF WARNINGS ISSUED	MAXIMUM SURFACE WINDS-KT (M/S)	ESTIMATED MSLP - MB
TC 01B	07 JAN - 11 JAN	5	17	45 (23)	991
TC 02B	09 NOV	1	2	50 (26)	989
TC 03A	09 NOV - 11 NOV	3	9	45 (23)	990
	1986 TOTALS:	8 *	28		

* OVERLAPPING DAYS INCLUDED ONLY ONCE IN SUM.

TABLE 3-6. FREQUENCY OF NORTH INDIAN OCEAN TROPICAL CYCLONES

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1971*	-	-	-	-	-	0	0	0	0	1	1	0	2
1972*	0	0	0	1	0	0	0	0	2	0	1	0	4
1973*	0	0	0	0	0	0	0	0	0	1	2	1	4
1974*	0	0	0	0	0	0	0	0	0	0	1	0	1
1975	1	0	0	0	2	0	0	0	0	1	2	0	6
1976	0	0	0	1	0	1	0	0	1	1	0	1	5
1977	0	0	0	0	1	1	0	0	0	1	2	0	5
1978	0	0	0	0	1	0	0	0	0	1	2	0	4
1979	0	0	0	0	1	1	0	0	2	1	2	0	7
1980	0	0	0	0	0	0	0	0	0	0	1	1	2
1981	0	0	0	0	0	0	0	0	0	1	1	1	3
1982	0	0	0	0	1	1	0	0	0	2	1	0	5
1983	0	0	0	0	0	0	0	1	0	1	1	0	3
1984	0	0	0	0	1	0	0	0	0	1	2	0	4
1985	0	0	0	0	2	0	0	0	0	2	1	1	6
1986	1	0	0	0	0	0	0	0	0	0	2	0	3
(1975-1986) AVERAGE	0.2	0.0	0.0	0.1	0.8	0.3	0.0	0.1	0.3	1.0	1.4	0.3	4.4
CASES	2	0	0	1	9	4	0	1	3	12	17	4	53

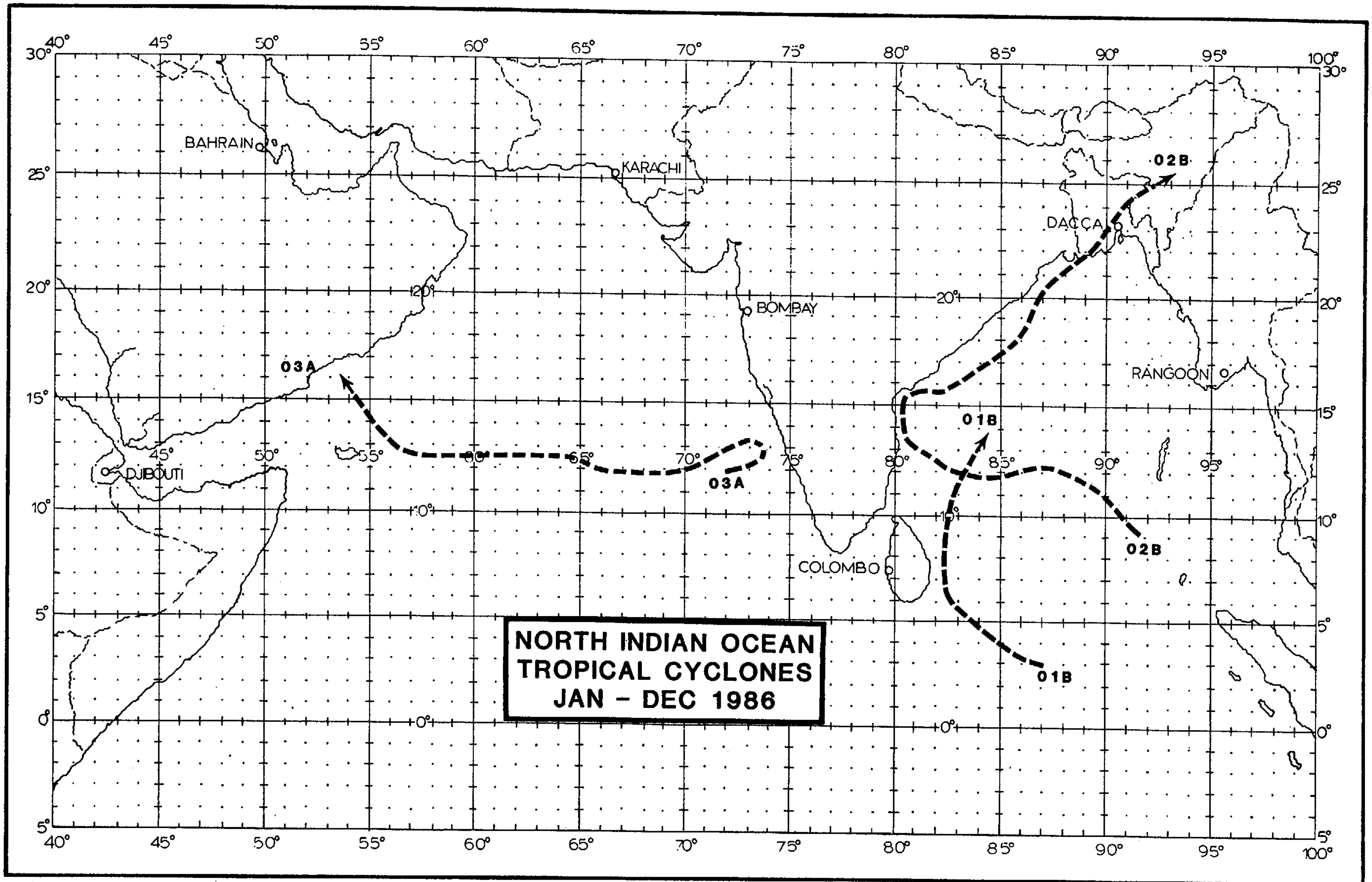
* JTWC WARNING RESPONSIBILITY BEGAN ON 4 JUN 71 FOR THE BAY OF BENGAL, EAST OF 90 DEGREES EAST LONGITUDE. AS DIRECTED BY CINCPAC, JTWC ISSUED WARNINGS ONLY FOR THOSE TROPICAL CYCLONES THAT DEVELOPED OR TRACKED THROUGH THAT PORTION OF THE BAY OF BENGAL. COMMENCING WITH THE 1975 TROPICAL CYCLONE SEASON, JTWC'S AREA OF RESPONSIBILITY WAS EXTENDED WESTWARD TO INCLUDE THE WESTERN PORTION OF THE BAY OF BENGAL AND THE ENTIRE ARABIAN SEA.

FORMATION ALERTS: 3 OF 9 FORMATION ALERTS DEVELOPED INTO SIGNIFICANT TROPICAL CYCLONES. TROPICAL CYCLONE FORMATION ALERTS WERE ISSUED FOR ALL OF THE SIGNIFICANT TROPICAL CYCLONES THAT DEVELOPED IN 1986.

WARNINGS: NUMBER OF CALENDAR WARNING DAYS: 8

NUMBER OF CALENDAR WARNING DAYS WITH TWO TROPICAL CYCLONES: 1

NUMBER OF CALENDAR WARNING DAYS WITH THREE TROPICAL CYCLONES: 0



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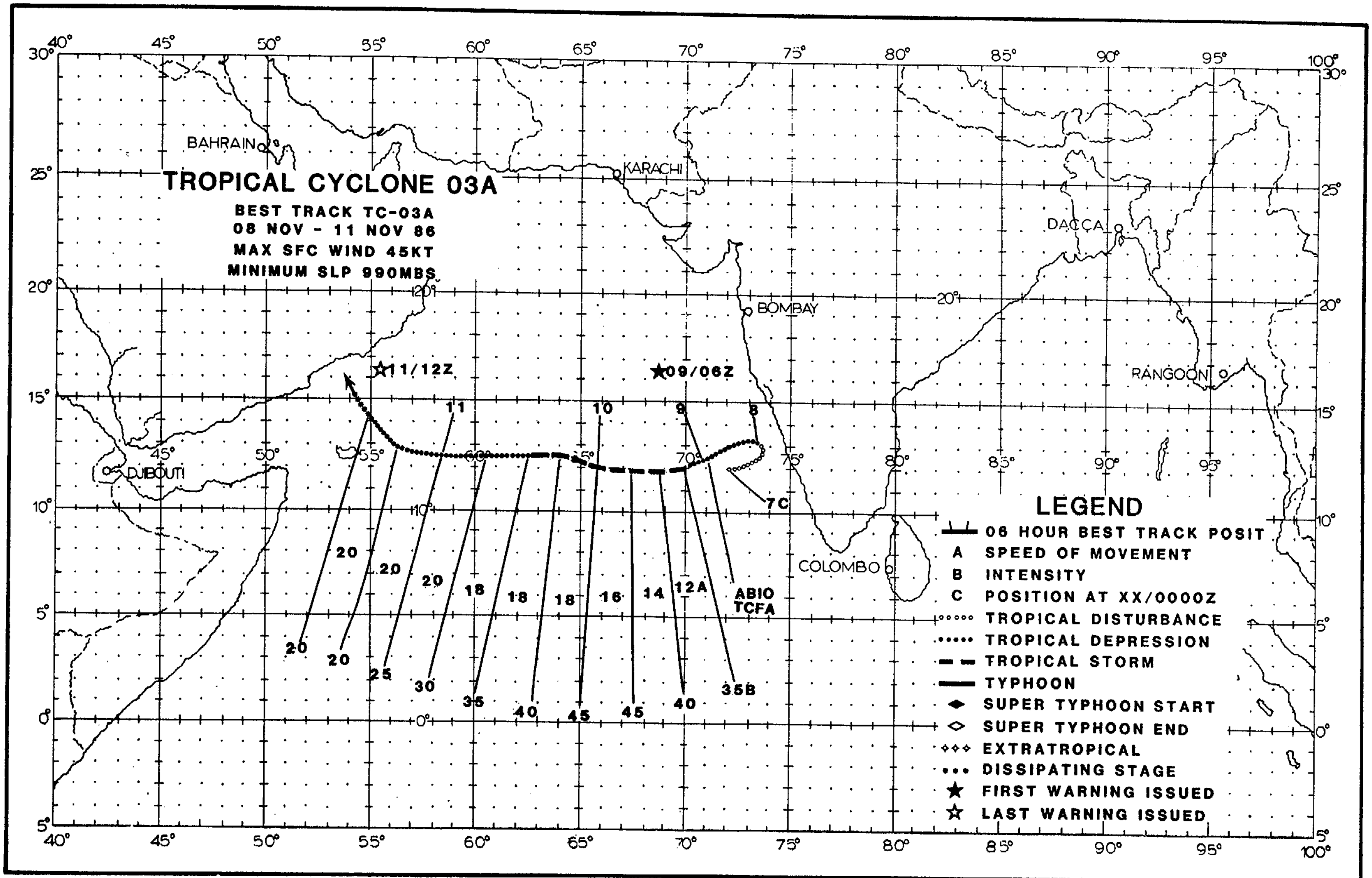
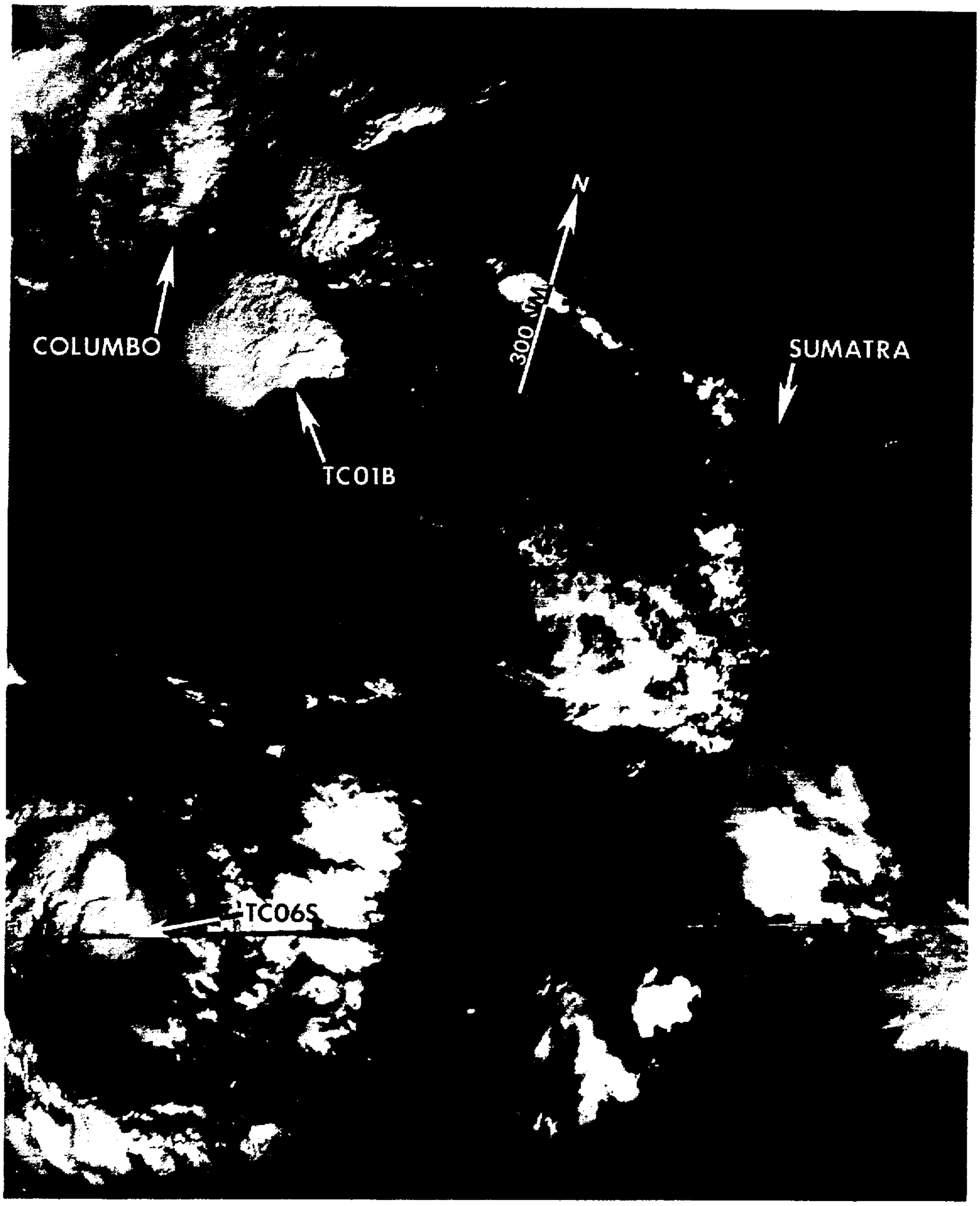
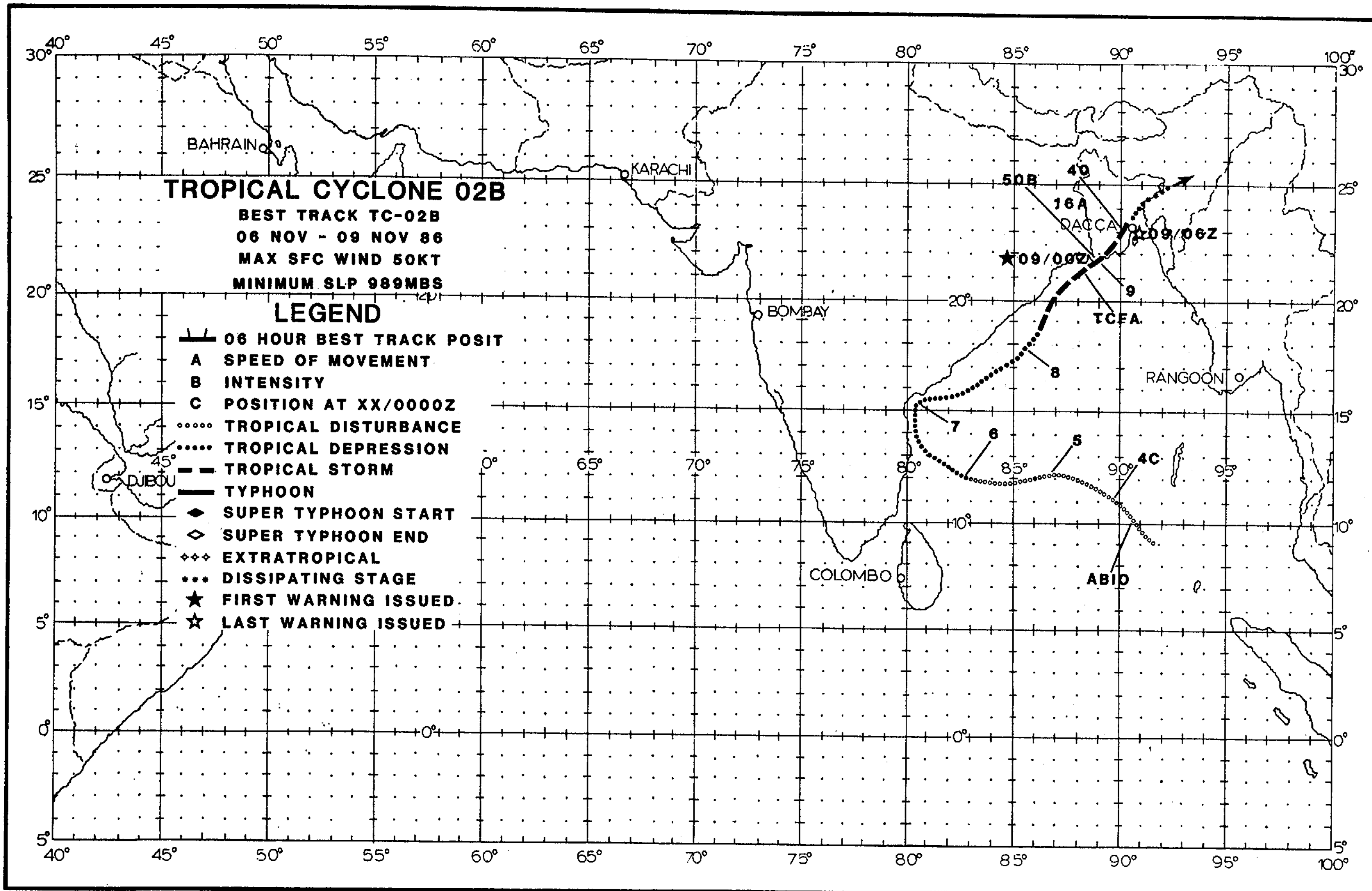


FWC/JTWC GUAM 3142/62 (NEW 2-76)

Figure 3-01B-1. The partially exposed low-level center of Tropical Cyclone 01B was located southeast of Sri Lanka on the 8th of January. The system was being sheared by upper-level flow associated with Tropical Cyclone 04S to the south, which was at typhoon intensity (080404Z January DMSP visual imagery).





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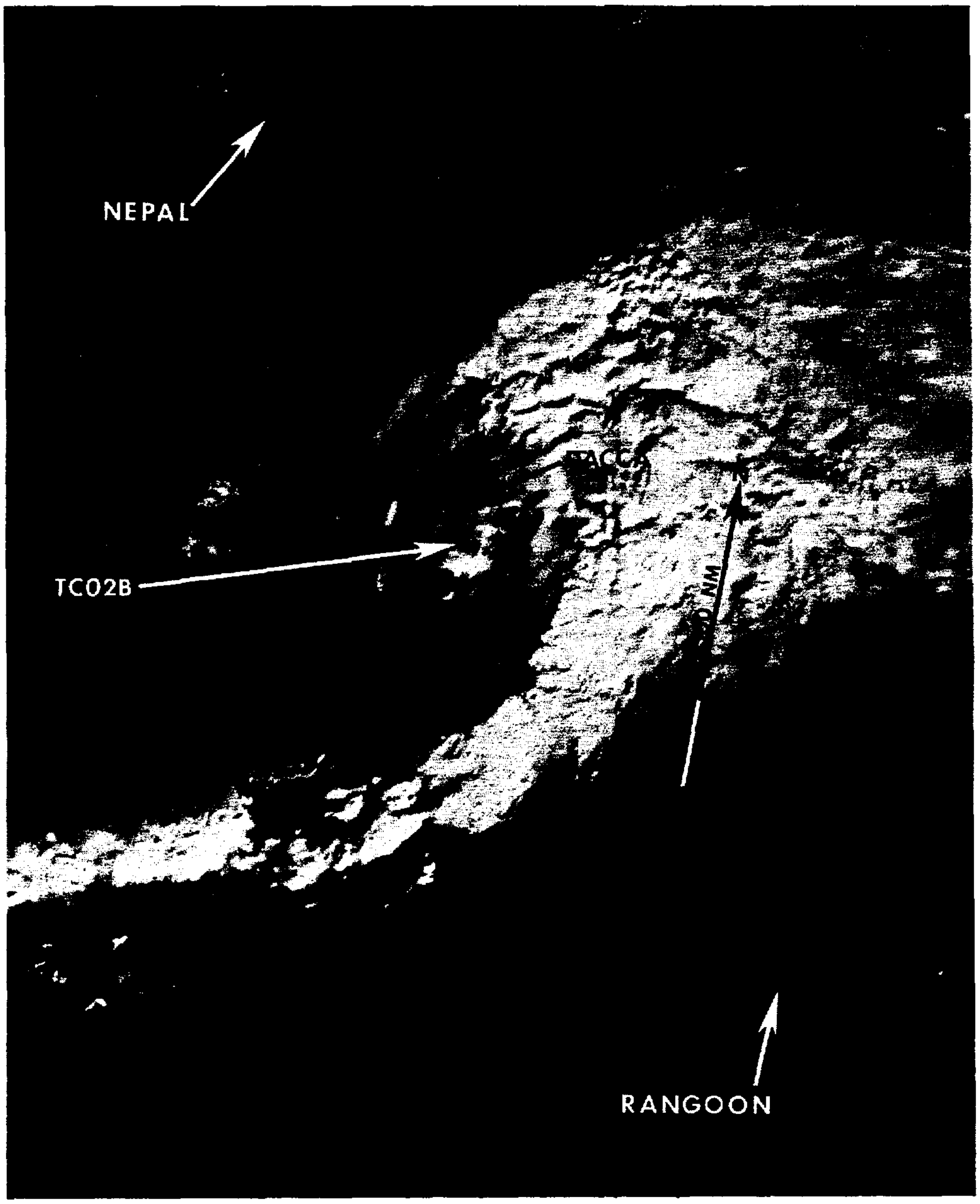
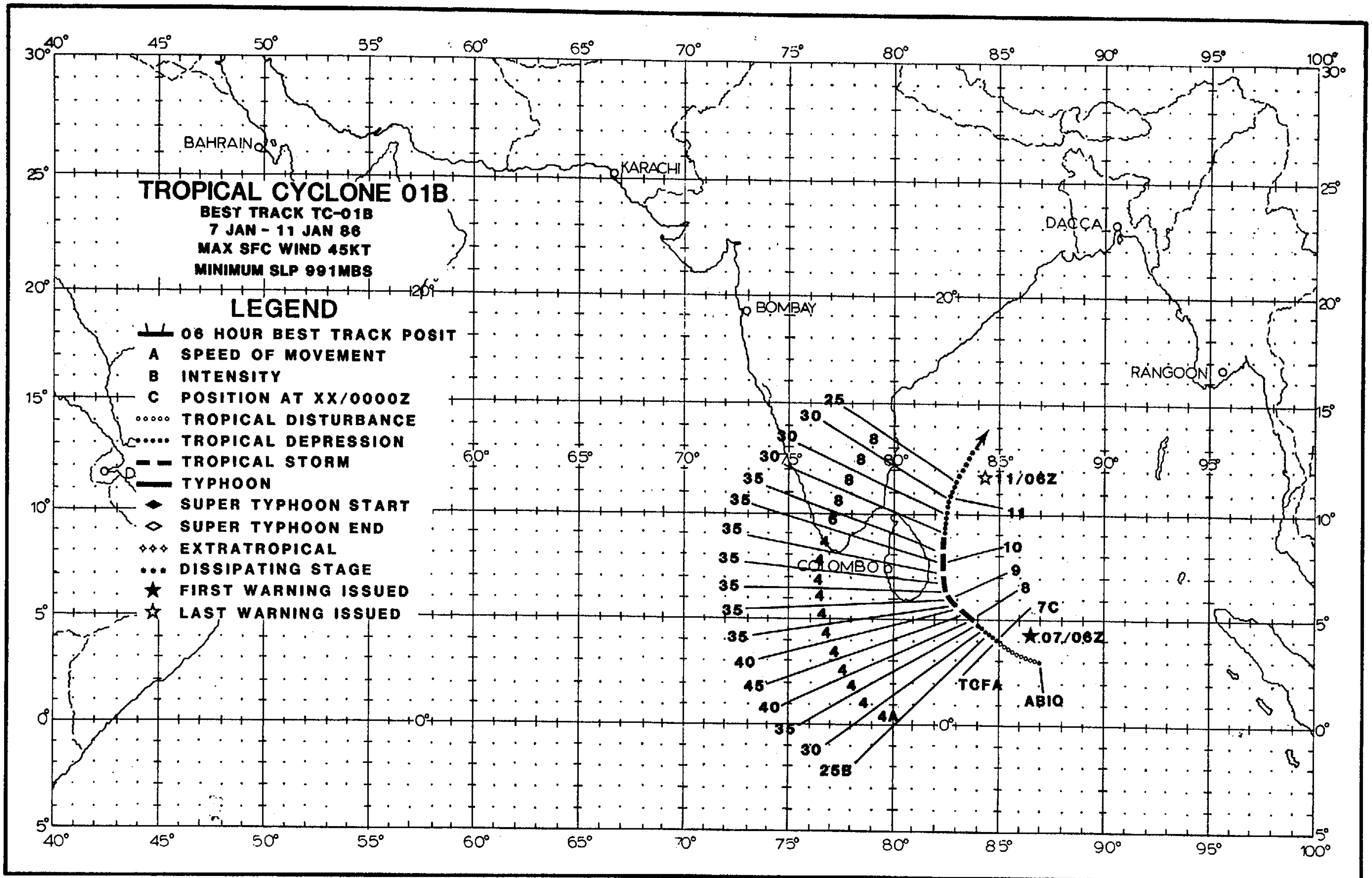


Figure 3-02B-1. Tropical Cyclone 02B was the only tropical cyclone to develop in the Bay of Bengal during the fall transition season. Two warnings were issued on the system. It began on 3 November as a disturbance in the Bay of Bengal approximately 60 nm (111 km) west of the Nicobar Islands. Over the next three days the disturbance continued to slowly intensify as it tracked toward the west. The disturbance then curved northward and skirted the Indian coast. Post analysis indicated tropical storm intensity had been attained 12-hours prior to the issuance of the first warning at 090000Z. Tropical Cyclone 02B continued on its northeastward track and immediately made landfall at the Ganges River Delta in Bangladesh at 090000Z. The maximum intensity of 50 kt (26 m/sec) was reached just prior to striking the coast. After landfall, Tropical Cyclone 02B weakened rapidly. Damage to the coastal villages in Bangladesh was substantial. Officials reported 11 dead and at least fifty others missing as a result of heavy flooding and wind gusts of up to 65 kt (33 m/sec). The image above shows Tropical Cyclone 02B three hours after landfall (090331Z November DMSP visual imagery).



FWC/JTWC GUAM 3142/62 (NEW 2-76)

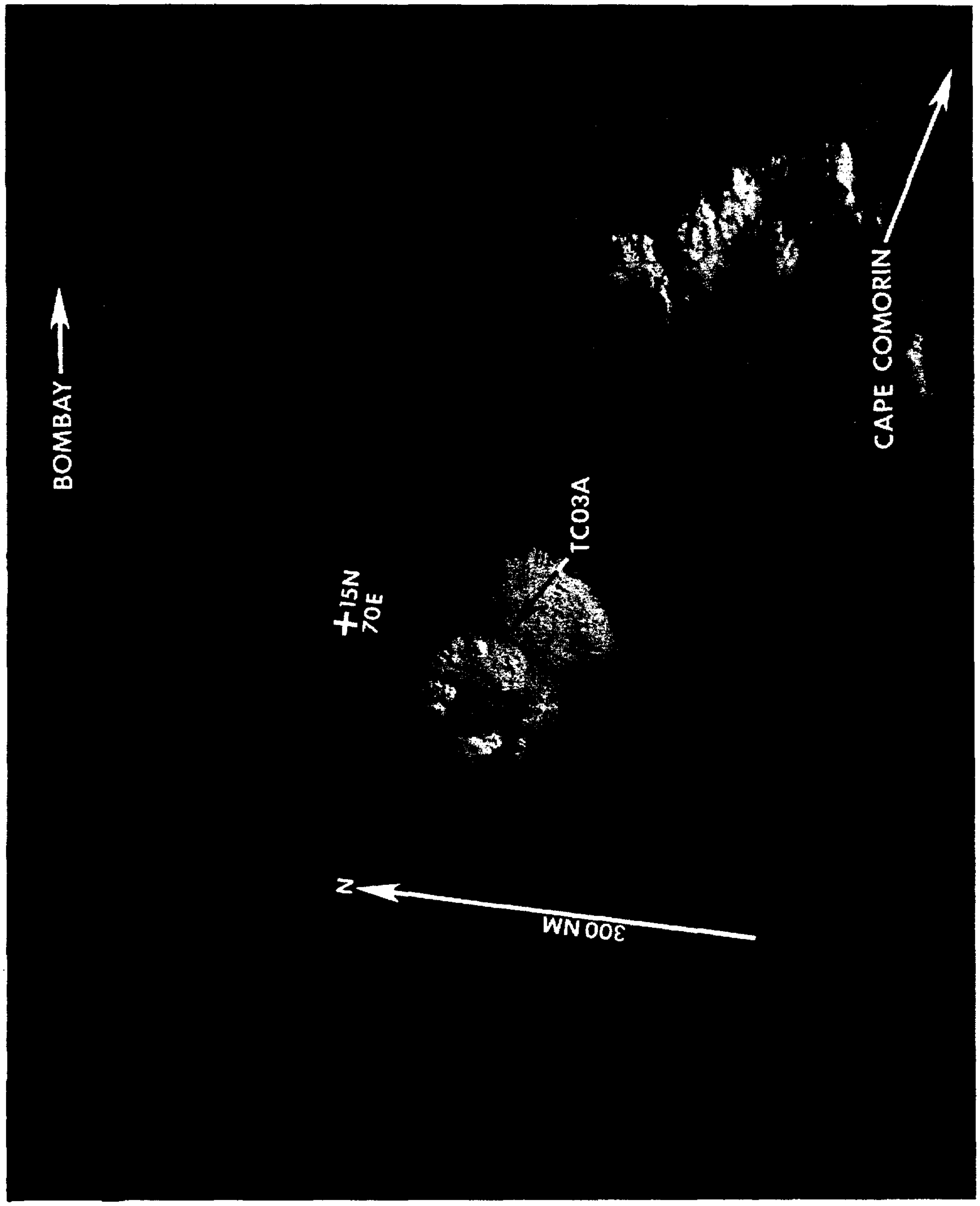


Figure 3-03A-1. Tropical Cyclone 03A was the only significant tropical cyclone to develop in the Arabian Sea in 1986. It was first carried on the Significant Tropical Cyclone Weather Advisory (ABIO PGTW) on November 1st when the area rapidly improved in organization. On November 2nd, the first Tropical Cyclone Formation Alert (TCFA) was issued. Shear over the disturbance suppressed development by separating the low-level circulation center and the upper-level anticyclone. On 6 November, the TCFA was cancelled after both the convection and organization had decreased. Satellite imagery indicated the anticyclone was no longer evident and the upper-level flow was unidirectional over the disturbance. However, on 8 November, redevelopment occurred. Dvorak intensity analysis of satellite imagery, at 080532Z, indicated winds of 35 kt (18 m/sec). Satellite imagery 12-hours later indicated winds of 45 kt (23 m/sec). JTWC issued its first warning on Tropical Cyclone 03A at 090600Z. Four hours after the first warning was issued, satellite imagery once again indicated shear over the cyclone with a separation of 75 nm (139 km) between the low-level and upper-level circulation centers. JTWC issued the final warning at 111200Z, after Tropical Cyclone 03A lost all of its convection. Tropical Cyclone 03A dissipated over water. There were no reports of damage. The satellite picture shows Tropical Cyclone 03A in the Arabian Sea one hour before the first warning was issued (090512Z November DMSP visual imagery).

CHAPTER IV - SUMMARY OF SOUTH PACIFIC AND SOUTH INDIAN OCEAN TROPICAL CYCLONES

1. GENERAL

Last year (1985) was the first year that southern hemisphere tropical cyclones were included in the Annual Tropical Cyclone Report. In retrospect, the JTWC area of responsibility (AOR) was expanded on 1 October 1980 -- to include the southern hemisphere from 180 degrees Longitude westward to the east coast of Africa. Details on tropical cyclones in this region for July 1980 to June 1982 are contained in Diercks et al, (1982). For the July 1982 through June 1984 period, reference the NOCC/JTWC TECH NOTE 86-1. As in earlier reports, data on tropical cyclones forming in, or moving into, the South Pacific Ocean east of 180 degrees Longitude, which is the Naval Western Oceanography Center (NAVWESTOCEANCEN) AOR, are included for completeness.

JTWC provides the sequential numbering for all South Pacific and South Indian Ocean significant tropical cyclones. The current convention (as stated in USCINCPACINST 3140.1 (series)) for labelling tropical cyclones that develop in the South Indian Ocean (west of 135 degrees East Longitude) is to add the suffix "S" to the assigned tropical cyclone number, while those originating in the South Pacific Ocean (east of 135 degrees East Longitude) receive a "P" suffix. The "P" suffix also applies to significant tropical cyclones which form east of 180 degrees Longitude in the South Pacific Ocean. Also, it should be noted that to encompass the southern hemisphere tropical cyclone season, which occurs from January through April, the limits of each tropical cyclone year are defined as 1 July to 30 June. Thus, the 1986 southern hemisphere tropical cyclone year is from 1 July 1985 to 30 June 1986. (This is in contrast to the convention of labelling northern hemisphere tropical cyclones which is based on the calendar year - 1 January to 31 December - to include the seasonal activity from May through December.)

TABLE 4-1. SOUTH PACIFIC AND SOUTH INDIAN OCEANS 1986 SIGNIFICANT TROPICAL CYCLONES

TROPICAL CYCLONE	PERIOD OF WARNING	CALENDAR DAYS OF WARNING	NUMBER OF WARNINGS ISSUED	MAXIMUM SURFACE WINDS-KT (M/S)	ESTIMATED MSLP - MB	BEST TRACK DISTANCE TRAVELED NM (KM)
01S ----------	23 SEP - 29 SEP	7	14	40 (21)	994	1470 (2722)
02S NICHOLAS	27 NOV - 07 DEC	11	21	75 (39)	967	1436 (2659)
03P ----------	15 DEC - 16 DEC	2	3	35 (18)	997	1093 (2024)
04S DELIFININA	07 JAN - 16 JAN	10	19	110 (57)	933	1399 (2591)
05S COSTA	07 JAN - 16 JAN	10	18	70 (36)	972	1684 (3119)
06S ----------	08 JAN - 10 JAN	3	5	50 (26)	987	553 (1024)
07S OPHELIA	11 JAN - 13 JAN	3	5	35 (18)	997	317 (587)
08S ----------	11 JAN - 14 JAN	4	7	35 (18)	997	900 (1667)
09S HECTOR	19 JAN - 24 JAN	5	10	45 (23)	991	447 (828)
10S PANCHO	21 JAN - 22 JAN	2	3	35 (18)	990	352 (652)
11P VERNON	23 JAN - 25 JAN	2	4	50 (26)	987	901 (1669)
12P WINIFRED	29 JAN - 01 FEB	4	7	90 (46)	953	526 (974)
13S ERINESTA	31 JAN - 10 FEB	11	21	115 (59)	927	2282 (4226)
14S FILOMENA	06 FEB - 10 FEB	5	9	55 (28)	984	1020 (1889)
15P IMA	06 FEB - 14 FEB	9	18	75 (39)	967	2161 (4002)
16P JUNE	07 FEB - 09 FEB	2	5	55 (28)	984	825 (1528)
17P KELI	08 FEB - 10 FEB	3	5	45 (23)	991	1551 (2872)
18S RHONDA	19 FEB - 20 FEB	2	4	55 (28)	984	855 (1583)
19S GISTA	19 FEB - 25 FEB	6	12	85 (44)	958	1558 (2885)
20S SELWYN	23 FEB - 25 FEB	3	6	55 (28)	984	707 (1309)
21S TIFFANY	27 FEB - 01 MAR	2	4	35 (18)	997	628 (1163)
22S VICTOR	03 MAR - 09 MAR	7	13	105 (54)	938	1715 (3176)
23P LUSI	03 MAR - 08 MAR	6	12	45 (23)	991	1527 (2828)
24P ALFRED	03 MAR - 04 MAR	2	2	30 (15)	1000	1781 (3298)
24P ALFRED*	06 MAR - 09 MAR	3	7	45 (23)	991	---- ----
25S HONORININA	09 MAR - 16 MAR	8	16	110 (57)	933	2741 (5076)
25S HONORININA*	19 MAR - 20 MAR	2	3	35 (18)	997	---- ----
26S IARIMA	13 MAR - 15 MAR	3	4	35 (18)	997	317 (587)
27S JEFOTRA	26 MAR - 01 APR	7	14	105 (54)	938	2114 (3915)
28S KRISOSTOMA^	08 APR - 13 APR	5	10	75 (39)	967	1363 (2524)
29P MARTIN	10 APR - 14 APR	5	11	75 (39)	967	1401 (2595)
30P ----------	16 APR - 16 APR	1	2	30 (15)	1000	760 (1408)
31S MANU	23 APR - 26 APR	4	7	70 (36)	972	546 (1011)
32S BILLY#	05 MAY - 12 MAY	8	14	95 (49)	948	1534 (2841)
33P NAMU	17 MAY - 23 MAY	6	13	85 (44)	958	1444 (2674)
	1986 TOTALS:	173	328			

* REGENERATED
^ TROPICAL CYCLONE 28S (KRISOSTOMA) WAS ALSO NAMED ALISON.
\# TROPICAL CYCLONE 32S (BILLY) WAS ALSO NAMED LILA.

NOTE: NAMES OF CYCLONES GIVEN BY REGIONAL WARNING CENTERS (NANDI, BRISBANE, DARWIN, PERTH AND MAURITIUS) AND APPENDED TO JTWC WARNINGS, WHEN AVAILABLE.

2. SOUTH PACIFIC AND SOUTH INDIAN OCEAN TROPICAL CYCLONES

The 1986 year (1 July 1985 through 30 June 1986) was unusually active, with 33 tropical cyclones (see Table 4-1) reaching warning status. This did not exceed the total of 35 tropical cyclones for 1985 (1 July 1984 - 30 June 1985) which was the busiest year to date for JTWC. Three tropical cyclones occurred in the South Pacific, east of 165 degrees East Longitude, which is only half the long-term mean. The Australian area (105 to 165 degrees East Longitude) accounted for 16 tropical cyclones compared to the climatological mean of 10.3 - five more than normal. Fourteen tropical cyclones developed in the South Indian Ocean, which is nearly six more than the long-term mean of 8.4 cyclones (see Tables 4-2 and 4-3).

Meteorological satellite surveillance of tropical cyclones has been updating climatologies since the early 1960s. (This meteorological watch from space detects tropical cyclones that might have previously gone undetected over the conventional data sparse oceanic areas.) Thus, tropical cyclone climatologies should benefit from increased surveillance from space in some areas, for example, the South Indian Ocean.

Caveat: Intensity estimates for southern hemisphere tropical cyclones are derived primarily from satellite imagery evaluation (Dvorak, 1984) and from intensity estimates reported by other regional centers. Only, in very rare instances are the intensity estimates based on surface observational data. Estimates of the minimum sea-level pressure are usually derived from the Atkinson and Holliday (1977) relationship between the maximum sustained one-minute surface wind and the minimum sea-level pressure (Table 4-4). This relationship has been shown to be representative for tropical cyclones in the western North Pacific and is also used by the Australian regional warning centers to provide intensity estimates. However, since these pressure estimates are usually based on wind intensities that were derived from interpretation of satellite imagery, considerable caution should be exercised when using these resultant pressure values in future tropical cyclone work.

TABLE 4-2. FREQUENCY OF CYCLONES BY MONTH AND YEAR

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
(1959 - 1978) AVERAGE*	----	----	----	0.4	1.5	3.6	6.1	5.8	4.7	2.1	0.5	----	24.7
1981	0	0	0	1	3	2	6	5	3	3	1	0	24
1982	1	0	0	1	1	3	9	4	2	3	1	0	25
1983	1	0	0	1	1	3	5	6	3	5	0	0	25
1984	1	0	0	1	2	5	5	10	4	2	0	0	30
1985	0	0	0	0	1	7	9	9	6	3	0	0	35
1986	0	0	1	0	1	1	9	9	8	4	2	0	33
(1981 - 1986) AVERAGE	0.5	0.0	0.2	0.7	1.5	3.5	7.2	7.2	4.3	3.3	0.7	0.0	28.7
CASES	3	0	1	4	9	21	43	43	26	20	4	0	172

* (GRAY, 1979)

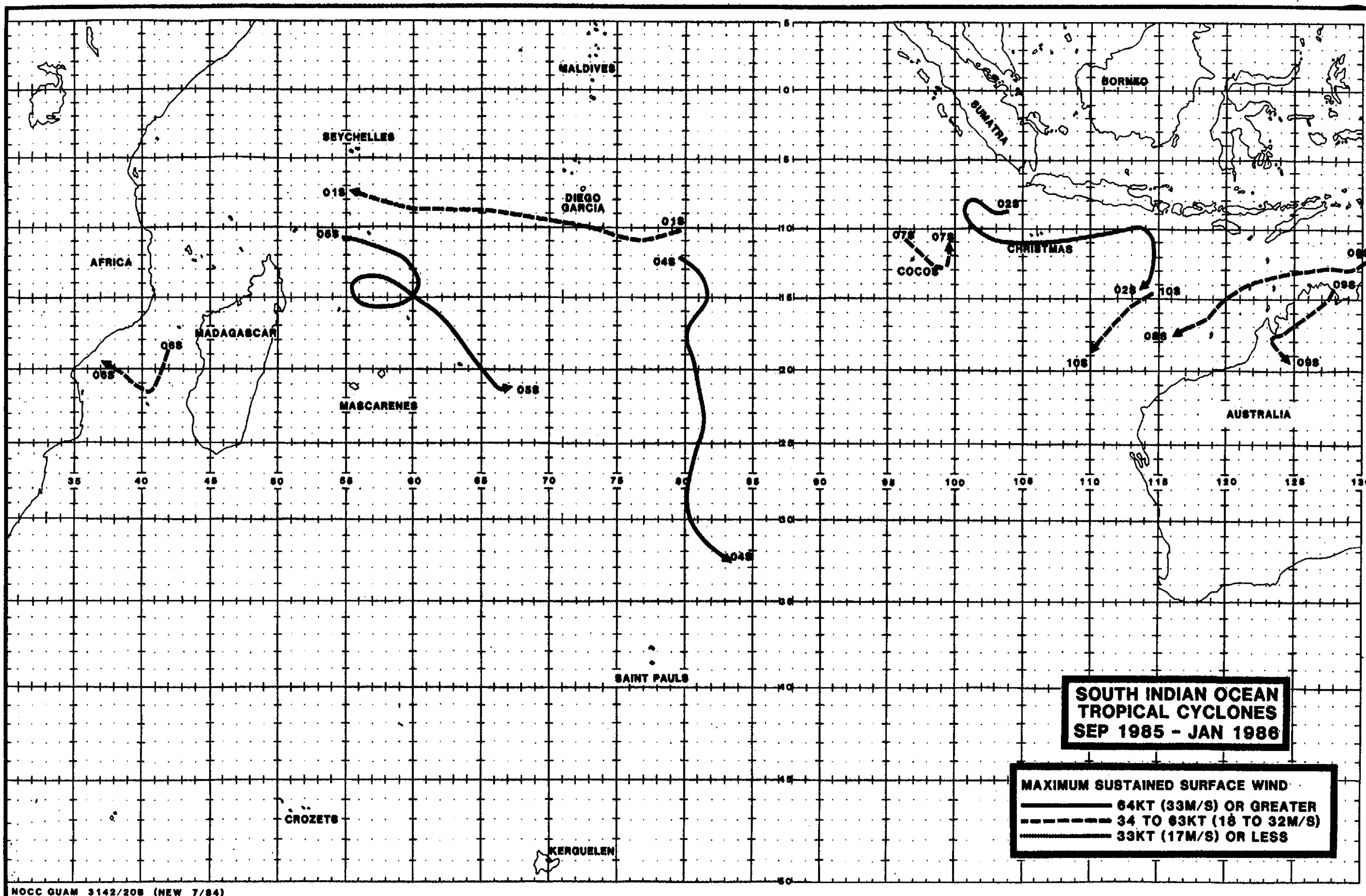
TABLE 4-3. YEARLY VARIATION OF TROPICAL CYCLONES BY OCEAN BASIN

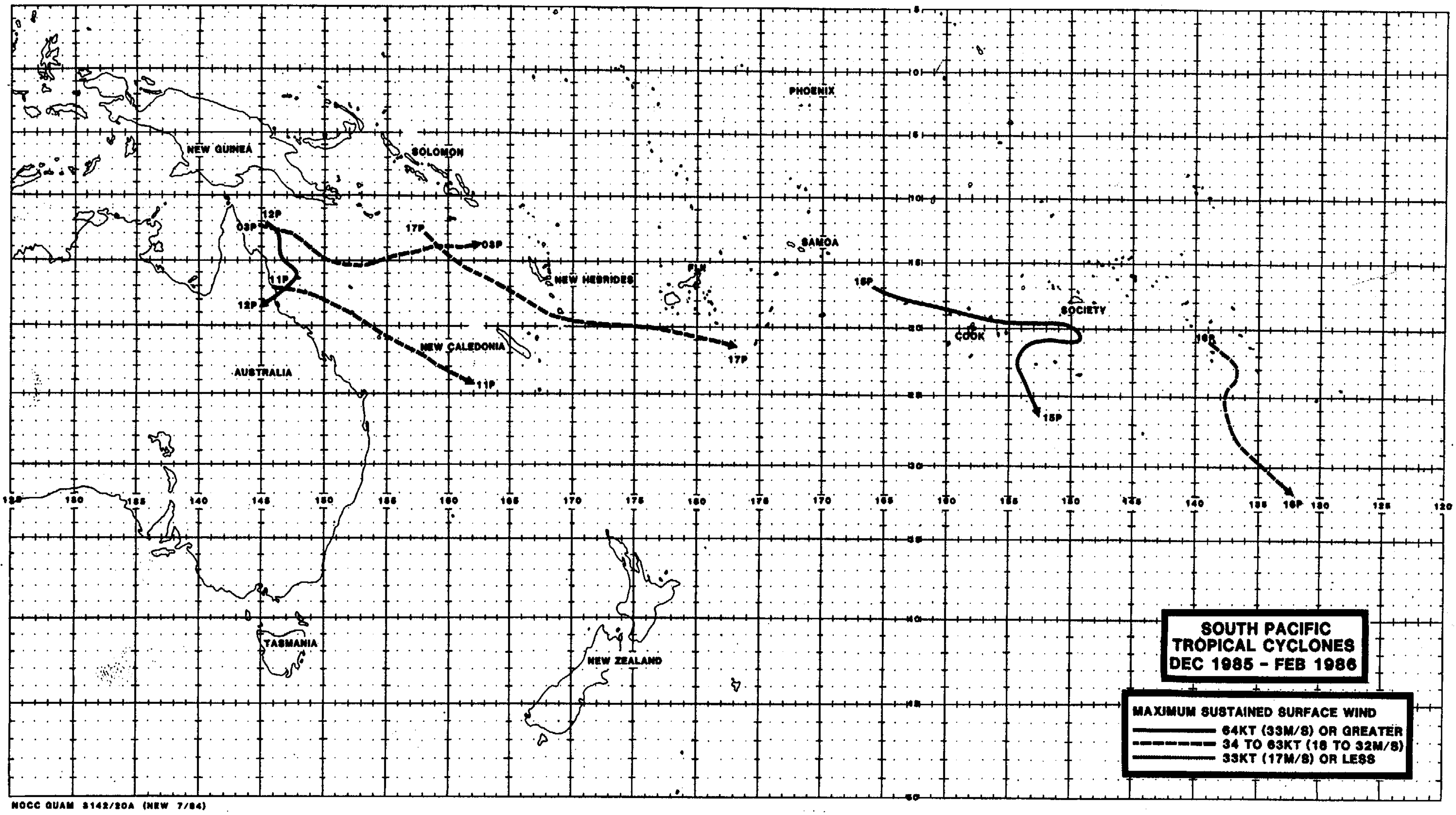
YEAR	(105E WESTWARD) SOUTH INDIAN	(105E-165E) AUSTRALIAN	(165E EASTWARD) SOUTH PACIFIC	TOTAL
(1959 - 1978) AVERAGE*	8.4	10.3	5.9	24.6
----	---	---	---	---
1981	13	8	3	24
1982	12	11	2	25
1983	7	6	12	25
1984	14	14	2	30
1985	14	15	6	35
1986	14	16	3	33
(1981 - 1986) AVERAGE	12.3	11.7	4.7	28.7
CASES	74	70	28	172

* (GRAY, 1979)

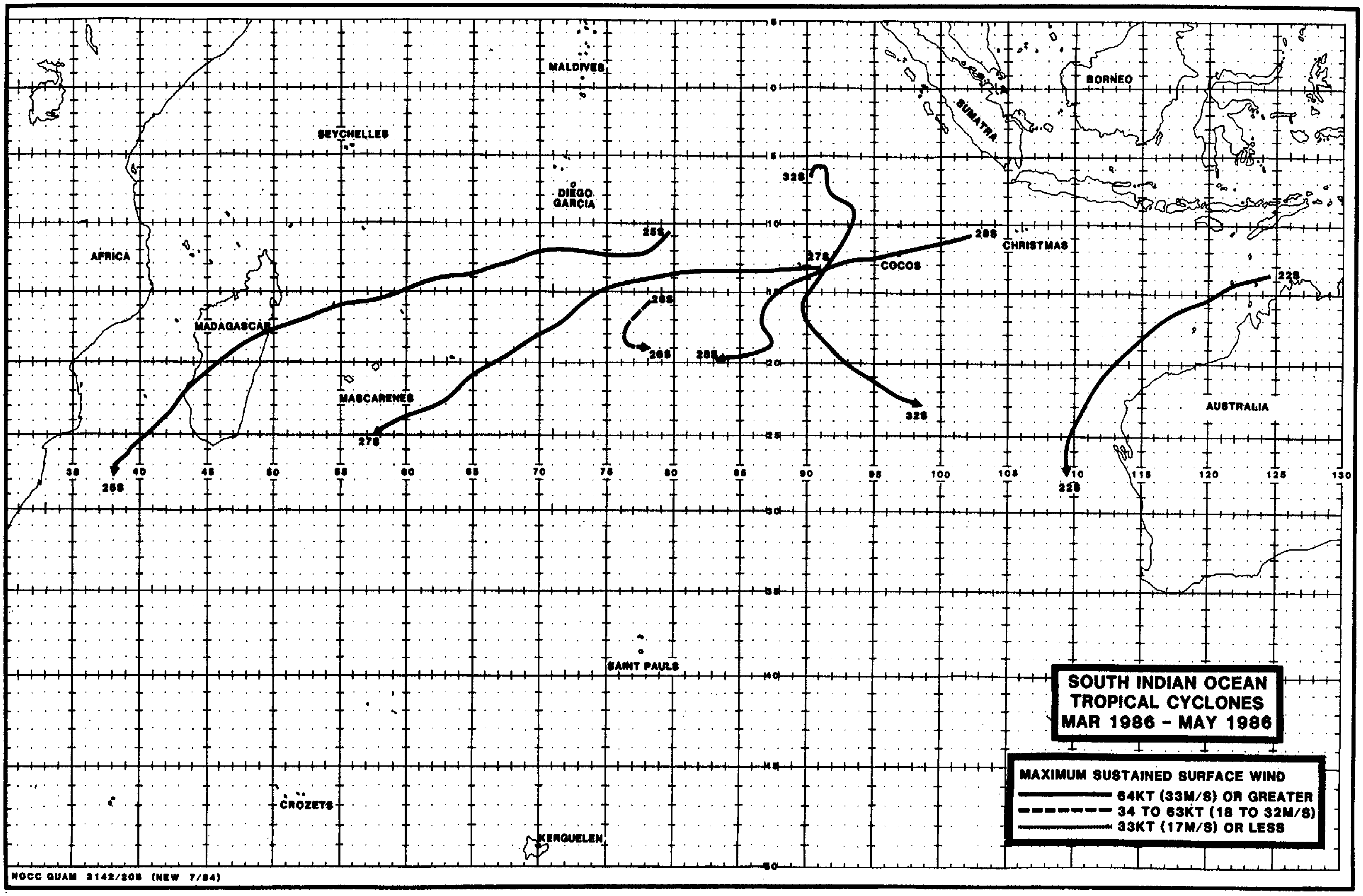
TABLE 4-4. MAXIMUM SUSTAINED SURFACE WINDS VERSUS MINIMUM SEA-LEVEL PRESSURE (ATKINSON AND HOLLIDAY, 1977)

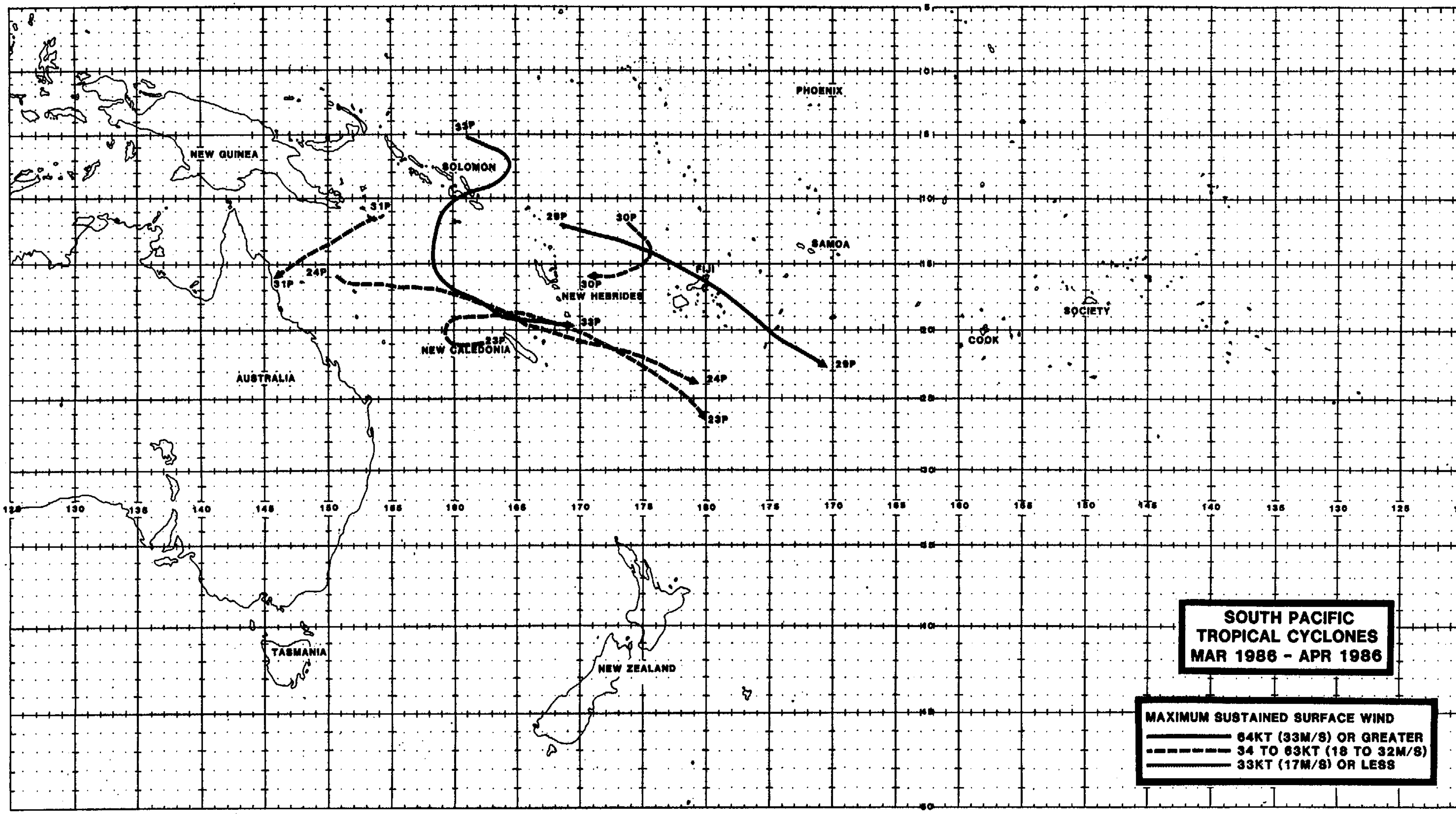
MAXIMUM SUSTAINED SURFACE WIND (KT)	EQUIVALENT MINIMUM SEA-LEVEL PRESSURE (MB)
30	1000
35	997
40	994
45	991
50	987
55	984
60	980
65	976
70	972
75	967
80	963
85	958
90	953
95	948
100	943
105	938
110	933
115	927
120	922
125	916
130	910
135	904
140	898
145	892
150	885
155	879
160	872
165	865
170	858

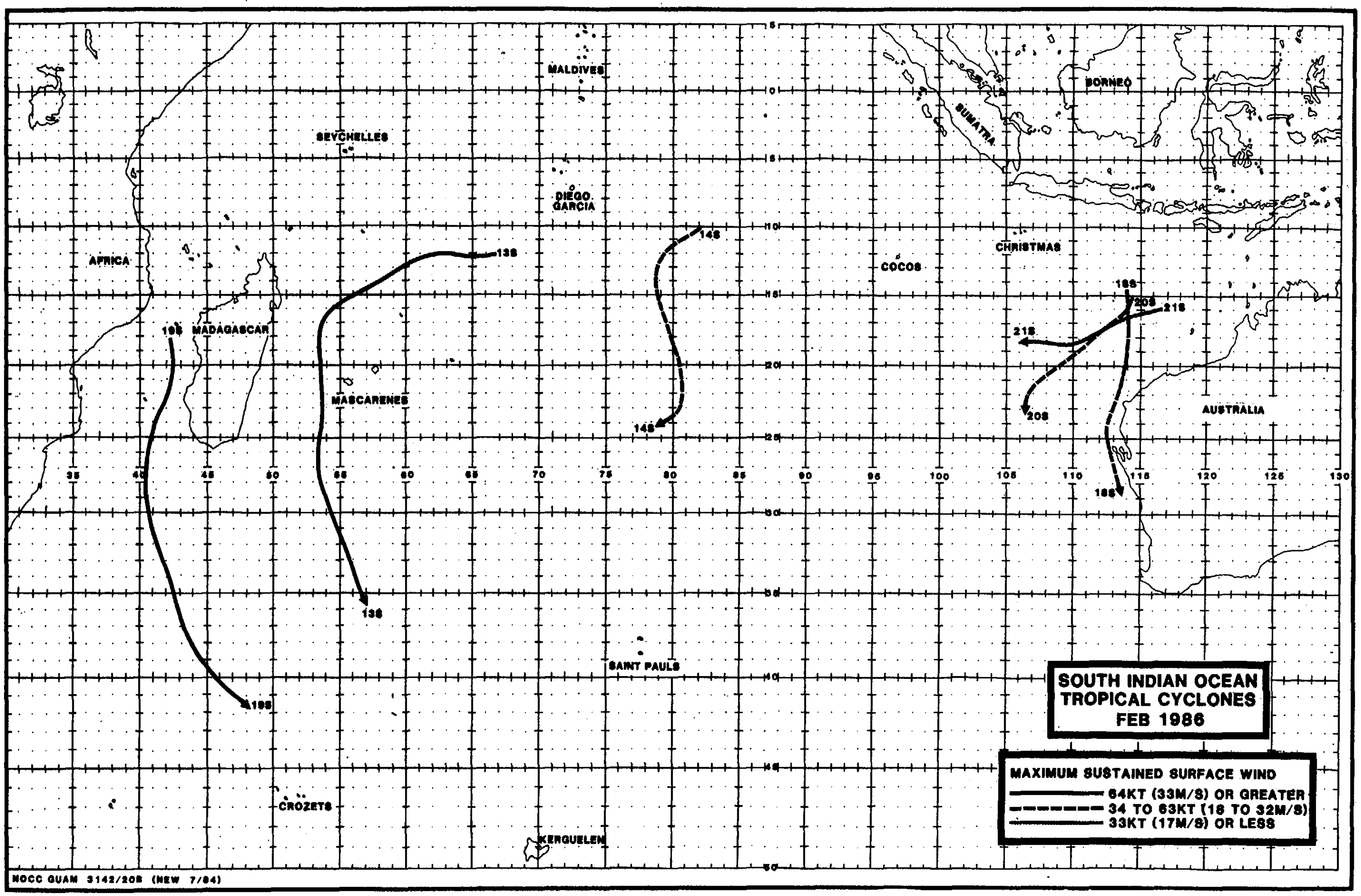

SOUTH INDIAN OCEAN
TROPICAL CYCLONES
SEP 1985 - JAN 1986
MAXIMUM SUSTAINED SURFACE WIND
64KT (33M/S) OR GREATER
34 TO 63KT (18 TO 32M/S)
33KT (17M/S) OR LESS
MALDIVES
SEYCHELLES
DIEGO GARCIA
AFRICA
MADAGASCAR
MASCARENES
SUMATRA
BORNEO
CHRISTMAS
COCOS
AUSTRALIA
SAINT PAULS
CROZETS
KERGUELEN
01S
02S
04S
05S
06S
07S
08S
09S
10S
NOCC GUAM 3142/208 (NEW 7/84)



SOUTH PACIFIC TROPICAL CYCLONES DEC 1985 - FEB 1986
MAXIMUM SUSTAINED SURFACE WIND
64KT (33M/S) OR GREATER
34 TO 63KT (18 TO 32M/S)
33KT (17M/S) OR LESS
NEW GUINEA
SOLOMON
PHOENIX
SAMOA
FIJI
NEW HEBRIDES
NEW CALEDONIA
AUSTRALIA
TASMANIA
NEW ZEALAND
COOK
SOCIETY
03P
11P
12P
15P
16P
17P
NOCC GUAM 3142/20A (NEW 7/84)


SOUTH INDIAN OCEAN
TROPICAL CYCLONES
MAR 1986 - MAY 1986
MAXIMUM SUSTAINED SURFACE WIND
64KT (33M/S) OR GREATER
34 TO 63KT (18 TO 32M/S)
33KT (17M/S) OR LESS
MALDIVES
SEYCHELLES
DIEGO GARCIA
AFRICA
MADAGASCAR
MASCARENES
SAINT PAULS
CROZETS
KERGUELEN
SUMATRA
BORNEO
CHRISTMAS
COCOS
AUSTRALIA
25S
26S
27S
28S
32S
22S
NOCC GUAM 3142/20S (NEW 7/84)


SOUTH PACIFIC
TROPICAL CYCLONES
MAR 1986 - APR 1986
MAXIMUM SUSTAINED SURFACE WIND
64KT (33M/S) OR GREATER
34 TO 63KT (18 TO 32M/S)
33KT (17M/S) OR LESS
NEW GUINEA
SOLOMON
PHOENIX
SAMOA
FIJI
NEW HEBRIDES
NEW CALEDONIA
AUSTRALIA
COOK
SOCIETY
TASMANIA
NEW ZEALAND
23P
24P
29P
30P
31P
32P
NOCC GUAM 3142/20A (NEW 7/84)


SOUTH INDIAN OCEAN
TROPICAL CYCLONES
FEB 1986
MAXIMUM SUSTAINED SURFACE WIND
64KT (33M/S) OR GREATER
34 TO 63KT (18 TO 32M/S)
33KT (17M/S) OR LESS
AFRICA
MADAGASCAR
SEYCHELLES
MALDIVES
DIEGO GARCIA
MASCARENES
COCOS
CHRISTMAS
SUMATRA
BORNEO
AUSTRALIA
SAINT PAULS
CROZETS
KERGUELEN
13S
14S
18S
19S
20S
21S
NOCC GUAM 3142/20S (NEW 7/84)

CHAPTER V - SUMMARY OF FORECAST VERIFICATION

1. ANNUAL FORECAST VERIFICATION

a. Western North Pacific Ocean

The position given for warning times and those at the 24-, 48- and 72-hour forecast times were verified against the final best track positions at the same valid times. The (scalar) forecast, cross track and along track errors (illustrated in Figure 5-1) were then calculated for each tropical cyclone and are presented in Tables 5-1A, 5-1B, 5-1C and 5-1D. Figure 5-2 provides the frequency distributions of forecast errors in 30 nm increments for 24-, 48-, and 72-hour forecasts of all 1986 tropical cyclones in the western North Pacific. A summation of the mean forecast errors, as calculated for all tropical cyclones in each year, is shown in Table 5-2A. Table 5-2B includes cross track and along track errors for 1986. A comparison of the annual mean forecast errors for all tropical cyclones as compared to those tropical cyclones that reached typhoon intensity can be seen in Table 5-3. The mean and median forecast errors for 1986 as compared to the ten previous years are graphed in Figure 5-3.

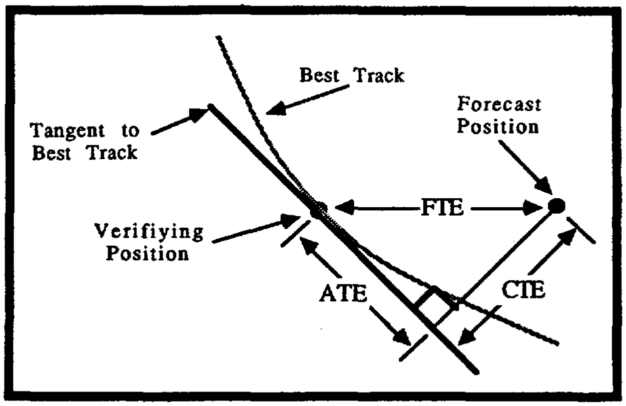
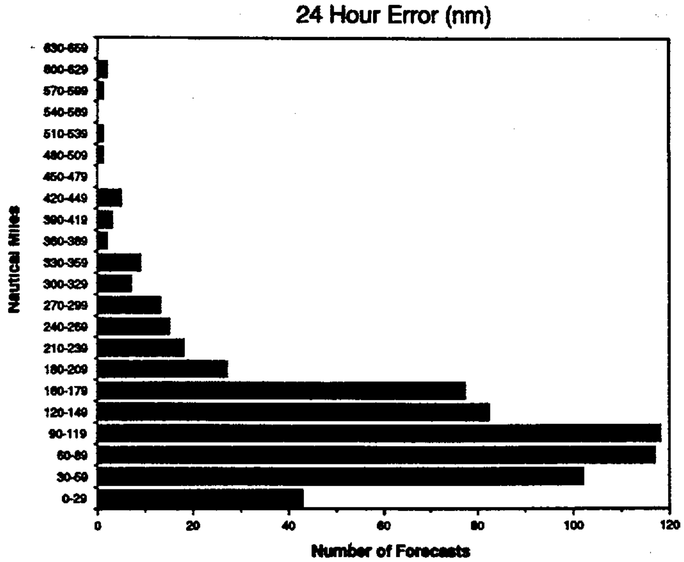


Figure 5-1. Definition of cross track error (CTE), along track error (ATE) and forecast track error (FTE). In this example, the CTE is positive (to the right of the Best Track) and the ATE is negative (behind or slower than the Best Track).

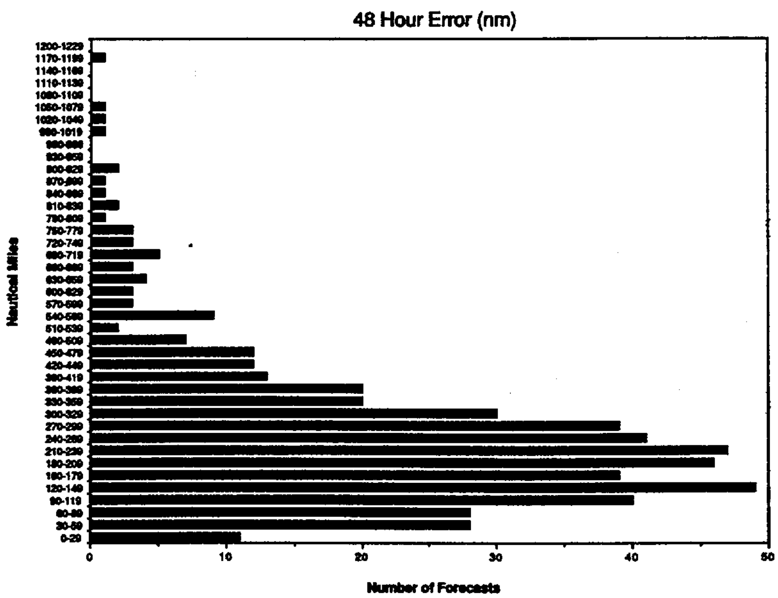
TABLE 5-1A. INITIAL POSITION ERROR SUMMARY FOR THE WESTERN NORTH PACIFIC SIGNIFICANT TROPICAL CYCLONES OF 1986 (ERRORS IN NM)

TROPICAL CYCLONE		ERROR	NUMBER OF WARNINGS
(01W)	TY JUDY	16	21
(02W)	TY KEN	17	18
(03W)	STY LOLA	11	26
(04W)	TS MAC	13	15
(05W)	TY NANCY	23	15
(06W)	TS OWEN	16	17
(07W)	STY PEGGY	11	35
(08W)	TY ROGER	12	19
(09W)	TS SARAH	55	22
(11E)	TY GEORGETTE	16	26
(10W)	TY TIP	24	25
(11W)	TS VERA #1	54	7
(11W)	TY VERA #2	17	48
(12W)	TY WAYNE	14	67
(13W)	TY ABBY	19	30
(14W)	TY BEN	22	46
(15W)	TY CARMEN	15	27
(16W)	TS DOM	25	11
(17W)	TY ELLEN	14	33
(18W)	TY FORREST	18	19
(19W)	TS GEORGIA	10	15
(20W)	TS HERBERT	26	16
(21W)	TS IDA	32	22
(22W)	TY JOE	12	24
(23W)	STY KIM	15	52
(24W)	TS LEX	34	8
(25W)	TY MARGE	29	38
(26W)	TY NORRIS	17	41
	MEAN	21	TOTAL 743



FORECAST ERRORS (NM)

	24-HR	48-HR	72-HR
MEAN:	121	261	394
MEDIAN:	121	255	383
STANDARD DEVIATION:	89	183	254
CASES:	646	531	409



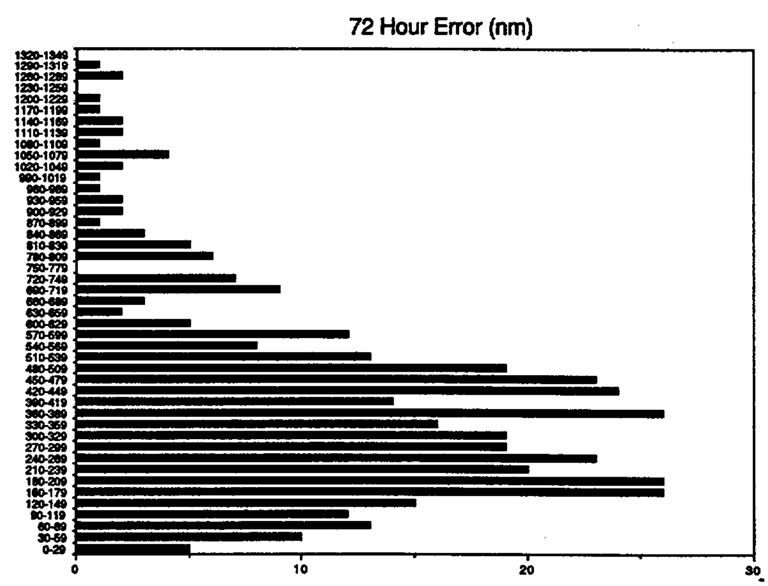


Figure 5-2. Frequency distribution of the 24-, 48-, and 72-hour forecast errors in 30 nm (56 km) increments for all significant tropical cyclones in the western North Pacific during 1986.

TABLE 5-1B. 24-HOUR FORECAST ERROR SUMMARY FOR THE WESTERN NORTH PACIFIC SIGNIFICANT TROPICAL CYCLONES OF 1986 (ERRORS IN NM)

TROPICAL CYCLONE		FORECAST ERROR	NUMBER OF WARNINGS	ALONG TRACK ERROR		CROSS TRACK ERROR	
				ABS MAG *	BIAS **	ABS MAG *	BIAS **
(01W)	TY JUDY	138	17	84	-56	93	-78
(02W)	TY KEN	78	15	62	11	31	-16
(03W)	STY LOLA	130	22	104	-86	63	-43
(04W)	TS MAC	123	11	96	-56	55	11
(05W)	TY NANCY	104	11	95	-92	32	20
(06W)	TS OWEN	70	14	63	-15	22	-9
(07W)	STY PEGGY	68	31	36	-1	47	29
(08W)	TY ROGER	75	15	59	-19	33	-18
(09W)	TS SARAH	273	18	208	-177	153	-104
(11E)	TY GEORGETTE	154	19	94	-78	87	-72
(10W)	TY TIP	180	23	114	-96	107	-107
(11W)	TS VERA #1	150	5	76	27	123	122
(11W)	TY VERA #2	131	44	96	-67	76	29
(12W)	TY WAYNE	124	59	101	-89	54	0
(13W)	TY ABBY	104	26	79	-37	51	38
(14W)	TY BEN	112	42	61	-2	81	-42
(15W)	TY CARMEN	84	23	57	-17	54	18
(16W)	TS DOM	66	9	56	-12	74	-66
(17W)	TY ELLEN	78	29	42	-4	54	-2
(18W)	TY FORREST	196	16	171	-158	58	-17
(19W)	TS GEORGIA	92	14	67	-61	46	46
(20W)	TS HERBERT	89	11	31	11	77	32
(21W)	TS IDA	139	19	87	-66	84	-24
(22W)	TY JOE	169	22	85	24	142	62
(23W)	STY KIM	116	51	82	-36	76	13
(24W)	TS LEX	78	7	41	7	62	-48
(25W)	TY MARGE	130	33	92	-59	68	33
(26W)	TY MORRIS	118	39	84	-75	73	13
	TOTALS	121	645	85	-50	70	-4

* ABS MAG = Absolute Magnitude (distance)
** BIAS is the median (middle value) of the sample.

Note: To measure forecast content with relation to a tropical cyclone track reference frame cross track and along track errors components have been generated in addition to the usual forecast errors. Specifics follow:

1. Cross track error component is a measure of how far a warning position is displaced left or right of the best track position. The samples consist of two parts: the absolute magnitude (distance) and the bias (negative values (minus sign) were left of track and positive values (plus sign) were right of track).

2. Along track error component is a measure of how far the warning position was displaced ahead or behind the best track position. It also consists of two parts: the absolute magnitude (distance) and the bias (negative values (minus sign) were behind/slow and positive values (plus sign) were ahead/fast).

TABLE 5-1C. 48-HOUR FORECAST ERROR SUMMARY FOR THE WESTERN NORTH PACIFIC SIGNIFICANT TROPICAL CYCLONES OF 1986 (ERRORS IN NM)

TROPICAL CYCLONE		FORECAST ERROR	NUMBER OF WARNINGS	ALONG TRACK ERROR		CROSS TRACK ERROR	
				ABS MAG	BIAS	ABS MAG	BIAS
(01W)	TY JUDY	331	11	310	-316	85	-75
(02W)	TY KEN	178	14	125	-29	86	-88
(03W)	STY LOLA	326	18	292	-300	105	-70
(04W)	TS MAC	188	7	147	-22	103	-79
(05W)	TY NANCY	198	7	180	-173	60	44
(06W)	TS OWEN	140	10	114	-64	72	-33
(07W)	STY PEGGY	172	27	100	8	117	110
(08W)	TY ROGER	105	9	83	-14	58	-38
(09W)	TS SARAH	671	14	507	-497	405	-394
(11E)	TY GEORGETTE	363	17	187	-63	267	-269
(10W)	TY TIP	447	18	362	-370	194	-191
(11W)	TS VERA #1	226	1	207	---	91	---
(11W)	TY VERA #2	289	40	207	-137	169	74
(12W)	TY WAYNE	274	46	237	-215	109	49
(13W)	TY ABBY	160	22	94	9	107	81
(14W)	TY BEN	204	38	124	26	131	-33
(15W)	TY CARMEN	140	19	104	-70	68	14
(16W)	TS DOM	60	4	18	-4	50	-36
(17W)	TY ELLEN	159	25	65	17	135	41
(18W)	TY FORREST	345	12	308	-257	124	-57
(19W)	TS GEORGIA	226	12	192	-194	101	99
(20W)	TS HERBERT	130	8	106	103	55	26
(21W)	TS IDA	236	15	147	-123	147	-55
(22W)	TY JOE	508	18	227	-22	424	-33
(23W)	STY KIM	280	51	167	-62	210	-54
(24W)	TS LEX	189	7	131	-117	112	-24
(25W)	TY MARGE	233	30	168	-97	139	89
(26W)	TY MORRIS	254	35	171	-151	168	108
	TOTALS	261	535	183	-115	151	-12

TABLE 5-1D. 72-HOUR FORECAST ERROR SUMMARY FOR THE WESTERN NORTH PACIFIC SIGNIFICANT TROPICAL CYCLONES OF 1986 (ERRORS IN NM)

TROPICAL CYCLONE		FORECAST ERROR	NUMBER OF WARNINGS	ALONG TRACK ERROR ABS MAG	ALONG TRACK ERROR BIAS	CROSS TRACK ERROR ABS MAG	CROSS TRACK ERROR BIAS
(01W)	TY JUDY	599	9	586	-594	92	-23
(02W)	TY KEN	288	14	184	80	179	25
(03W)	STY LOLA	581	14	560	-576	127	-27
(04W)	TS MAC	89	3	82	43	31	-10
(05W)	TY NANCY	521	3	498	-505	101	100
(06W)	TS OWEN	128	6	67	-47	82	-17
(07W)	STY PEGGY	332	23	163	7	257	252
(08W)	TY ROGER	198	5	154	-155	101	-103
(09W)	TS SARAH	800	8	530	-540	585	-594
(11E)	TY GEORGETTE	374	16	219	101	276	-263
(10W)	TY TIP	774	16	544	-518	420	-369
(11W)	TS VERA #1	---	0	---	---	---	---
(11W)	TY VERA #2	543	36	363	-253	340	-10
(12W)	TY WAYNE	468	38	390	-377	196	119
(13W)	TY ABBY	225	18	158	83	147	114
(14W)	TY BEN	261	32	139	38	190	-133
(15W)	TY CARMEN	173	15	141	-138	73	-21
(16W)	TS DOM	29	1	24	---	17	---
(17W)	TY ELLEN	291	21	139	17	227	36
(18W)	TY FORREST	427	8	353	-388	172	-176
(19W)	TS GEORGIA	402	8	354	-356	205	202
(20W)	TS HERBERT	217	4	134	133	162	-28
(21W)	TS IDA	325	11	211	-207	205	-35
(22W)	TY JOE	431	8	113	-104	334	-246
(23W)	STY KIM	488	31	355	14	317	-153
(24W)	TS LEX	416	7	366	-369	183	143
(25W)	TY MARGE	288	26	180	-105	189	150
(26W)	TY NORRIS	334	31	214	-151	224	214
	TOTALS	394	412	276	-170	227	-12

TABLE 5-2A. ANNUAL MEAN FORECAST ERRORS FOR THE WESTERN NORTH PACIFIC

YEAR	24-HOUR FORECAST	24-HOUR RIGHT-ANGLE	48-HOUR FORECAST	48-HOUR RIGHT-ANGLE	72-HOUR FORECAST	72-HOUR RIGHT-ANGLE
1971	111	64	212	118	317	117
1972	117	72	245	146	381	210
1973	108	74	197	134	253	162
1974	120	78	226	157	348	245
1975	138	84	288	181	450	290
1976	117	71	230	132	338	202
1977	148	83	283	157	407	228
1978	127	75	271	179	410	297
1979	124	77	226	151	316	223
1980	126	79	243	164	389	287
1981 *	123	75	220	119	334	168
1982 *	113	67	237	139	341	206
1983 *	117	72	259	152	405	237
1984 *	117	66	233	137	363	231
1985 *	117	66	231	134	367	214
1986	121	**	261	**	394	**

* THE TECHNIQUE FOR CALCULATING RIGHT-ANGLE ERROR WAS REVISED IN 1981; THEREFORE, A DIRECT CORRELATION IN RIGHT-ANGLE STATISTICS CANNOT BE MADE FOR THE ERRORS COMPUTED BEFORE 1981 AND THE ERRORS COMPUTED SINCE 1981.

** IN 1986 RIGHT-ANGLE ERROR WAS REPLACED BY CROSS TRACK ERROR (SEE FIGURE 5-1 FOR THE DEFINITION OF CROSS TRACK ERROR).

TABLE 5-2B. 1986 MEAN FORECAST, CROSS TRACK AND ALONG TRACK ERRORS FOR THE WESTERN NORTH PACIFIC. (ERRORS IN NM)

FORECAST ERROR:		CROSS TRACK		ALONG TRACK	
	FORECAST	ABS MAG	BIAS	ABS MAG	BIAS
24-HOUR	121	70	(-4)	85	(-50)
48-HOUR	261	151	(-12)	183	(-115)
72-HOUR	394	227	(-12)	276	(-170)

TABLE 5-3. ANNUAL MEAN FORECAST ERRORS FOR THE WESTERN NORTH PACIFIC (ERRORS ARE IN NAUTICAL MILES)

	24-HOUR		48-HOUR		72-HOUR	
YEAR	ALL	TYPHOON*	ALL	TYPHOON*	ALL	TYPHOON*
1950-1958		170				
1959		117 **		267 **		
1960		177 **		354 **		
1961		136		274		
1962		144		287		476
1963		127		246		374
1964		133		284		429
1965		151		303		418
1966		136		280		432
1967		125		276		414
1968		105		229		337
1969		111		237		349
1970	104	98	190	181	279	272
1971	111	99	212	203	317	308
1972	117	116	245	245	381	382
1973	108	102	197	193	253	245
1974	120	114	226	218	348	357
1975	138	129	288	279	450	442
1976	117	117	230	232	338	336
1977	148	140	283	266	407	390
1978	127	120	271	241	410	459
1979	124	113	226	219	316	319
1980	126	116	243	221	389	362
1981	123	117	220	215	334	342
1982	113	114	237	229	341	337
1983	117	110	259	247	405	384
1984	117	110	233	228	363	361
1985	117	112	231	228	367	355
1986	121	117	261	261	394	403

* Forecasts were verified when the Tropical Cyclone intensities were over 35 (18 m/sec).
** Forecast positions north of 35 degrees North Latitude were not verified.

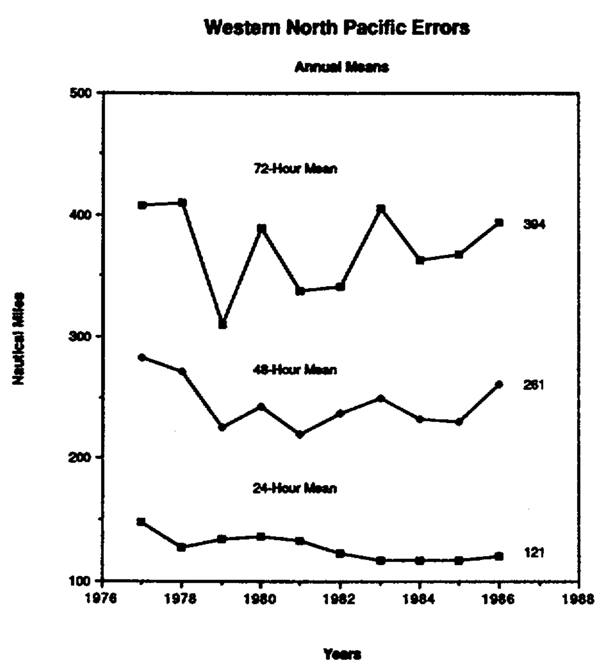


Figure 5-3. Annual mean forecast errors (in nm) for all tropical cyclones in the western North Pacific.

b. North Indian Ocean

The positions given for warning times and those at the 24-, 48-, and 72-hour valid times were verified for tropical cyclones in the North Indian Ocean by the same methods used for the western North Pacific. It should be noted that due to low number of North Indian Ocean tropical cyclones, these error statistics should not be taken as representative of any trend. Table 5-4 is the forecast along track and cross track error summary for the North Indian Ocean. Table 5-5A contains a summary of the annual mean forecast errors for each year. Table 5-5B includes cross and along track error for 1986. Forecast errors are plotted in Figure 5-4 (Seventy-two hour forecast errors were evaluated for the first time in 1979). There were no verifying 72-hour forecast in 1983 and 1985.

TABLE 5-4. FORECAST ERROR SUMMARY FOR THE NORTH INDIAN OCEAN SIGNIFICANT TROPICAL CYCLONES OF 1986 (ERRORS IN NM)

INITIAL POSITION

TROPICAL CYCLONE	ERROR	NUMBER OF WARNINGS
TC 01B	36	17
TC 02B	70	2
TC 03A	78	9
MEAN	52	TOTAL 28

24-HOUR FORECASTS

TROPICAL CYCLONE	FORECAST ERROR	ALONG TRACK ERROR		CROSS TRACK ERROR	
		ABS MAG	BIAS	ABS MAG	BIAS
TC 01B	78	59	-56	46	-41
TC 02B	---	---	---	---	---
TC 03A	259	247	-250	69	68
MEAN	134	118	-117	53	-7

48-HOUR FORECASTS

TROPICAL CYCLONE	FORECAST ERROR	ALONG TRACK ERROR		CROSS TRACK ERROR	
		ABS MAG	BIAS	ABS MAG	BIAS
TC 01B	129	89	-89	74	-75
TC 02B	---	---	---	---	---
TC 03A	401	384	N/A *	113	N/A *
MEAN	168	131	-89	80	-75

72-HOUR FORECASTS

TROPICAL CYCLONE	FORECAST ERROR	ALONG TRACK ERROR		CROSS TRACK ERROR	
		ABS MAG	BIAS	ABS MAG	BIAS
TC 01B	269	189	-190	180	-182
TC 02B	---	---	---	---	---
TC 03A	---	---	---	---	---
MEAN	269	189	-190	180	-182

* SAMPLE TOO SMALL TO COMPUTE MEDIAN FOR BIAS.

TABLE 5-5A. ANNUAL MEAN FORECAST ERRORS FOR THE NORTH INDIAN OCEAN

YEAR	24-HOUR FORECAST	24-HOUR RIGHT-ANGLE	48-HOUR FORECAST	48-HOUR RIGHT-ANGLE	72-HOUR FORECAST	72-HOUR RIGHT-ANGLE
1971 *	232	---	410	---	---	---
1972 *	224	101	292	112	---	---
1973 *	182	99	299	160	---	---
1974 *	137	81	238	146	---	---
1975	145	99	228	144	---	---
1976	138	108	204	159	---	---
1977	122	94	292	214	---	---
1978	133	86	202	128	---	---
1979	151	99	270	202	437	371
1980	115	73	93	87	167	126
1981 **	109	65	176	103	197	73
1982 **	138	66	368	175	762	404
1983 **	117	46	153	67	---	---
1984 **	154	71	274	127	388	159
1985 **	123	51	242	109	---	---
1986	134	***	168	***	269	***

* THE WESTERN BAY OF BENGAL AND ARABIAN SEA WERE NOT INCLUDED IN THE JTWC AREA OF RESPONSIBILITY UNTIL THE 1975 TROPICAL CYCLONE SEASON.

** THE TECHNIQUE FOR CALCULATING RIGHT-ANGLE ERROR WAS REVISED IN 1981; THEREFORE, A DIRECT CORRELATION IN RIGHT-ANGLE STATISTICS CANNOT BE MADE FOR THE ERRORS COMPUTED BEFORE 1981 AND THE ERRORS COMPUTED SINCE 1981.

*** IN 1986 RIGHT-ANGLE ERROR WAS REPLACED BY CROSS TRACK ERROR (SEE FIGURE 5-1 FOR THE DEFINITION OF CROSS TRACK ERROR).

TABLE 5-5B. ANNUAL MEAN FORECAST ERRORS FOR THE NORTH INDIAN OCEAN (ERRORS IN NAUTICAL MILES)

FORECAST ERROR:

YEAR	24-HOUR	48-HOUR	72-HOUR
1986	134	168	269

CROSS TRACK ERROR:

	24-HOUR		48-HOUR		72-HOUR	
YEAR	ABS MAG	BIAS	ABS MAG	BIAS	ABS MAG	BIAS
1986	53	-7	80	-49	180	-182

ALONG TRACK ERROR:

	24-HOUR		48-HOUR		72-HOUR	
YEAR	ABS MAG	BIAS	ABS MAG	BIAS	ABS MAG	BIAS
1986	118	-118	131	-134	189	-190

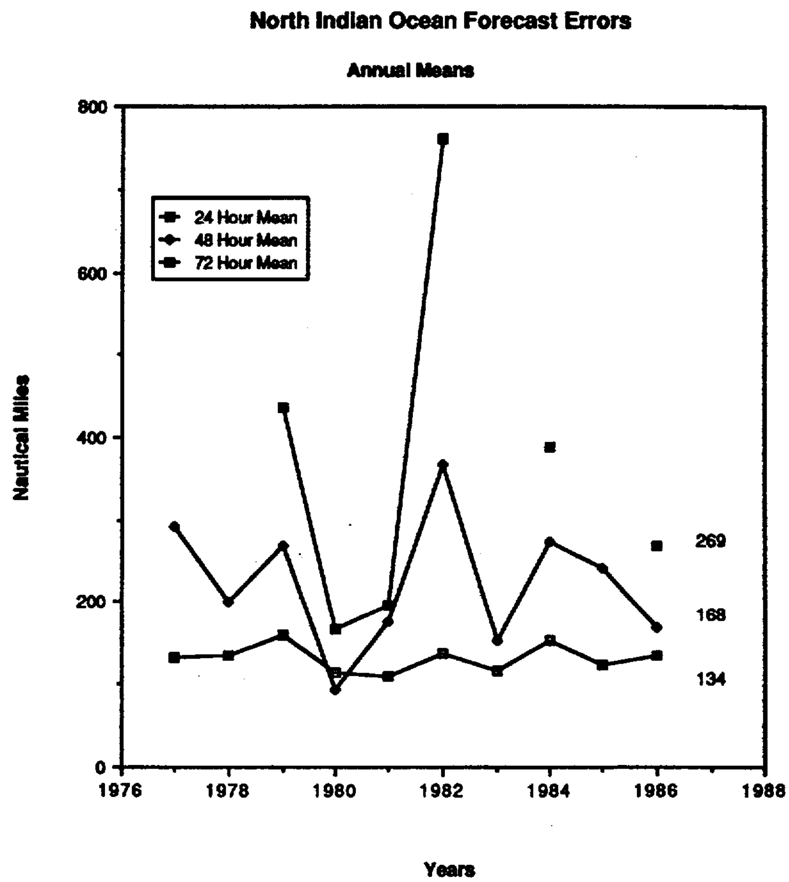


Figure 5-4. Annual mean forecast errors (in nm) for all tropical cyclones in the North Indian Ocean.

c. South Pacific and South Indian Oceans

Verification statistics for forecasts in the southern hemisphere can be obtained from the raw data sets addressed in Annex A.

2. COMPARISON OF OBJECTIVE TECHNIQUES

a. General

Objective techniques used by JTWC are divided into five main categories:

(1) extrapolation;

(2) climatological and analog techniques;

(3) model output statistics;

(4) dynamic models; and

(5) empirical and analytical techniques;

In September 1981, JTWC began to initialize its array of objective forecast techniques (described below) on the six-hour old preliminary best track position (an interpolative process) rather than the forecast (partially extrapolated) warning position, e.g. the 0600Z warning is now supported by objective techniques developed from the 0000Z preliminary best track position. This operational change has yielded several advantages:

*Techniques can now be requested much earlier in the warning development time line, i.e. as soon as the track can be approximated by one or more fix positions after the valid time of the previous warning;

*Receipt of these techniques is virtually assured prior to the development of the next warning; and

*Improved (mean) forecast accuracy. This latter aspect arises because JTWC now has more reliable approximation of the short-term tropical cyclone movement. Further, since most of the objective techniques are biased towards persistence, this new procedure optimizes their performance and provides more consistent guidance on short-term movement, indirectly yielding a more accurate initial position estimate as well as lowering 24-hour forecast errors.

b. Description of Objective Techniques

(1). XTRP — Forecast positions for 24- and 48-hours are derived from the extension of a straight line which connects the most recent and 12-hour old preliminary best track positions.

(2). CLIM — A climatological aid providing 24-, 48-, and 72-hour tropical cyclone forecast positions (and intensity changes in the western North Pacific) based upon the position of the tropical cyclone. The output is based upon data records from 1945 to 1981 for the western North Pacific Ocean and 1900 to 1981 for the North Indian Ocean.

(3). TPAC — Forecast positions are generated from a blend of climatology and persistence. The 24- and 48-hour positions are equally weighted between climatology and persistence and three quarters climatology and persistence, respectively; the 72-hour position is one quarter persistence and three quarters climatology. Persistence is a straight line extension of a line connecting the current and 12-hour old positions. Climatology is based on data from 1945 to 1981 for the western North Pacific Ocean and 1900 to 1981 for the North Indian Ocean.

(4). TYAN — An updated analog program which combines the earlier versions TYFN 75 and INJAN 74. The program scans a 30-year climatology with a similar history (within a specified acceptance envelope) to the current tropical cyclone. For the western North Pacific Ocean, three forecasts of position and intensity are provided for 24-, 48-, and 72-hours: RECR - a weighted mean of all tropical cyclones which were categorized as "recurving" during their best track period; STRA - a weighted mean of all accepted tropical cyclones which were categorized as moving "straight" (westward) during their best track period: TOTL - a weighted mean of all accepted tropical cyclones, including those used in the RECR and STRA forecast. For the North Indian Ocean, a single (total) forecast track is provided for the 12-hour intervals to 72-hours.

(5). COSMOS — A model output statistics (MOS) routine based on the geostrophic steering at the 850-, 700-, and 500-mb levels. The steering is derived from the HATTRACK point advection model run on Global prognostic fields from the FLENUMOCEANCEN's NOGAPS prediction system. The MOS forecast is then blended with the 6-hour past movement to generate the forecast track.

(6). One-way Interactive Tropical Cyclone Model (OTCM) — A coarse-mesh, three-layer in the vertical, primitive equation model with a 205km grid spacing over a 6400 x 4700 km domain. The model's fields are computed around a bogused, digitized cyclone vortex using FLENUMOCEANCEN's Numerical Variational Analysis (NVA) or NOGAPS prognostic fields for the specified valid time. The past motion of the tropical cyclone is compared to initial steering fields and a bias correction is computed and applied to the model. FLENUMOCEANCEN's NOGAPS global prognostic fields are used at 12-hour intervals to update the model's boundaries. The resultant forecast positions are derived by locating the 850 mb vortex at six-hour intervals to 72-hours.

(7). Nested Tropical Cyclone Model (NTCM) — A primitive equation model with properties similar to the OTCM. The NTCM differs by containing a finer scale "nested "grid, initializing on NVA analysis fields only, not containing a (persistence) bias correction, and being a channel model which runs independent of FLENUMOCEANCEN's prognostic fields (i.e., it does not require updating of its boundaries). The "nested grid" covers a 1200 x 1200 km area with a 41 km grid spacing which moves within the coarse-mesh domain to keep an 850 mb vortex at its center.

(8). TAPT — An empirical technique which utilizes upper-tropospheric wind fields to estimate acceleration associated with the tropical cyclone's interaction with the mid-latitude westerlies. It includes guidelines for the duration of acceleration, upper-limits, and probable path of the cyclone.

(9). CLIPER — A statistical regression technique based on climatology, current intensity, position and past movement. This technique is used as a crude measure of real forecast skill when verifying forecast accuracy.

(10). THETA-E — An empirically derived relationship between a tropical cyclone's minimum sea-level pressure (MSLP) and 700 mb equivalent potential temperature (Theta-E) was developed by Sikora (1976) and Dunnavan (1981). By monitoring MSLP and trends, the forecaster can evaluate the potential for sudden, rapid deepening of a tropical cyclone.

(11). WIND RADIUS — Following an analytical model of the radial profiles of sea-level pressures and winds in mature tropical cyclones (Holland, 1980), a set of radii for 30-, 50-, and 100-knot winds based on the tropical cyclone's maximum winds have been produced to aid the forecaster in determining forecast wind radii.

(12). DVORAK — An estimation of tropical cyclone's current and 24-hour forecast intensity is made from interpolation of satellite imagery (DVORAK, 1984) and provided to the forecaster. These intensity estimates are used in conjunction with other intensity-related data and trends to forecast tropical cyclone intensity.

JTWC uses TPAC, TAPT, TYAN78, COSMOS, OTCM and NTCM operationally to develop track forecasts.

c. Testing and Results

A comparison of selected techniques is included in Table 5-6 for all western North Pacific tropical cyclones, Table 5-7 for all North Indian Ocean tropical cyclones. In these tables, " x-axis " refers to techniques listed vertically. For example (Table 5-6) in the 470 cases available for a (homogeneous) comparison, the average forecast error at 24-hours was 124 nm (230 km) for RECR and 110 nm (204 km) for COSM. The difference of 14 nm (26 km) is shown in the lower right. (Differences are not always exact, due to computational round-off which occurs for each of the cases available for comparison).

TABLE 5-6. 1986 ERROR STATISTICS FOR SELECTED OBJECTIVE TECHNIQUES IN THE WESTERN NORTH PACIFIC OCEAN

24-HOUR FTE MEAN ERRORS (N. MI)

	JTWC		NTCM		CLIP		OTCM		CSUM		RECR		TOTL		COSM		TPAC		CLIM		XTRP	
JTWC	643	122																				
	122	0																				
NTCM	529	121	544	129																		
	127	6	129	0																		
CLIP	490	121	502	127	502	126																
	126	5	126	-1	126	0																
OTCM	589	120	514	126	475	123	603	126														
	125	5	126	0	125	2	126	0														
CSUM	498	122	431	125	407	127	501	125	505	111												
	111	-11	112	-13	113	-14	110	-15	111	0												
RECR	576	121	499	127	463	125	561	123	470	110	589	128										
	126	5	130	3	127	2	124	1	124	14	128	0										
TOTL	589	121	510	127	472	124	575	125	483	110	588	128	603	129								
	128	7	131	4	128	4	125	0	125	15	130	2	129	0								
COSM	583	119	505	123	480	124	567	124	492	110	555	120	566	121	593	121						
	121	2	123	0	123	-1	120	-4	122	12	122	2	122	1	121	0						
TPAC	593	121	512	125	475	123	578	126	489	111	571	126	585	128	572	121	607	129				
	128	7	130	5	128	5	125	-1	126	15	129	3	128	0	121	0	129	0				
CLIM	593	121	512	125	475	123	578	126	489	111	571	126	585	128	572	121	607	129	607	171		
	171	50	171	46	171	48	168	42	173	62	168	42	168	40	163	42	171	42	171	0		
XTRP	597	120	516	126	477	123	582	126	492	111	571	126	585	128	575	121	607	129	607	171	611	133
	129	9	134	8	131	8	128	2	129	18	134	8	132	4	125	4	133	4	133	-38	133	0

NUMBER OF CASES	X-AXIS TECHNIQUE ERROR
Y-AXIS TECHNIQUE ERROR	ERROR DIFFERENCE (Y - X)

48-HOUR FTE MEAN ERRORS (N. MI)

	JTWC		NTCM		CLIP		OTCM		CSUM		RECR		TOTL		COSM		TPAC		CLIM		XTRP	
JTWC	528	260																				
	260	0																				
NTCM	430	258	466	276																		
	269	11	276	0																		
CLIP	402	254	432	271	432	269																
	261	7	269	-2	269	0																
OTCM	469	256	432	270	402	261	505	231														
	224	-32	228	-42	225	-36	231	0														
CSUM	398	261	362	270	345	269	414	224	424	227												
	225	-36	223	-47	220	-49	224	0	227	0												
RECR	476	259	432	271	402	264	475	226	399	221	510	265										
	262	3	263	-8	257	-7	260	34	268	47	265	0										
TOTL	485	259	439	271	407	264	484	229	407	223	508	266	519	265								
	262	3	259	-12	251	-13	260	31	268	45	267	1	265	0								
COSM	475	256	433	263	415	266	472	226	412	227	480	259	486	257	507	249						
	248	-8	247	-16	244	-22	243	17	244	17	250	-9	251	-6	249	0						
TPAC	485	258	439	268	409	263	483	230	411	227	492	263	501	262	489	250	520	255				
	247	-11	248	-20	240	-23	247	17	255	28	251	-12	250	-12	245	-5	255	0				
CLIM	485	258	439	268	409	263	483	230	411	227	492	263	501	262	489	250	520	255	520	316		
	306	48	311	43	308	45	314	84	328	101	308	45	308	46	307	57	316	61	316	0		
XTRP	486	258	440	268	409	263	484	230	411	227	492	263	501	262	489	250	520	255	520	316	521	299
	292	34	289	21	278	15	290	60	299	72	298	35	297	35	288	38	299	44	299	-17	299	0

JTWC - OFFICIAL JTWC FORECAST
NTCM - NESTED TROPICAL CYCLONE MODEL
CLIP - CLIPER (CLImatolgy and PERsistence)
OTCM - ONE-WAY TROPICAL CYCLONE MODEL
CSUM - C.S.U. MODEL (Synoptic-Statistical)
RECR - RECURVER ANALOG (TYAN 78)
TOTL - TOTAL ANALOG (TYAN 78)
COSM - COSMOS (Model Output Statistics)
TPAC - CLIMATOLOGY AND PERSISTENCE BLEND
CLIM - CLIMATOLOGY
XTRP - 12-HOUR EXTRAPOLATION

72-HOUR FTE MEAN ERRORS (N. MI)

	JTWC		NTCM		CLIP		OTCM		CSUM		RECR		TOTL		COSM		TPAC		CLIM		XTRP	
JTWC	406	392																				
	392	0																				
NTCM	332	396	386	457																		
	438	42	457	0																		
CLIP	312	397	363	460	363	430																
	414	17	430	-30	430	0																
OTCM	315	404	318	449	300	414	369	355														
	348	-56	356	-93	354	-60	355	0														
CSUM	283	401	288	458	279	429	301	347	335	349												
	346	-55	348	-110	346	-83	346	-1	349	0												
RECR	360	397	355	455	336	426	341	349	314	342	416	423										
	414	17	426	-29	425	-1	423	74	439	97	423	0										
TOTL	367	398	363	455	341	427	349	351	320	345	414	422	424	406								
	387	-11	399	-56	393	-34	409	58	418	73	408	-14	406	0								
COSM	359	398	358	450	348	428	343	352	324	351	389	423	398	402	414	431						
	429	31	428	-22	430	2	399	47	406	55	435	12	435	33	431	0						
TPAC	368	397	361	448	341	425	349	355	322	350	398	421	407	404	396	437	423	376				
	341	-56	376	-72	375	-50	380	25	388	38	369	-52	371	-33	377	-60	376	0				
CLIM	368	397	361	448	341	425	349	355	322	350	398	421	407	404	396	437	423	376	423	417		
	371	-26	421	-27	421	-4	428	73	437	87	407	-14	410	6	419	-18	417	41	417	0		
XTRP	364	395	355	447	335	422	344	357	318	350	394	419	401	402	392	440	417	374	417	414	418	478
	468	73	463	16	461	39	470	113	498	148	476	57	477	75	472	32	477	103	477	63	478	0

TABLE 5-7. 1986 ERROR STATISTICS FOR SELECTED OBJECTIVE TECHNIQUES IN THE NORTHERN INDIAN OCEAN

24-HOUR FTE MEAN ERRORS (N. MI)

	JTWC	NTCM	OTCM	RECR	TOTL	TPAC	CLIM	XTRP
JTWC	16 134 134 0							
NTCM	13 138 137 -1	15 137 137 0						
OTCM	11 160 277 117	9 178 271 93	11 277 277 0					
RECR	12 141 140 -1	12 150 145 -5	9 270 150 -120	14 143 143 0				
TOTL	8 189 182 -7	8 191 190 -1	6 303 199 -104	10 177 177 0	10 177 177 0			
TPAC	15 140 164 24	14 146 163 17	11 277 188 -89	14 143 156 13	10 177 201 24	17 161 161 0		
CLIM	15 140 183 43	14 146 179 33	11 277 211 -66	14 143 177 34	10 177 233 56	17 161 176 15	17 176 176 0	
XTRP	15 140 153 13	14 146 155 9	11 277 173 -104	14 143 140 -3	10 177 174 -3	17 161 153 -8	17 176 153 -23	17 153 153 0

NUMBER OF CASES	X-AXIS TECHNIQUE ERROR
Y-AXIS TECHNIQUE ERROR	ERROR DIFFERENCE (Y - X)

48-HOUR FTE MEAN ERRORS (N. MI)

	JTWC	NTCM	OTCM	RECR	TOTL	TPAC	CLIM	XTRP
JTWC	7 168 168 0							
NTCM	6 129 208 79	8 199 199 0						
OTCM	2 134 528 394	2 254 528 274	2 528 528 0					
RECR	4 200 232 32	3 247 157 -90	1 602 166 -436	5 249 249 0				
TOTL	1 401 459 58	0 0 0 0	0 0 0 0	2 387 387 0	2 387 387 0			
TPAC	6 179 162 -17	7 209 118 -91	2 528 98 -430	5 249 211 -38	2 387 370 -17	9 174 174 0		
CLIM	6 179 178 -1	7 209 102 -107	2 528 68 -460	5 249 207 -42	2 387 408 21	9 174 170 -4	9 170 170 0	
XTRP	6 179 172 -7	7 209 153 -56	2 528 135 -393	5 249 220 -29	2 387 345 -42	9 174 196 22	9 170 196 26	9 196 196 0

JTWC - OFFICIAL JTWC FORECAST
NTCM - NESTED TROPICAL CYCLONE MODEL
OTCM - ONE-WAY TROPICAL CYCLONE MODEL
RECR - RECURVER ANALOG (TYAN 78)
TOTL - TOTAL ANALOG (TYAN 78)
TPAC - CLIMATOLOGY AND PERSISTENCE BLEND
CLIM - CLIMATOLOGY
XTRP - 12-HOUR EXTRAPOLATION

72-HOUR FTE MEAN ERRORS (N. MI)

	JTWC	NTCM	OTCM	TPAC	CLIM	XTRP
JTWC	5 269 269 0					
NTCM	5 269 438 169	5 438 438 0				
OTCM	1 254 1015 761	1 400 1015 615	1 1015 1015 0			
TPAC	4 286 142 -144	4 451 142 -309	1 1015 182 -833	4 142 142 0		
CLIM	4 286 152 -134	4 451 152 -299	1 1015 166 -849	4 142 152 10	4 152 152 0	
XTRP	4 286 196 -90	4 451 196 -255	1 1015 229 -786	4 142 196 54	4 152 196 44	4 196 196 0

CHAPTER VI - NAVENVPREDRSCHFAC TROPICAL CYCLONE SUPPORT SUMMARY

The Advanced Tropical Cyclone Model (ATCM)

(Hodur, R.M., NAVENVPREDRSCHFAC)

The Advanced Tropical Cyclone Model (ATCM) is being developed to improve forecasts of tropical cyclone paths to 72-hours. The ATCM is really the Navy Operational Regional Atmospheric Prediction System (NORAPS) redesigned to run optionally as a tropical cyclone model. Given this redesign, NORAPS can produce forecasts each watch for a given region, such as the tropical western Pacific, and if the ATCM option is included, any and all, tropical storms present in the forecast domain will be bogused into the initial fields. The forecast storm position(s) will be computed in the model at some selected interval and sent to JTWC upon completion of the forecast. Forecast fields (e.g., sea-level pressure, mean Planetary Boundary Layer (PBL) winds) can be sent also, as is currently done for all NORAPS areas.

Although the redesign of NORAPS to function as the ATCM is complete, the exact method of bogusing the tropical storm has not yet been determined. Currently, four methods of bogusing the tropical storm are being evaluated. Other tests are being conducted to evaluate the significance of interactions between storms which occur in multiple storm situations. Upon completion of these tests, the bogusing method which produces the smallest forecast errors will be incorporated into the ATCM and the system will be ready for operational evaluation.

Tropical Cyclone Prediction Research

(Elsberry, R.L. and J.E. Peak, NAVPOSTGRADSCH)

In view of high personnel turnover of the JTWC forecasters, more objective approaches to the tropical cyclone forecasting processes are being developed. The performance of different tropical cyclone forecast aids (NTCM, OTCM, RECR, TOTL, CY50) for various cyclone characteristics and different environmental conditions has been evaluated. The factors affecting the accuracy of objective forecast aids are being incorporated into a decision tree to assist the forecaster in following a logical and reasonable path in selecting the appropriate aid in a given situation. A post-processing scheme for adjusting the OTCM predictions, which achieved a 30% reduction in 72-hour forecast error on the dependent sample is proposed for operational testing. An objective method for determining the warning position from a variety of fixes has been given to NEPRF for testing.

would be unwarranted at lower risk levels. A rule for deciding such actions can be derived on an expected outcome basis (e.g. cost/benefits ratio). The CHARM model is now being adapted for seven North Pacific sites: Pearl Harbor, Guam, Subic Bay, Buckner Bay, Yokosuka, Sasebo, and Pusan.

Evaluation Of JTWC Objective Aids

(Tsui, T.L., and R.J. Miller, NAVENVPREDRSCHFAC)

The objective aid forecasts used at the Joint Typhoon Warning Center (JTWC) during the 1978-85 period are evaluated. Forecast accuracy is judged on error measures of forecast error, cross-track error, and along-track error. The evaluation includes the consistency, as well as the accuracy, of the objective aid forecasts. In addition, the data are stratified according to season, maximum storm intensity, and storm path type for a more detailed error analysis. During the first eight-year period (1978-85), HPAC, the climatology/persistence model, and OTCM, a dynamical model, emerged as the best and most consistent aids.

Results also show that the forecasters at JTWC can assimilate the wealth of objective aids and provide reliable forecast guidance. When storms move erratically or fail to attain typhoon strength, JTWC forecasts are superior than the objective aids.

Automated Tropical Cyclone Forecasting System

(Miller, R.J., and T.L. Tsui, NAVENVPREDRSCHFAC)

The Automated Tropical Cyclone Forecasting (ATCF) system is an IBM PC compatible software package currently being developed for the Joint Typhoon Warning Center (JTWC). ATCF is designed to allow JTWC forecasters to display graphically tropical cyclone forecast information, merge and analyze synoptic wind fields, provide objective fix guidance, select optimum objective forecast aid, and expedite the issuance of tropical cyclone warnings. One great advantage of using ATCF is the standardization of the tropical cyclone forecasting procedures, so that during the course of the tropical cyclone warning preparation, forecasters will not neglect consideration of any decisional steps or available options. ATCF automatically saves all tropical cyclone data, computes the real-time and post-storm statistics, and allows forecasters to randomly access any past storm data. A communication package included in ATCF simplifies the data transfer procedure between JTWC and Fleet Numerical Oceanography Center in Monterey, California.

When the ATCF is fully developed, it can be used as a training aid to simulate the actual Tropical Cyclone Inner Regional Circulation Classification

(Gray, W.M, Colorado State University)

The goals of the project are 1) to analyze the details of inner 270 nm (500 km) radial and vertical structure of tropical cyclones of the western North Pacific, and 2) to determine the various classes of inner region circulations. The results are expected to assist in determining the proper inner core circulation bogusing method in the initialization procedure of the new Advanced Tropical Cyclone Model.

Aircraft reconnaissance data will be used for knowledge of the inner 150 nm (278 km) radius cyclone circulation at lower tropospheric levels. Rawinsonde and Japanese Geostationary Meteorological Satellite (GMS) satellite data will be used for information on the circulation characteristics (with some overlapping) between 150-270 nm (278-500 km) radii and for estimates of the vertical resolution of the cyclone circulation at all radii. It is anticipated that there are four or five distinctive inner cyclone circulation patterns which need to be documented for analytic incorporation into the numerical model.

Navy Tactical Applications Guide (NTAG), Vol. 6

(Fett, R.W., NAVENVPREDRSCHFAC)

An effort is now underway to develop a series of examples demonstrating the use of high quality satellite data for analysis and forecasting in the tropics. Both polar orbiter and geostationary satellite data are used to study the evolution of certain weather effects or of a particular weather phenomenon at a given time.

These examples are intended for publishing in the NTAG volume 6, Part I, Tropical Weather Analysis and Forecast Applications, and Volume 6, Part II, Tropical Cyclone Weather Analysis and Forecast Applications. NTAG Volume 6, Part I is presently in the publishing process. Distribution is anticipated in early 1987. Part II is still in the research process. Publication is anticipated in 1988/89.

Tropical Cyclone Condition Setting Aid

(Jarrell, J.D., Sci. Appl. International Corporation)

The tropical cyclone wind probabilities formed the basis for the development of a model to aid in threat analysis and decision making. The Cyclone Hurricane Acceptable Risk Model (CHARM) developed by Jarrell assumes that at some high risk or high probability level, decision makers would order tropical cyclone condition evasion actions that tropical cyclone warning procedure. New forecasters can gather valuable hands-on experience of the warning procedure during their training period.

North Pacific Tropical Cyclone Climatology

(Miller, R.J. and T.L. Tsui, NAVENVPREDRSCHFAC)

A tropical cyclone climatology for the North Pacific has been developed and now is being reviewed by EGPACOM. Data used for the western basin were taken from the JTWC tropical cyclone data base and covered a period of 40 years, 1945-84. Eastern basin data spanned the 34 years period 1949-82 and were obtained from the consolidated world-wide tropical cyclone data base at National Climatic Data Center, Asheville, N.C.

Storms for both basins were sorted according to month/day of the year into twenty four 31-day overlapping periods. For each period, four charts are supplied: 1) actual storm paths; 2) mean storm paths 3) average storm speed; and 4) storm constancy and frequency.

Evaluation Of CSUM Objective Aid

(Tsui, T.L. and R.J. Miller, NAVENVPREDRSCHFAC)

CSUM is a statistical tropical cyclone prediction model developed by Matsumoto and Gray (Colorado State University), and was implemented into the JTWC combined ARQ procedure in September 1985. Preliminary results of all 35 storms since implementation indicate that CSUM gives good objective guidance. The mean 72-hour forecast error for CSUM was 303 nm (561 km) compared to 315 nm (583 km) and 330 nm (611 km) for COSMOS and OTCM respectively for the same period. In a head-to-head comparison, CSUM had a lower mean error than all other objective aids. The median 72-hour cross-track and along-track errors indicate that CSUM possesses no track bias but is one of the slower techniques in terms of predicted storm speed.

ANNEX A

1. GENERAL

Due to the rapid growth of personal computers in the meteorological community, and saved publishing costs, raw tropical cyclone track (best track, initial warning, 24-hour forecast, 48-hour forecast, and 72-hour forecast) and fix (satellite, aircraft, radar and synoptic) data will be available separately, upon request, to be copied on 5.25 inch "floppy" diskettes. These data sets include: one (1 January - 31 December 1986) for the western North Pacific and North Indian Oceans, and the other (1 July 1985 - 30 June 1986) for the South Pacific and South Indian Oceans. The first data set requires four and the second requires two 5.25 inch "floppy" diskettes. Agencies or individuals desiring these data sets should forward the appropriate number of diskettes (four, two or six for both data sets) to NAVOCEANCOMCEN/JTWC, Guam with their request for one of two computer systems - Z-DOS (Zenith computer compatible) or MS-DOS (Zenith or IBM computer compatible). Once your request has been received the requested data will be promptly copied onto your diskettes and returned with an explanation of the recorded data formats. The use of "floppy" diskettes should facilitate the transfer of these bulky raw data files to your computer.

2. WESTERN NORTH PACIFIC VERIFICATION STATISTICS

This section includes only verification statistics for each warning in the western North Pacific. Pre- and post-warning best track positions are not printed, but are available in the raw data set that can be requested (see paragraph 1. above). (Similar verification statistics for the North and South Indian Ocean and western South Pacific are not included in this publication, but can be generated from the raw track and fix data files mentioned in the section 1. above.)

Typhoon Judy (01W)

DTG	W#	BT Lat	BT Lon	Pos Er	24 Er	48 Er	72 Er	BT Wn	WW Er	24 WE	48 WE	72 WE
86020100	1	4.6N	143.6E	24	110	51	276	30	0	10	10	10
86020106	2	5.1N	142.1E	13	8	54	359	30	0	-5	-5	-5
86020112	3	5.5N	140.5E	35	251	216	523	30	0	10	0	-5
86020118	4	5.9N	138.9E	9	114	265	682	35	-5	-5	0	-10
86020200	5	6.5N	137.4E	13	109	300	701	45	-5	5	0	-15
86020206	6	7.8N	136.2E	18	57	353	732	50	0	5	0	5
86020212	7	8.8N	134.8E	18	125	471	790	50	0	10	-10	10
86020218	8	9.7N	133.6E	24	243	560	746	55	0	10	-15	15
86020300	9	10.5N	132.4E	6	240	501	585	55	5	-10	-40	5
86020306	10	11.3N	131.7E	12	296	542		60	0	-15	-15	
86020312	11	12.4N	131.3E	12	126	324		60	0	-35	-15	
86020318	12	13.6N	131.3E	30	184			60	-5	-40		
86020400	13	14.9N	131.6E	6	98			65	0	-40		
86020406	14	16.1N	132.3E	0	80			70	-5	-15		
86020412	15	17.1N	133.6E	17	94			75	5	5		
86020418	16	18.0N	135.2E	25	56			80	-5	10		
86020500	17	18.6N	136.5E	28	165			85	-10	10		
86020506	18	18.6N	137.9E	6				60	0			
86020512	19	18.7N	139.2E	11				45	0			
86020518	20	18.8N	140.5E	24				35	0			
86020600	21	18.8N	141.8E	6				30	0			
		AVERAGE		16	138	331	599					
		# OF CASES		21	17	11	9					

Typhoon Ken (02W)

DTG	W#	BT Lat	BT Lon	Pos Er	24 Er	48 Er	72 Er	BT Wn	WW Er	24 WE	48 WE	72 WE
86042618	1	7.4N	139.7E	48	121	273	444	45	-10	-20	-15	25
86042700	2	7.7N	139.6E	24	98	236	402	50	0	-5	20	60
86042706	3	8.0N	139.4E	0	43	92	222	60	0	-5	35	65
86042712	4	8.6N	139.3E	25	51	97	210	70	-5	0	40	65
86042718	5	9.1N	139.3E	22	24	84	194	75	-5	10	50	70
86042800	6	9.6N	139.3E	6	139	264	346	80	-5	25	55	75
86042806	7	9.9N	139.3E	8	118	294	608	90	-5	35	60	55
86042812	8	10.1N	139.1E	18	125	299	539	85	0	40	60	60
86042818	9	10.2N	138.9E	30	156	354	565	80	10	40	45	45
86042900	10	10.3N	138.7E	6	30	126	156	70	5	5	30	35
86042906	11	10.3N	138.4E	0	48	133	149	60	5	5	30	40
86042912	12	10.3N	138.1E	8	37	70	43	55	5	0	5	0
86042918	13	10.3N	137.8E	6	57	80	59	50	5	0	15	25
86043000	14	10.3N	137.4E	13	72	88	88	45	5	5	20	30
86043006	15	10.2N	137.1E	12	59			40	5	0		
86043012	16	10.1N	136.7E	30				40	0			
86043018	17	9.8N	136.2E	48				35	0			
86050100	18	9.6N	135.7E	8				30	0			
		AVERAGE		17	78	178	288					
		# OF CASES		18	15	14	14					

Super Typhoon Lola (03W)

DTG	W#	BT Lat	BT Lon	Pos Er	24 Er	48 Er	72 Er	BT Wn	WW Er	24 WE	48 WE	72 WE
86051700	1	7.8N	159.7E	48	166	157	274	40	-10	-20	-60	-75
86051706	2	8.0N	159.6E	12	78	165	335	50	0	-10	-55	-50
86051712	3	8.0N	159.4E	25	53	142	293	55	0	-10	-60	-40
86051718	4	8.1N	159.2E	38	34	76	248	60	0	-15	-65	-30
86051800	5	8.2N	159.0E	12	86	259	477	65	0	-35	-50	-20
86051806	6	8.6N	159.0E	8	90	264	461	75	0	-40	-35	-5
86051812	7	9.3N	158.9E	8	68	275	486	80	0	-40	-25	5
86051818	8	9.8N	158.5E	13	98	285	541	90	0	-35	5	30
86051900	9	10.3N	158.0E	6	140	303	642	115	0	5	25	65
86051906	10	11.0N	157.1E	0	118	340	785	130	0	15	35	65
86051912	11	11.6N	156.3E	8	68	285	828	140	-5	20	40	65
86051918	12	12.3N	155.4E	6	100	383	1028	150	0	35	55	70
86052000	13	13.4N	154.2E	8	104	406	947	140	10	0	15	15
86052006	14	14.4N	153.2E	8	68	204	792	135	-5	-5	5	15
86052012	15	15.2N	152.3E	6	120	414		130	5	-5	15	
86052018	16	16.3N	151.5E	8	138	510		125	0	10	30	
86052100	17	17.5N	150.9E	6	159	628		120	0	25	35	
86052106	18	18.9N	150.5E	6	178	778		115	0	20	35	
86052112	19	20.4N	150.3E	6	176			110	0	15		
86052118	20	22.1N	150.5E	17	244			95	10	25		
86052200	21	23.8N	151.0E	6	239			80	0	5		
86052206	22	25.8N	152.1E	6	338			80	0	10		
86052212	23	27.8N	153.9E	6				75	0			
86052218	24	30.2N	156.3E	12				65	0			

86052300	25	32.8N	159.9E	8				55	0			
86052306	26	35.3N	164.4E	10				50	0			
		AVERAGE		11	130	326	581					
		# OF CASES		26	22	18	14					

Tropical Storm Mac (04W)

DTG	W#	BT Lat	BT Lon	Pos Er	24 Er	48 Er	72 Er	BT Wn	WW Er	24 WE	48 WE	72 WE
86052600	1	20.8N	121.2E	19	110	104	33	35	0	-5	15	10
86052606	2	21.3N	121.7E	42	109	142	65	45	0	15	30	25
86052612	3	22.0N	122.0E	6	123	265	169	45	5	15	25	20
86052618	4	22.6N	122.1E	29	168	255		45	0	15	15	
86052700	5	23.2N	122.6E	13	118	139		45	0	20	15	
86052706	6	23.3N	122.8E	12	29	203		40	0	15	20	
86052712	7	23.5N	123.0E	11	70	209		40	-5	10	25	
86052718	8	23.5N	123.3E	12	86			35	0	10		
86052800	9	23.5N	123.6E	16	166			30	5	10		
86052806	10	23.4N	124.1E	6	196			30	5	-5		
86052812	11	23.4N	125.1E	13	180			30	0	-5		
86052818	12	23.7N	126.3E	13				30	0			
86052900	13	24.0N	127.7E	0				30	0			
86052906	14	24.4N	129.3E	0				30	0			
86052912	15	24.9N	130.9E	6				25	0			
		AVERAGE		13	123	188	89					
		# OF CASES		15	11	7	3					

Typhoon Nancy (05W)

DTG	W#	BT Lat	BT Lon	Pos Er	24 Er	48 Er	72 Er	BT Wn	WW Er	24 WE	48 WE	72 WE
86062118	1	14.2N	129.1E	13	74	198	707	30	0	-15	-20	-5
86062200	2	15.5N	127.8E	18	59	128	508	50	0	-10	-10	5
86062206	3	16.6N	126.4E	0	31	104	347	55	0	5	15	20
86062212	4	17.8N	125.3E	21	60	101		65	0	-10	10	
86062218	5	18.9N	124.1E	12	42	244		70	0	-5	5	
86062300	6	20.0N	123.0E	6	24	300		75	0	5	15	
86062306	7	21.3N	122.2E	0	88	310		75	-5	0	15	
86062312	8	22.5N	121.8E	6	152			80	0	20		
86062318	9	23.7N	121.7E	6	341			70	0	10		
86062400	10	25.6N	121.7E	17	131			65	0	0		
86062406	11	28.1N	121.9E	20	145			55	0	5		
86062412	12	29.8N	123.7E	28				50	0			
86062418	13	32.1N	127.5E	107				50	0			
86062500	14	34.5N	129.6E	51				45	0			
86062506	15	36.3N	132.5E	34				30	10			
		AVERAGE		23	104	198	521					
		# OF CASES		15	11	7	3					

Tropical Storm Owen (06W)

DTG	W#	BT Lat	BT Lon	Pos Er	24 Er	48 Er	72 Er	BT Wn	WW Er	24 WE	48 WE	72 WE
86062800	1	15.3N	135.3E	24	106	165	203	30	0	10	10	30
86062806	2	15.3N	134.3E	35	49	69	17	35	0	10	20	35
86062812	3	15.6N	133.2E	24	68	111	74	35	0	10	30	55
86062818	4	16.0N	132.4E	59	129	147	86	35	5	10	35	55
86062900	5	16.3N	131.5E	13	52	54	157	35	0	-5	15	35
86062906	6	16.5N	130.6E	6	42	109	229	40	0	5	25	35
86062912	7	16.7N	129.9E	6	38	132		45	5	15	30	
86062918	8	17.0N	129.2E	6	38	172		50	0	20	30	
86063000	9	17.5N	128.6E	27	85	242		50	-10	10	15	
86063006	10	18.1N	128.0E	6	70	197		45	-5	0	5	
86063012	11	18.7N	127.6E	0	66			45	0	0		
86063018	12	19.3N	127.2E	30	38			40	0	-5		
86070100	13	20.2N	126.8E	8	142			40	0	0		
86070106	14	21.8N	127.0E	8	60			40	0	0		
86070112	15	23.1N	127.3E	0				35	0			
86070118	16	24.4N	127.6E	13				35	0			
86070200	17	25.7N	128.0E	13				30	0			
		AVERAGE		16	70	140	128					
		# OF CASES		17	14	10	6					

Super Typhoon Peggy (07W)

DTG	W#	BT Lat	BT Lon	Pos Er	24 Er	48 Er	72 Er	BT Wn	WW Er	24 WE	48 WE	72 WE
86070300	1	13.9N	151.8E	35	77	117	164	30	0	-5	-30	-30
86070306	2	14.0N	150.6E	8	68	87	146	35	-5	-15	-35	-35

DTG	W#	BT Lat	BT Lon	Pos Er	24 Er	48 Er	72 Er	BT Wn	WW Er	24 WE	48 WE	72 WE
86070312	3	14.1N	149.2E	23	74	116	189	40	-5	-20	-35	-40
86070318	4	14.3N	147.8E	12	18	54	71	45	-10	-30	-40	-40
86070400	5	14.4N	146.4E	6	12	49	90	55	0	-20	-30	-35
86070406	6	14.6N	145.2E	8	27	78	212	60	0	-20	-30	-25
86070412	7	14.7N	144.0E	12	55	154	298	70	0	-15	-35	-15
86070418	8	14.8N	142.7E	17	61	125	198	85	-15	-25	-30	-10
86070500	9	15.0N	141.3E	0	54	105	177	95	-5	-10	-20	10
86070506	10	15.0N	140.0E	6	62	170	371	100	0	-5	-5	5
86070512	11	15.1N	138.7E	0	79	269	484	105	0	0	15	25
86070518	12	15.3N	137.3E	6	100	293	524	115	5	5	20	35
86070600	13	15.5N	136.0E	6	25	109	345	120	0	-10	10	45
86070606	14	15.7N	134.5E	12	21	213	462	125	0	5	20	45
86070612	15	16.0N	133.2E	0	60	292	520	135	-5	15	25	45
86070618	16	16.4N	131.8E	6	138	377	573	135	0	15	30	45
86070700	17	16.7N	130.4E	8	155	386	608	140	0	20	40	50
86070706	18	16.9N	129.0E	6	146	374	602	135	5	15	35	55
86070712	19	17.1N	127.7E	13	132	309	503	130	0	0	20	15
86070718	20	17.3N	126.5E	25	151	309	525	125	0	5	15	10
86070800	21	17.3N	125.6E	8	18	103	183	120	-5	5	10	-15
86070806	22	17.4N	124.6E	6	38	114	210	115	5	10	25	-15
86070812	23	17.6N	123.6E	0	79	156	175	110	0	5	25	-5
86070818	24	17.8N	122.7E	17	116	198		100	0	15	0	
86070900	25	17.9N	122.0E	0	17	41		90	0	10	5	
86070906	26	18.1N	121.4E	6	34	22		85	0	10	20	
86070912	27	18.6N	120.8E	6	41	13		80	0	10	10	
86070918	28	19.1N	120.2E	21	59			75	0	0		
86071000	29	19.5N	119.4E	8	49			70	0	5		
86071006	30	19.9N	118.8E	6	58			65	5	5		
86071012	31	20.7N	118.2E	21	69			65	5	15		
86071018	32	21.4N	117.4E	17				65	0			
86071100	33	22.3N	116.6E	6				60	0			
86071106	34	22.9N	115.7E	41				50	5			
86071112	35	23.5N	114.8E	16				40	0			
		AVERAGE		11	68	172	332					
		# OF CASES		35	31	27	23					

Typhoon Roger (08W)

DTG	W#	BT Lat	BT Lon	Pos Er	24 Er	48 Er	72 Er	BT Wn	WW Er	24 WE	48 WE	72 WE
86071300	1	16.7N	139.4E	0	108	174	211	40	0	-30	-5	5
86071306	2	17.6N	138.1E	50	128	177	218	45	0	0	-10	5
86071312	3	18.6N	137.0E	18	51	117	232	55	0	0	-10	25
86071318	4	19.6N	136.1E	23	66	138	311	60	-5	0	0	35
86071400	5	20.6N	135.1E	8	22	71	16	65	5	5	5	15
86071406	6	21.4N	134.1E	6	49	130		65	0	-25	-25	
86071412	7	22.3N	133.0E	6	48	81		65	-5	-35	-25	
86071418	8	23.0N	132.0E	0	40	39		70	-10	-30	-15	
86071500	9	23.9N	131.1E	55	79	18		75	0	-15	-20	
86071506	10	24.6N	130.5E	12	91			80	-5	-15		
86071512	11	25.2N	129.9E	6	20			85	-5	-10		
86071518	12	25.8N	129.4E	6	65			80	-10	-5		
86071600	13	26.4N	129.1E	6	94			75	0	0		
86071606	14	27.2N	128.9E	0	109			70	0	0		
86071612	15	28.2N	129.2E	12	157			65	0	0		
86071618	16	29.3N	129.6E	0				55	0			
86071700	17	30.6N	130.7E	8				55	0			
86071706	18	31.9N	132.4E	8				45	0			
86071712	19	32.8N	134.8E	8				45	0			
		AVERAGE		12	75	105	198					
		# OF CASES		19	15	9	5					

Tropical Storm Sarah (09W)

DTG	W#	BT Lat	BT Lon	Pos Er	24 Er	48 Er	72 Er	BT Wn	WW Er	24 WE	48 WE	72 WE
86073012	1	15.2N	130.5E	24	139	190	147	30	0	5	20	30
86073018	2	15.5N	129.3E	6	85	257	564	30	0	10	15	0
86073100	3	15.9N	128.1E	18	96	341	693	30	0	0	15	-5
86073106	4	16.3N	126.9E	35	172	453	806	35	-5	5	20	-10
86073112	5	16.6N	125.8E	13	183	495	831	40	-10	-5	0	-20
86073118	6	16.7N	125.0E	6	182	562	971	40	0	0	5	-20
86080100	7	16.9N	124.2E	18	171	562	1092	45	0	0	10	0
86080106	8	17.1N	124.2E	52	324	706	1294	45	5	5	25	-10
86080112	9	17.4N	124.0E	123	447	776		45	0	10	-5	
86080118	10	18.0N	124.1E	160	506	893		45	0	10	-10	
86080200	11	18.5N	124.8E	288	621	1067		45	-5	-5	5	
86080206	12	19.0N	125.3E	29	68	912		45	0	5	40	
86080212	13	19.8N	126.2E	6	183	1002		50	-5	-5	10	

DTG	W#	BT Lat	BT Lon	Pos Er	24 Er	48 Er	72 Er	BT Wn	WW Er	24 WE	48 WE	72 WE
86080218	14	20.5N	126.9E	11	306	1186		50	-5	-5	5	
86080300	15	21.3N	127.8E	6	245			55	-5	0		
86080306	16	22.0N	128.5E	13	414			50	0	5		
86080312	17	23.3N	129.6E	39	332			50	-5	10		
86080318	18	25.3N	131.6E	42	439							
86080400	19	27.8N	133.8E	24				40	0			
86080406	20	30.3N	136.7E	71				35	5			
86080412	21	33.3N	139.9E	51				30	5			
86080418	22	36.2N	143.0E	173				30	0			
		AVERAGE		55	273	671	800					
		# OF CASES		22	18	14	8					

Typhoon Georgette (11E)

DTG	W#	BT Lat	BT Lon	Pos Er	24 Er	48 Er	72 Er	BT Wn	WW Er	24 WE	48 WE	72 WE
86080906	1	14.6N	176.3E	8	44	214	472	40	-5	0	0	10
86080912	2	14.9N	175.1E	6	58	294	574	45	0	10	25	40
86080918	3	15.1N	173.9E	6	92	346	583	45	5	5	20	40
86081000	4	15.3N	172.7E	13	144	391	578	50	-5	0	10	25
86081006	5	15.4N	171.7E	13	101	327	432	55	0	10	30	50
86081012	6	15.6N	170.9E	17	179	458	521	60	0	15	35	60
86081018	7	15.7N	170.4E	30	184	358	366	65	0	10	30	65
86081100	8	15.9N	170.0E	6	127	251	208	65	0	0	0	40
86081106	9	16.0N	169.7E	18	134	228	262	65	0	5	20	45
86081112	10	16.2N	169.5E	12	91	198	366	65	0	5	25	45
86081118	11	16.5N	169.4E	37	113	217	430	65	0	5	30	45
86081200	12	16.7N	169.4E	27	138	366	530	65	0	5	35	45
86081206	13	17.1N	169.1E	24	174	472	397	60	10	25	40	55
86081212	14	17.5N	168.5E	8	162	491	170	60	5	30	45	55
86081218	15	18.2N	167.9E	24	217	596	66	60	0	15	15	20
86081300	16	19.0N	167.3E	12	272	548	36	60	0	15	5	5
86081306	17	19.7N	166.3E	8	306	421		50	0	5	0	
86081312	18	20.5N	164.3E	0	244			45	0	-10		
86081318	19	20.8N	162.1E	29	151			40	0	-10		
86081400	20	21.2N	159.9E	6				35	0			
86081406	21	22.0N	157.4E	25				35	0			
86081412	22	22.4N	154.8E	24				35	-5			
86081418	23	21.7N	151.8E	16				35	0			
86081500	24	20.0N	152.0E	6				35	0			
86081506	25	19.1N	153.2E	17				30	0			
86081512	26	19.2N	155.6E	13				30	-5			
		AVERAGE		16	154	363	374					
		# OF CASES		26	19	17	16					

Typhoon Tip (10W)

DTG	W#	BT Lat	BT Lon	Pos Er	24 Er	48 Er	72 Er	BT Wn	WW Er	24 WE	48 WE	72 WE
86081306	1	18.7N	156.9E	6	128	279	387	50	0	5	5	-15
86081312	2	18.8N	156.4E	11	176	393	541	55	0	15	30	20
86081318	3	18.8N	155.9E	6	176	392	558	55	5	20	35	35
86081400	4	18.6N	156.1E	18	144	326	436	60	0	20	15	30
86081406	5	19.0N	156.4E	53	168	329	444	60	0	20	10	30
86081412	6	19.5N	156.4E	0	148	284	490	60	0	15	10	40
86081418	7	19.9N	156.4E	6	135	256	534	60	0	5	15	45
86081500	8	20.5N	156.3E	25	165	296	710	60	0	-5	20	45
86081506	9	21.3N	156.2E	24	145	262	726	60	0	-15	15	40
86081512	10	22.7N	155.9E	24	41	371	917	60	0	-10	15	35
86081518	11	23.7N	154.8E	13	208	562	980	65	-5	-20	20	
86081600	12	24.4N	154.0E	16	208	695	1274	75	-10	10	30	50
86081606	13	24.9N	153.5E	16	156	636	1065	80	-15	10	30	50
86081612	14	25.2N	153.2E	17	231	654	1126	80	-5	20	40	50
86081618	15	25.4N	153.0E	28	290	715	1121	75	0	25	40	55
86081700	16	25.7N	152.9E	11	310	739	1071	70	0	20	35	55
86081706	17	26.2N	153.3E	47	353	676		70	0	-5	-25	
86081712	18	26.5N	154.4E	29	113	181		65	0	-10	-20	
86081718	19	26.8N	155.4E	22	151			60	0	-15		
86081800	20	27.0N	156.7E	32	236			60	0	-10		
86081806	21	27.0N	157.7E	37	108			60	0	-10		
86081812	22	27.0N	158.7E	17	166			55	0	0		
86081818	23	27.0N	159.8E	34	189			55	0	0		
86081900	24	27.1N	161.2E	63				50				
86081906	25	27.5N	162.5E	41				50				
		AVERAGE		24	180	447	774					
		# OF CASES		25	23	18	16					

Tropical Storm Vera#1 (11W)

DTG	W#	BT Lat	BT Lon	Pos Er	24 Er	48 Er	72 Er	BT Wn	WW Er	24 WE	48 WE	72 WE
86081518	1	19.0N	129.4E	13	177	226		30	0	15	35	
86081600	2	18.9N	129.6E	13	167			35	0	15		
86081606	3	18.8N	129.8E	83	227			35	0	30		
86081612	4	18.6N	129.9E	80	100			35	0	15		
86081618	5	18.4N	129.9E	105	81			40	-5	15		
86081700	6	18.2N	129.8E	17				40	0			
86081706	7	17.9N	129.0E	65				30	10			
		AVERAGE		54	150	226	####					
		# OF CASES		7	5	1	0					

Typhoon Vera#2 (11W)

DTG	W#	BT Lat	BT Lon	Pos Er	24 Er	48 Er	72 Er	BT Wn	WW Er	24 WE	48 WE	72 WE
86081712	1	21.3N	137.0E	69	151	215	583	30	10	0	0	-20
86081718	2	22.1N	137.4E	45	140	312	699	35	5	0	-5	-25
86081800	3	22.5N	137.6E	72	295	686	1021	40	0	-5	-25	-50
86081806	4	22.9N	137.7E	8	232	576	859	40	0	5	-25	-60
86081812	5	23.5N	137.9E	12	236	554	876	45	0	5	-30	-65
86081818	6	23.5N	137.4E	37	306	604	918	45	5	5	-30	-70
86081900	7	22.7N	137.9E	0	27	434	706	50	0	-10	-30	-65
86081906	8	22.6N	138.8E	50	297	484	734	50	0	-20	-40	-60
86081912	9	22.7N	140.1E	8	179	272	450	50	0	-20	-50	-60
86081918	10	22.4N	141.0E	8	151	194	353	55	0	-15	-50	-55
86082000	11	21.4N	141.5E	13	90	62	251	65	5	5	-10	0
86082006	12	21.3N	142.0E	27	64	134	388	70	5	-5	-10	5
86082012	13	21.3N	142.5E	6	62	143	481	75	5	-10	-5	5
86082018	14	21.3N	143.0E	12	42	201	592	80	0	-15	-5	5
86082100	15	21.4N	143.4E	6	33	156	520	85	-5	-20	0	10
86082106	16	21.5N	144.1E	6	34	271	629	95	-5	-5	30	35
86082112	17	21.6N	144.7E	8	83	352	719	100	0	15	35	35
86082118	18	21.7N	145.2E	13	83	376	726	105	0	20	35	35
86082200	19	21.9N	145.6E	6	147	455	852	110	0	30	40	35
86082206	20	22.1N	145.7E	11	222	537	953	110	5	40	40	35
86082212	21	22.2N	145.4E	11	192	469	825	105	15	35	35	30
86082218	22	22.2N	145.0E	18	219	480	787	105	0	-15	-25	-30
86082300	23	22.2N	144.4E	6	126	401	666	100	0	-5	-15	-10
86082306	24	22.1N	143.4E	17	162	451	690	95	0	-10	-20	-20
86082312	25	22.2N	142.4E	0	45	226	322	95	0	0	-10	-20
86082318	26	22.2N	141.0E	0	39	212	289	95	0	-5	-10	-20
86082400	27	22.3N	140.0E	33	67	243	272	90	0	0	10	20
86082406	28	22.8N	138.7E	18	105	253	286	90	0	0	10	25
86082412	29	23.0N	137.2E	6	114	184	180	90	5	10	5	10
86082418	30	23.4N	135.3E	17	104	101	167	90	0	-5	-15	-5
86082500	31	23.9N	133.6E	13	92	61	214	90	0	-10	-15	-10
86082506	32	24.5N	132.0E	18	40	114	479	90	-10	-10	-10	-5
86082512	33	25.0N	130.3E	0	52	40	169	90	0	-15	5	15
86082518	34	25.5N	128.8E	12	100	63	188	85	0	-10	5	15
86082600	35	26.1N	127.5E	8	87	51	392	85	0	-5	5	20
86082606	36	26.7N	126.3E	13	72	128	311	85	0	0	10	30
86082612	37	27.3N	125.5E	21	59	133		90	0	5	20	
86082618	38	27.9N	125.0E	16	86	186		85	0	5	20	
86082700	39	28.8N	124.6E	12	93	396		80	0	5	20	
86082706	40	29.9N	124.2E	22	139	367		75	0	20	25	
86082712	41	31.1N	124.3E	24	169			70	0	10		
86082718	42	32.3N	124.7E	8	75			65	0	-5		
86082800	43	33.7N	125.3E	36	405			65	-5	0		
86082806	44	35.2N	126.1E	12	247			60	-5	10		
86082812	45	36.7N	127.1E	6				50	0			
86082818	46	38.3N	128.6E	11				45	0			
86082900	47	39.9N	130.4E	8				40	0			
86082906	48	42.6N	132.5E	55				30	0			
		AVERAGE		17	131	289	543					
		# OF CASES		48	44	40	36					

Typhoon Wayne (12W)

DTG	W#	BT Lat	BT Lon	Pos Er	24 Er	48 Er	72 Er	BT Wn	WW Er	24 WE	48 WE	72 WE
86081806	1	15.8N	117.1E	12	115	212	374	35	0	-20	-15	-10
86081812	2	16.1N	116.6E	29	73	170	422	45	-10	-20	-5	-15
86081818	3	16.4N	115.9E	17	46	149	407	55	-10	-15	-5	-30
86081900	4	17.1N	115.4E	13	53	227	472	60	0	5	5	-30
86081906	5	17.8N	114.8E	6	42	273		65	0	15	-20	
86081912	6	18.4N	114.2E	8	95	361		65	5	10	-50	
86081918	7	19.0N	113.5E	24	172	410		70	0	-20	-60	
86082000	8	19.7N	113.3E	0	218			70	0	-5		

86082006	9	20.4N	113.6E	6	161			70	0	-50		
86082012	10	21.1N	114.3E	13	149			65	0	-60		
86082018	11	21.8N	115.1E	13	168			65	0	-55		
86082100	12	22.3N	116.3E	17	65	199	322	70	-5	-20	-10	-10
86082106	13	22.8N	117.3E	13	65	197	443	75	-5	40	-5	0
86082112	14	23.2N	118.4E	11	77	210	554	85	-15	-5	-5	10
86082118	15	23.7N	119.3E	11	127	193	501	80	5	5	0	35
86082200	16	24.1N	120.4E	20	141	243	608	70	0	10	10	55
86082206	17	24.7N	121.7E	22	156	420	816	50	15	20	25	55
86082212	18	25.0N	123.0E	8	256	672	1069	50	20	25	40	65
86082218	19	24.9N	124.1E	30	338	783	1158	50	20	5	25	30
86082300	20	24.4N	124.7E	21	318	837		55	-10	-30	0	
86082306	21	24.6N	125.2E	12	380			55	-10	-20		
86082312	22	24.2N	124.6E	16	275			55	-15	-15		
86082318	23	23.7N	123.9E	13	80			60	-20	0		
86082400	24	23.2N	123.5E	11	239			65	-20	0		
86082406	25	22.6N	122.5E	32	208			55	-15	5		
86082412	26	21.7N	121.4E	16	139			45	-10	0		
86082418	27	21.4N	119.9E	30				35	-5			
86082500	28	21.0N	118.7E	51				30	0			
86082506	29	20.8N	117.6E	0				30	0			
86082800	30	19.7N	120.2E	38	160	354	597	35	0	5	-5	-15
86082806	31	20.1N	120.6E	11	160	252	379	35	5	20	15	10
86082812	32	20.3N	120.9E	8	131	211	365	40	5	15	5	10
86082818	33	20.5N	121.0E	16	70	102	254	40	5	0	-10	0
86082900	34	20.6N	121.1E	6	6	40	168	40	0	-5	-25	0
86082906	35	20.7N	121.2E	33	99	193	374	40	0	-5	-10	-5
86082912	36	20.8N	121.3E	0	30	115	362	45	0	0	-10	-15
86082918	37	21.1N	121.4E	0	29	169	390	50	-5	-15	-5	-20
86083000	38	21.5N	121.8E	25	36	192	414	55	-5	-5	5	-10
86083006	39	21.7N	122.1E	6	119	287	445	60	-5	-5	5	
86083012	40	21.9N	122.4E	6	126	331	497	65	-5	5	5	5
86083018	41	21.9N	122.6E	6	108	314	450	70	-5	20	15	35
86083100	42	21.9N	122.8E	6	119	340	477	70	5	30	25	30
86083106	43	21.8N	123.1E	6	138	337	504	75	5	25	25	30
86083112	44	21.6N	123.2E	6	116	310	497	75	5	5	20	35
86083118	45	21.4N	123.2E	6	145	319	539	70	5	0	20	20
86090100	46	21.1N	123.1E	13	119	267	482	70	5	-5	15	0
86090106	47	20.8N	122.7E	13	109	150	165	75	0	-10	0	-25
86090112	48	20.3N	122.5E	6	92	131	242	85	-5	-5	-5	-15
86090118	49	19.9N	122.2E	25	25	132	331	85	-5	0	-15	-10
86090200	50	19.5N	121.9E	12	21	46	254	85	0	15	-10	0
86090206	51	19.2N	121.7E	18	47	168	400	85	0	15	-5	0
86090212	52	19.1N	121.3E	12	53	235	440	80	0	5	-5	5
86090218	53	19.3N	120.7E	30	72	273	504	75	5	-5	0	10
86090300	54	19.0N	120.0E	6	62	270	531	70	0	-30	-15	5
86090306	55	18.5N	119.3E	24	121	323	593	70	0	-25	-15	20
86090312	56	18.4N	118.5E	0	138	269		75	-5	-5	10	
86090318	57	18.4N	117.7E	8	88	187		85	-15	0	10	
86090400	58	18.9N	116.8E	6	107	304		90	0	5	20	
86090406	59	19.4N	115.4E	8	111	411		85	0	-10	0	
86090412	60	19.6N	113.7E	8	139			80	5	-35		
86090418	61	19.6N	112.4E	0	91			75	5	-30		
86090500	62	19.9N	111.2E	6	170			70	5	-15		
86090506	63	20.3N	109.8E	8				70	0			
86090512	64	20.6N	108.4E	8				65	0			
86090518	65	20.3N	106.7E	25				60	5			
86090600	66	19.8N	104.9E	34				45	5			
86090606	67	19.7N	103.2E	21				30	10			
		AVERAGE		14	124	274	468					
		# OF CASES		67	59	46	38					

Typhoon Abby (13W)

DTG	W#	BT Lat	BT Lon	Pos Er	24 Er	48 Er	72 Er	BT Wn	WW Er	24 WE	48 WE	72 WE
86091306	1	12.0N	146.2E	21	292	363	381	25	0	0	10	35
86091312	2	12.6N	144.8E	12	271	267	202	30	0	0	15	35
86091318	3	13.4N	142.5E	65	348	134	51	30	0	-10	15	30
86091400	4	14.3N	140.4E	13	42	36	153	35	-5	10	20	
86091406	5	15.1N	138.2E	48	6	79	207	35	-5	5	15	20
86091412	6	15.2N	136.0E	12	153	223	307	40	0	10	20	20
86091418	7	15.8N	135.0E	24	126	214	295	45	-5	10	20	20
86091500	8	16.7N	134.2E	12	25	48	157	50	0	5	0	10
86091506	9	17.7N	133.4E	33	29	94	187	55	-5	0	-5	5
86091512	10	18.0N	132.2E	17	90	192	330	55	0	5	-5	-5
86091518	11	18.3N	131.2E	17	78	180	310	60	-5	5	0	-5
86091600	12	18.8N	130.3E	13	120	264	432	60	-5	0	-5	5
86091606	13	19.3N	129.5E	41	133	224	313	65	-5	-5	-5	10
86091612	14	19.5N	128.6E	18	39	123	197	65	0	-10	-10	5

DTG	W#	BT Lat	BT Lon	Pos Er	24 Er	48 Er	72 Er	BT Wn	WW Er	24 WE	48 WE	72 WE
86091618	15	19.6N	127.8E	34	57	156	167	70	-5	-10	-5	15
86091700	16	19.8N	127.2E	6	74	140	74	75	0	-5	0	40
86091706	17	20.3N	126.6E	8	89	175	143	80	-5	-5	5	45
86091712	18	20.8N	125.8E	6	114	198	147	85	0	0	20	60
86091718	19	21.0N	125.1E	21	115	143		85	0	5	30	
86091800	20	21.3N	124.3E	18	94	79		90	0	15	50	
86091806	21	21.9N	123.6E	13	104	169		90	5	15	45	
86091812	22	22.3N	122.9E	0	38	29		95	0	15	55	
86091818	23	22.6N	122.1E	0	45			90	0	20		
86091900	24	23.2N	121.5E	8	12			90	5	25		
86091906	25	23.9N	121.2E	19	61			85	5	45		
86091912	26	24.6N	121.3E	0	156			80	10	45		
86091918	27	25.4N	121.4E	12				70	10			
86092000	28	26.4N	121.8E	16				55	0			
86092006	29	27.6N	122.5E	36				45	0			
86092012	30	29.2N	123.7E	20				35	5			
		AVERAGE		19	104	160	225					
		# OF CASES		30	26	22	18					

Typhoon Ben (14W)

DTG	W#	BT Lat	BT Lon	Pos Er	24 Er	48 Er	72 Er	BT Wn	WW Er	24 WE	48 WE	72 WE
86091900	1	10.5N	160.4E	139	380	469	590	30	0	10	15	40
86091906	2	11.0N	159.8E	12	246	307	411	35	0	10	20	50
86091912	3	11.8N	159.4E	49	234	222	242	35	0	10	15	50
86091918	4	12.8N	159.1E	57	174	156	197	35	0	5	20	45
86092000	5	13.8N	158.7E	17	18	80	142	40	0	5	25	40
86092006	6	15.1N	157.9E	31	91	59	19	45	0	15	35	35
86092012	7	15.8N	156.6E	0	108	294	311	45	5	15	50	45
86092018	8	16.1N	155.3E	39	197	355	345	50	5	25	50	40
86092100	9	16.3N	154.1E	13	150	213	161	55	5	35	50	40
86092106	10	16.4N	153.2E	29	167	167	130	55	10	40	45	30
86092112	11	16.5N	152.7E	50	156	109	86	60	10	45	40	25
86092118	12	16.6N	152.2E	68	154	100	95	55	15	35	20	0
86092200	13	16.7N	151.7E	8	64	116	91	50	10	5	-10	-20
86092206	14	16.7N	151.3E	12	121	162	108	45	10	5	-15	-15
86092212	15	16.8N	150.7E	6	153	183	87	45	5	-5	-25	-10
86092218	16	16.9N	149.9E	13	173	191	114	50	5	-10	-30	-10
86092300	17	17.2N	148.7E	13	30	50	174	55	10	5	-20	10
86092306	18	17.5N	147.3E	26	67	119	291	60	10	0	5	10
86092312	19	17.8N	146.0E	13	51	125	287	70	5	-10	-5	20
86092318	20	18.0N	144.8E	11	57	154	291	80	0	-15	-5	20
86092400	21	18.4N	143.7E	13	21	127	268	85	5	-10	15	35
86092406	22	18.7N	142.7E	18	62	200	336	95	0	0	25	40
86092412	23	19.2N	141.7E	18	102	227	364	105	0	20	40	35
86092418	24	19.4N	140.8E	18	102	253	386	115	0	25	45	40
86092500	25	19.7N	140.0E	6	51	191	317	120	5	20	20	20
86092506	26	20.0N	139.4E	6	84	230	447	115	5	10	5	10
86092512	27	20.5N	139.1E	12	89	245	339	110	0	5	0	-5
86092518	28	20.8N	138.8E	18	84	243	369	110	-5	0	-5	-5
86092600	29	21.2N	138.7E	6	62	105	122	105	0	-5	-10	-10
86092606	30	21.4N	138.7E	8	69	98	239	100	0	-5	-10	-5
86092612	31	21.6N	138.7E	8	115	295	547	95	5	-5	-20	-30
86092618	32	21.9N	138.9E	6	90	257	451	95	5	-10	-20	-35
86092700	33	22.2N	139.2E	11	93	300		95	0	-10	-20	
86092706	34	22.6N	139.4E	13	54	280		95	-5	-15	-20	
86092712	35	23.2N	139.8E	16	128	371		90	-5	-20	-15	
86092718	36	23.9N	140.2E	13	163	346		90	-5	-15	-15	
86092800	37	24.8N	140.7E	13	62	138		85	0	-15	-10	
86092806	38	26.1N	141.4E	12	115	214		85	-5	-10	-10	
86092812	39	27.4N	142.1E	13	163			85	0	-10		
86092818	40	29.0N	142.7E	13	95			80	0	-15		
86092900	41	30.8N	143.5E	24	60			75	0	-5		
86092906	42	32.7N	144.8E	16	41			70	0	0		
86092912	43	34.5N	146.6E	24				65	5			
86092918	44	36.0N	148.7E	49				65	0			
86093000	45	37.4N	151.1E	20				55	5			
86093006	46	38.9N	154.1E	9				50	0			
		AVERAGE		22	112	204	261					
		# OF CASES		46	42	38	32					

Typhoon Carmen (15W)

DTG	W#	BT Lat	BT Lon	Pos Er	24 Er	48 Er	72 Er	BT Wn	WW Er	24 WE	48 WE	72 WE
86100200	1	10.9N	152.9E	85	139	173	254	35	-5	0	5	5
86100206	2	11.4N	151.3E	49	126	208	264	40	-5	10	5	5
86100212	3	12.0N	150.7E	31	102	145	193	40	-5	15	15	5
86100218	4	12.7N	149.5E	42	99	109	125	45	-5	15	10	5

86100300	5	13.3N	148.2E	8	8	29	21	45	5	15	15	20
86100306	6	13.8N	146.8E	6	21	48	45	45	10	15	10	25
86100312	7	14.3N	145.5E	8	13	54	81	50	10	20	5	25
86100318	8	14.8N	144.2E	8	19	83	63	55	5	10	0	25
86100400	9	15.5N	143.2E	6	48	115	47	60	5	5	10	35
86100406	10	16.1N	142.3E	18	102	146	43	65	0	-5	5	25
86100412	11	16.7N	141.7E	6	72	71	152	65	5	-5	15	25
86100418	12	17.3N	140.9E	13	70	34	266	75	0	-5	20	20
86100500	13	17.9N	140.2E	6	51	16	300	85	-10	5	10	-5
86100506	14	18.6N	139.5E	0	37	55	324	90	-5	10	0	-5
86100512	15	19.2N	138.8E	0	6	165	417	95	-5	15	0	5
86100518	16	19.7N	138.3E	8	41	294		100	-5	15	0	
86100600	17	20.4N	138.0E	6	85	315		95	0	5	-10	
86100606	18	21.3N	137.8E	25	129	361		90	5	0	-10	
86100612	19	22.4N	137.8E	8	21	246		85	5	-15	-15	
86100618	20	23.5N	138.0E	16	74			85	0	-20		
86100700	21	24.5N	138.5E	6	192			80	0	-20		
86100706	22	26.5N	139.5E	18	171			80	0	-20		
86100712	23	28.7N	140.8E	12	308			80	0	-15		
86100718	24	31.0N	142.0E	0				80	-10			
86100800	25	33.3N	143.2E	12				80	-5			
86100806	26	35.4N	144.8E	0				70	-5			
86100812	27	37.4N	146.8E	15				60	0			
		AVERAGE		15	84	140	173					
		# OF CASES		27	23	19	15					

Tropical Storm Dom (16W)

DTG	W#	BT Lat	BT Lon	Pos Er	24 Er	48 Er	72 Er	BT Wn	WW er	24 WE	48 WE	72 WE
86100900	1	15.4N	114.9E	6	25	12	29	40	5	25	30	25
86100906	2	16.0N	114.0E	12	24	34		40	10	30	15	
86100912	3	16.3N	113.3E	27	32	50		45	0	5	5	
86100918	4	16.6N	112.6E	79	137	144		45	-5	-5	-10	
86101000	5	16.8N	111.7E	76	104			40	0	-5		
86101006	6	17.0N	110.9E	42	42			40	5	0		
86101012	7	17.1N	110.1E	12	17			35	5	5		
86101018	8	17.2N	109.3E	6	160			35	0	0		
86101100	9	17.3N	108.5E	6	54			35	0	-5		
86101106	10	17.3N	107.7E	8				35	0			
86101112	11	17.4N	106.9E	0				30	0			
		AVERAGE		25	66	60	29					
		# OF CASES		11	9	4	1					

Typhoon Ellen (17W)

DTG	W#	BT Lat	BT Lon	Pos Er	24 Er	48 Er	72 Er	BT Wn	WW ER	24 WE	48 WE	72 WE
86101100	1	10.8N	126.6E	8	132	185	217	45	0	5	-10	-10
86101106	2	11.2N	125.1E	22	119	139	213	45	5	5	-10	-10
86101112	3	11.6N	123.7E	13	49	80	144	45	0	0	0	-5
86101118	4	12.0N	122.3E	19	42	121	194	40	0	0	-5	-5
86101200	5	12.6N	121.1E	23	48	125	166	40	0	0	-5	5
86101206	6	13.2N	120.0E	17	73	182	228	40	5	0	0	10
86101212	7	13.9N	119.3E	32	158	225	302	45	-5	0	-5	15
86101218	8	14.5N	118.7E	60	199	264	320	50	-5	5	5	10
86101300	9	15.1N	118.2E	8	84	118	170	55	-5	0	15	10
86101306	10	15.5N	118.0E	19	95	124	161	60	0	5	15	10
86101312	11	15.9N	118.0E	13	29	61	140	60	0	0	20	15
86101318	12	16.4N	118.0E	8	6	59	185	65	0	5	20	15
86101400	13	16.9N	118.0E	6	49	108	299	70	0	10	5	5
86101406	14	17.4N	118.0E	0	83	202	425	75	0	5	5	0
86101412	15	17.8N	117.3E	35	107	272	516	80	0	10	5	0
86101418	16	17.9N	117.6E	25	95	287	520	80	-5	-5	-10	-10
86101500	17	18.0N	117.4E	6	18	130	253	75	0	-10	-5	5
86101506	18	18.3N	117.3E	6	36	147	286	75	0	-5	-5	10
86101512	19	18.6N	117.2E	6	97	235	447	70	0	0	0	10
86101518	20	18.8N	117.1E	6	99	226	469	70	-5	-10	-5	5
86101600	21	19.0N	116.8E	17	120	225	466	75	0	0	5	10
86101606	22	19.2N	116.5E	6	101	237		70	5	0	10	
86101612	23	19.4N	116.0E	0	25	25		65	0	-5	5	
86101618	24	19.7N	115.4E	8	40	22		65	0	-5	10	
86101700	25	20.1N	114.9E	0	109	187		65	0	-5	5	
86101706	26	20.4N	114.6E	6	52			65	0	0		
86101712	27	20.7N	114.2E	19	34			60	0	0		
86101718	28	20.9N	113.9E	6	41			55	0	5		
86101800	29	21.1N	113.5E	0	123			50	0	10		
86101806	30	21.1N	113.1E	8				45	5			
86101812	31	21.1N	112.6E	0				40	5			

DTG	W#	BT Lat	BT Lon	Pos Er	24 Er	48 Er	72 Er	BT Wn	WW ER	24 WE	48 WE	72 WE
86101818	32	21.1N	112.0E	6				35	5			
86101900	33	20.1N	111.1E	66				30	5			
		AVERAGE		14	78	159	291					
		# OF CASES		33	29	25	21					

Typhoon Forrest (18W)

DTG	W#	BT Lat	BT Lon	Pos Er	24 Er	48 Er	72 Er	BT Wn	WW ER	24 WE	48 WE	72 WE
86101518	1	15.6N	153.6E	52	151	138	57	55	-25	-35	-15	0
86101600	2	16.3N	151.9E	8	91	34	141	60	5	-15	10	25
86101606	3	16.9N	150.2E	24	79	38	164	65	5	-25	10	30
86101612	4	17.5N	148.3E	6	80	169	226	70	5	0	10	25
86101618	5	18.2N	146.8E	18	135	251	247	90	-5	10	20	30
86101700	6	18.7N	145.3E	0	67	223	657	100	-5	25	25	35
86101706	7	19.4N	144.3E	0	64	290	869	110	-10	20	25	40
86101712	8	20.1N	143.3E	6	84	352	1060	95	0	-5	0	25
86101718	9	20.6N	142.7E	8	76	426		90	5	-15	-10	
86101800	10	21.2N	142.2E	6	83	557		90	0	-15	-10	
86101806	11	21.7N	142.2E	8	135	738		90	-5	-15	0	
86101812	12	22.2N	142.3E	6	198	927		90	-5	-10	15	
86101818	13	22.7N	142.5E	17	356			90	-5	-5		
86101900	14	23.5N	143.3E	13	444			85	-5	0		
86101906	15	24.4N	144.7E	8	512			80	0	0		
86101912	16	25.8N	146.7E	37	580			75	0	15		
86101918	17	27.8N	149.3E	40				70	-10			
86102000	18	31.1N	152.9E	62				65	-10			
86102006	19	34.3N	156.7E	16				55	-5			
		AVERAGE		18	196	345	427					
		# OF CASES		19	16	12	8					

Tropical Storm Georgia (19W)

DTG	W#	BT Lat	BT Lon	Pos Er	24 Er	48 Er	72 Er	BT Wn	WW ER	24 WE	48 WE	72 WE
86101806	1	11.5N	127.3E	6	106	264	388	45	-10	10	-15	-5
86101812	2	12.0N	126.2E	6	111	227	381	50	-5	-5	-15	-5
86101818	3	12.3N	125.2E	19	175	297	442	55	-10	-10	-15	-5
86101900	4	12.5N	124.2E	23	158	288	491	50	0	-10	10	30
86101906	5	12.8N	123.0E	6	113	296	454	40	0	-5	5	45
86101912	6	13.1N	121.0E	12	89	271	410	35	0	5	15	40
86101918	7	13.2N	119.4E	26	102	387	433	40	0	10	15	25
86102000	8	13.4N	118.1E	19	18	72	214	45	0	10	25	30
86102006	9	13.7N	117.1E	0	47	71		45	0	5	35	
86102012	10	14.0N	115.9E	0	87	155		45	0	5	40	
86102018	11	14.1N	114.6E	17	104	174		45	0	5	45	
86102100	12	14.3N	113.2E	6	50	207		45	0	15	30	
86102106	13	14.5N	111.4E	6	59			50	0	25		
86102112	14	14.9N	110.0E	6	64			50	0	20		
86102118	15	15.2N	108.8E	6				50	0			
		AVERAGE		10	92	226	402					
		# OF CASES		15	14	12	8					

Tropical Storm Herbert (20W)

DTG	W#	BT Lat	BT Lon	Pos Er	24 Er	48 Er	72 Er	BT Wn	WW ER	24 WE	48 WE	72 WE
86110800	1	13.1N	119.9E	13	48	26	101	35	-5	-10	0	11
86110806	2	13.4N	119.0E	12	46	63	158	40	-5	-10	5	15
86110812	3	13.9N	118.2E	35	155	225	299	45	-10	-5	15	25
86110818	4	14.2N	117.6E	42	180	209	311	50	-10	-5	20	30
86110900	5	14.2N	116.9E	8	135	192		55	0	10	15	
86110906	6	14.0N	116.2E	38	106	182		60	0	5	20	
86110912	7	13.8N	115.5E	24	72	84		60	-5	10	30	
86110918	8	13.7N	114.8E	18	44	57		60	-5	15	30	
86111000	9	13.6N	114.0E	13	25			55	5	20		
86111006	10	13.6N	113.1E	0	37			55	5	25		
86111012	11	13.6N	112.2E	13	126			50	0	-5		
86111018	12	13.7N	111.7E	107				45	-5			
86111100	13	13.8N	111.2E	59				45	-5			
86111106	14	13.9N	110.6E	13				40	0			
86111112	15	14.2N	110.1E	13				35	0			
86111118	16	14.4N	109.4E	6				30	0			
		AVERAGE		26	89	130	217					
		# OF CASES		16	11	8	4					

Tropical Storm Ida (21W)

DTG	W#	BT Lat	BT Lon	Pos Er	24 Er	48 Er	72 Er	BT Wn	WW ER	24 WE	48 WE	72 WE
86111018	1	6.0N	133.5E	78	99	77	166	30	5	20	5	5
86111100	2	6.4N	132.6E	67	32	128	263	30	5	15	10	-5
86111106	3	6.8N	131.6E	37	60	201	259	25	10	10	15	0
86111112	4	7.4N	130.5E	18	72	237	322	30	5	5	15	5
86111118	5	8.0N	129.4E	6	102	232	373	35	5	5	10	15
86111200	6	8.6N	128.2E	8	88	165	341	40	5	0	10	5
86111206	7	9.2N	127.1E	30	118	186	384	45	5	5	5	10
86111212	8	9.9N	126.1E	6	157	244	366	45	5	10	5	20
86111218	9	10.7N	124.9E	17	155	246	373	40	5	5	15	30
86111300	10	11.8N	123.7E	48	127	223	331	35	5	0	0	40
86111306	11	12.8N	122.2E	32	18	120	395	30	5	5	10	45
86111312	12	13.4N	120.6E	6	87	278		30	5	5	20	
86111318	13	13.8N	119.2E	21	107	385		35	5	15	30	
86111400	14	14.0N	118.0E	6	134	379		40	5	0	35	
86111406	15	14.7N	116.8E	13	173	436		45	0	10	45	
86111412	16	15.7N	115.9E	32	230			45	5	15		
86111418	17	16.7N	115.1E	66	248			40	10	15		
86111500	18	17.8N	114.2E	13	288			55	0	20		
86111506	19	18.5N	113.9E	11	346			50	5	15		
86111512	20	19.5N	114.2E	68				45	0			
86111518	21	20.2N	115.0E	102				35	5			
86111600	22	20.0N	116.0E	23				30	10			
		AVERAGE		32	139	236	325					
		# OF CASES		22	19	15	11					

Typhoon Joe (22W)

DTG	W#	BT Lat	BT Lon	Pos Er	24 Er	48 Er	72 Er	BT Wn	WW ER	24 WE	48 WE	72 WE
86111818	1	13.6N	128.0E	12	67	56	177	40	-10			
86111900	2	13.7N	127.1E	12	59	242	508	45	-5			
86111906	3	13.8N	126.1E	13	109	307	579	50	0			
86111912	4	14.3N	125.4E	8	134	291	424	55	0			
86111918	5	14.8N	124.8E	21	184	351	453	60	0			
86112000	6	15.4N	124.4E	6	80	107	95	65	0			
86112006	7	16.1N	124.2E	19	59	25	271	60	10			
86112012	8	16.7N	124.1E	8	137	474	940	75	0			
86112018	9	17.4N	123.9E	18	137	476		80	0			
86112100	10	18.1N	123.9E	6	132	545		90	0	-25	-30	
86112106	11	18.9N	123.9E	6	177	623		100	0	-25	-30	
86112112	12	19.6N	123.9E	8	200	668		100	0	0		
86112118	13	20.2N	124.0E	0	203	751		100	0	0		
86112200	14	20.7N	124.1E	6	177	737		90	0	-5	-25	
86112206	15	21.2N	124.2E	18	440	1025		85	0	-10	-10	
86112212	16	21.6N	124.4E	6	221	773		75	0	-5	-5	
86112218	17	22.1N	124.6E	8	244	824		70	0	-5	0	
86112300	18	22.5N	124.9E	13	281	866		70	0	-10	0	
86112306	19	22.9N	125.1E	24	222			65	0	15		
86112312	20	23.3N	125.5E	13	122			60	-5	5		
86112318	21	23.7N	125.9E	8	197			55	-5	10		
86112400	22	24.0N	126.3E	18	129			55	0	0		
86112406	23	24.3N	126.8E	6				40	5			
86112412	24	24.5N	127.3E	30								
		AVERAGE		12	169	508	431					
		# OF CASES		24	22	18	8					

Super Typhoon Kim (23W)

DTG	W#	BT Lat	BT Lon	Pos Er	24 Er	48 Er	72 Er	BT Wn	WW ER	24 WE	48 WE	72 WE
86112806	1	7.9N	162.9E	19	60	148	274	40	-10	-10	-5	5
86112812	2	8.4N	161.8E	6	47	182	378	45	-5	-5	5	0
86112818	3	8.8N	160.6E	6	92	234	423	50	-5	-5	5	0
86112900	4	9.1N	159.4E	6	40	246	423	60	0	10	25	10
86112906	5	9.3N	158.4E	6	69	249	393	65	5	10	15	5
86112912	6	9.4N	157.5E	18	109	301	475	70	10	20	5	0
86112918	7	9.7N	156.8E	43	153	318	436	75	10	20	5	-5
86113000	8	10.1N	155.0E	35	148	293	374	80	5	25	0	-5
86113006	9	10.7N	155.2E	21	162	249	322	80	10	20	0	5
86113012	10	11.4N	154.3E	19	142	214	258	80	10	0	-5	-5
86113018	11	12.1N	153.6E	25	153	199	252	85	10	0	-5	-5
86120100	12	13.1N	152.8E	6	48	210	403	85	0	-35	-60	-50
86120106	13	14.0N	152.2E	6	108	287	475	95	-5	-35	-50	-45
86120112	14	14.7N	151.4E	8	145	305	414	110	10	-25	-35	-45
86120118	15	15.2N	150.6E	17	170	378	502	115	-5	-25	-20	-25
86120200	16	15.6N	149.8E	13	136	323	394	120	-5	-10	0	0
86120206	17	15.6N	149.0E	21	141	287	374	125	-5	-5	-5	5

DTG	W#	BT Lat	BT Lon	Pos Er	24 Er	48 Er	72 Er	BT Wn	WW ER	24 WE	48 WE	72 WE
86120212	18	15.5N	148.2E	12	133	264	420	130	0	-5	-10	10
86120218	19	15.5N	147.4E	12	64	70	213	135	0	10	5	25
86120300	20	15.5N	146.5E	0	72	100	141	135	0	15	5	10
86120306	21	15.5N	145.4E	0	44	185	207	130	5	0	0	-5
86120312	22	15.5N	144.2E	0	84	140	204	125	0	-15	5	-10
86120318	23	15.7N	143.0E	0	63	115	255	120	0	-15	5	-15
86120400	24	15.9N	141.9E	8	124	221	393	120	0	-5	10	-25
86120406	25	16.5N	141.1E	8	108	217	414	120	0	5	5	-20
86120412	26	17.4N	140.8E	42	61	299	703	120	0	20	5	-30
86120418	27	17.6N	140.4E	31	99	368	788	115	0	15	-10	-25
86120500	28	17.5N	140.1E	25	193	640	1182	110	-5	5	-35	-20
86120506	29	17.5N	139.9E	11	248	719	1218	100	0	0	-30	-15
86120512	30	17.5N	139.6E	25	286	700	1260	90	0	-10	-30	-15
86120518	31	17.4N	138.9E	27	248	642	1162	85	0	-20	-25	-20
86120600	32	17.2N	138.1E	12	115	70		80	-5	-45		
86120606	33	17.2N	137.1E	34	130	322		85	-15	-45		
86120612	34	17.1N	136.1E	6	97	388		90	-15	-45	-35	
86120618	35	17.2N	135.1E	8	76	341		95	-15	-25	-30	
86120700	36	17.3N	134.2E	12	89	263		100	-10	-15	-25	
86120706	37	17.3N	133.4E	12	107	233		95	-10	-10	-20	
86120712	38	17.2N	132.9E	12	174	305		90	-10	-10	-20	
86120718	39	16.9N	132.7E	32	166	303		80	0	-10	-15	
86120800	40	16.6N	132.6E	18	81	160		75	-5	-10	-15	
86120806	41	16.2N	132.5E	6	91	235		70	-5	-10	-10	
86120812	42	15.9N	132.4E	6	109	235		65	-5	-15	-5	
86120818	43	15.9N	132.6E	24	115	254		65	-5	-15	-5	
86120900	44	16.1N	132.6E	0	80	282		60	0	0	5	
86120906	45	16.1N	132.3E	12	102	252		55	5	5	5	
86120912	46	16.2N	132.1E	6	54	199		55	0	0	10	
86120918	47	16.3N	132.0E	13	109	233		50	5	5	10	
86121000	48	16.3N	131.9E	6	83	219		50	0	10	10	
86121006	49	16.5N	131.8E	17	118	285		45	5	10	10	
86121012	50	16.7N	131.6E	8	135	295		40	5	10	5	
86121018	51	17.3N	131.3E	30	121	288		35	5	5	5	
86121100	52	17.8N	131.1E	12								
		AVERAGE		15	116	280	488					
		# OF CASES		52	51	51	31					

Tropical Storm Lex (24W)

DTG	W#	BT Lat	BT Lon	Pos Er	24 Er	48 Er	72 Er	BT Wn	WW ER	24 WE	48 WE	72 WE
86120318	1	8.1N	163.0E	25	106	150	199	30	0	-5	40	65
86120400	2	8.1N	162.1E	48	133	119	251	35	0	20	45	60
86120406	3	8.3N	161.3E	18	90	133	509	40	0	30	45	60
86120412	4	8.7N	160.5E	35	108	124	451	40	5	35	55	70
86120418	5	9.4N	159.6E	32	30	166	496	35	10	30	50	65
86120500	6	9.8N	158.7E	13	40	199	465	35	10	30	45	65
86120506	7	10.2N	157.5E	8	42	432	543	30	10	20	30	40
86120512	8	10.6N	156.4E	95				30	-5			
		AVERAGE		34	78	189	416					
		# OF CASES		8	7	7	7					

Typhoon Marge (25W)

DTG	W#	BT Lat	BT Lon	Pos Er	24 Er	48 Er	72 Er	BT Wn	WW ER	24 WE	48 WE	72 WE
86121406	1	7.3N	160.0E	48	156	215	119	30	0	15	15	20
86121412	2	7.0N	158.6E	0	125	163	136	30	0	10	5	40
86121418	3	7.2N	157.3E	36	112	152	101	30	0	-5	-15	5
86121500	4	7.3N	155.9E	185	346	427	337	30	0	0	-15	0
86121506	5	7.7N	154.6E	223	404	449	379	35	0	-15	-20	0
86121512	6	8.2N	153.3E	42	90	112	102	40	0	-25	-20	0
86121518	7	8.5N	152.0E	64	110	161	131	45	0	-15	-5	5
86121600	8	8.9N	150.7E	13	24	165	207	50	0	-10	5	10
86121606	9	9.3N	149.5E	42	173	303	303	55	0	5	15	10
86121612	10	9.7N	148.4E	21	140	243	249	65	0	5	15	10
86121618	11	10.2 N	147.2E	24	155	214	159	70	0	5	15	0
86121700	12	10.4 N	146.2E	12	89	104	64	75	0	5	15	0
86121706	13	10.5 N	145.3E	12	67	95	90	70	0	10	15	5
86121712	14	10.6N	144.7E	24	60	53	192	70	0	10	10	10
86121718	15	10.8N	144.0E	19	96	122	297	70	0	10	0	0
86121800	16	10.6N	143.2E	0	59	162	453	70	0	5	-5	0
86121806	17	10.5N	142.0E	17	50	210	462	70	0	5	-10	10
86121812	18	10.5N	140.9E	12	49	233	449	70	0	0	-5	15
86121818	19	10.5N	140.0E	17	72	304	453	70	0	-10	-5	25
86121900	20	10.8N	139.2E	8	55	337	427	70	0	-10	-5	35
86121906	21	11.1N	138.0E	6	104	352	431	75	-5	-15	5	45
86121912	22	11.6N	136.8E	13	193	396	485	80	-5	-10	10	45
86121918	23	12.0N	135.4E	36	282	443	486	90	-15	-5	25	50

DTG	W#	BT Lat	BT Lon	Pos Er	24 Er	48 Er	72 Er	BT Wn	WW ER	24 WE	48 WE	72 WE
86122000	24	11.5N	134.3E	40	284	399	326	90	-15	-5	35	55
86122006	25	10.9N	133.1E	22	263	377	274	95	-10	15	55	60
86122012	26	10.1N	132.7E	22	199	344	370	90	0	20	50	50
86122018	27	9.8N	130.1E	6	98	184		90	0	25	35	
86122100	28	9.2N	128.5E	6	62	49		90	0	20	25	
86122106	29	9.3N	126.9E	6	61	114		80	10	30	25	
86122112	30	9.7N	125.4E	19	24	123		75	5	25	25	
86122118	31	10.0N	123.8E	13	40			60	10	20		
86122200	32	10.1N	122.0E	6	114			50	0	5		
86122206	33	10.3N	121.1E	0	121			40	5	0		
86122212	34	10.7N	120.3E	6				40	0			
86122218	35	11.1N	119.5E	25				40	0			
86122300	36	11.6N	118.9E	40				35	0			
86122306	37	12.1N	118.2E	31				35	0			
86122312	38	12.3N	117.4E	6				30				
		AVERAGE		29	130	233	288					
		# OF CASES		38	33	30	26					

Typhoon Norris (26W)

DTG	W#	BT Lat	BT Lon	Pos Er	24 Er	48 Er	72 Er	BT Wn	WW ER	24 WE	48 WE	72 WE
86122118	1	8.6N	166.9E	84	202	307	345	30	0	10	10	20
86122200	2	8.9N	166.2E	35	102	178	74	30	0	10	10	25
86122206	3	9.2N	165.5E	22	78	115	55	30	0	10	10	20
86122212	4	9.7N	164.5E	31	107	181	231	30	0	0	5	10
86122218	5	10.1N	163.5E	24	82	138	168	30	0	0	10	15
86122300	6	10.6N	162.5E	18	30	124	169	30	5	5	5	15
86122306	7	11.0N	161.5E	19	109	242	244	30	5	5	10	25
86122312	8	11.4N	160.2E	47	174	314	282	35	0	5	10	10
86122318	9	11.5N	159.3E	0	86	189	188	40	-5	10	15	15
86122400	10	11.5N	158.3E	12	90	128	188	40	0	10	10	10
86122406	11	11.6N	156.8E	26	114	151	244	40	0	0	0	-10
86122412	12	11.5N	155.1E	13	107	91	217	40	0	0	-5	-10
86122418	13	11.3N	153.9E	19	88	88	203	40	0	5	0	-10
86122500	14	10.8N	152.8E	19	25	118	213	40	0	-5	-10	-15
86122506	15	10.3N	151.6E	53	65	153	218	45	0	0	-15	-20
86122512	16	10.1N	150.2E	13	145	158	183	45	0	-5	-15	-25
86122518	17	10.2N	149.2E	36	168	182	156	45	0	-5	-10	-30
86122600	18	10.5N	148.4E	12	76	148	106	50	0	0	-5	-20
86122606	19	10.9N	147.3E	6	76	141	117	50	0	-5	-10	-20
86122612	20	11.4N	146.2E	8	54	89	265	55	0	0	-10	-10
86122618	21	11.7N	144.8E	6	13	140	343	55	0	0	-15	-5
86122700	22	11.7N	143.5E	6	53	135	358	60	0	0	-15	
86122706	23	11.8N	142.2E	6	88	220	384	65	0	5	-10	5
86122712	24	12.2N	140.8E	8	123	300	470	65	0	0	0	10
86122718	25	12.5N	139.6E	6	135	339	447	65	5	-5	5	20
86122800	26	13.1N	138.9E	0	159	401	470	70	0	-15	0	20
86122806	27	13.6N	138.3E	19	182	457	748	75	0	-20	-10	10
86122812	28	13.9N	137.8E	6	164	498	836	80	0	5	15	35
86122818	29	13.8N	137.5E	12	217	578	1002	85	0	5	15	30
86122900	30	13.7N	137.3E	0	161	397	679	90	0	5	25	40
86122906	31	13.2N	136.9E	13	207	449	741	90	0	10	30	45
86122912	32	12.7N	136.4E	19	210	449		85	0	15	40	
86122918	33	11.9N	135.6E	35	227	469		80	0	20	35	
86123000	34	11.2N	134.5E	0	155	387		80	0	10	25	
86123006	35	10.5N	133.2E	25	176	431		75	0	10	25	
86123012	36	10.0N	131.8E	13	79			70	0	20		
86123018	37	10.0N	130.1E	6	127			60	0	5		
86123100	38	10.0N	128.3E	0	102			55	0	5		
86123106	39	10.0N	126.7E	6	65			50	0	10		
86123112	40	10.2N	125.1E	0				40	0			
86123118	41	10.4N	123.3E	0				35	0			
		AVERAGE		17	118	254	334					
		# OF CASES		41	39	35	31					

APPENDIX I

DEFINITIONS

BEST TRACK - A subjectively smoothed path, versus a precise and very erratic fix-to-fix path, used to represent tropical cyclone movement.

CENTER - The vertical axis or core of a tropical cyclone. Usually determined by wind, temperature, and/or pressure distribution.

CYCLONE - A closed atmospheric circulation rotating about an area of low pressure (counter-clockwise in the northern hemisphere).

EPHEMERIS - Position of a body (satellite) in space as a function of time; used for gridding satellite imagery. Since ephemeris gridding is based solely on the predicted position of the satellite, it is susceptible to errors from vehicle pitch, orbital eccentricity, and the oblateness of the earth.

EXPLOSIVE DEEPENING - A decrease in the minimum sea-level pressure of a tropical cyclone of 2.5 mb/hr for 12 hours or 5.0 mb/hr for six hours (ATR 1971).

EXTRATROPICAL - A term used in warnings and tropical summaries to indicate that a cyclone has lost its "tropical" characteristics. The term implies both poleward displacement from the tropics and the conversion of the cyclone's primary energy sources from release of latent heat of condensation to baroclinic processes. The term carries no implications as to strength or size.

EYE - A term used to describe the central area of a tropical cyclone when it is more than half the surrounded by wall cloud.

FUJIWHARA EFFECT - An interaction in which tropical cyclones within about 700 nm (1296 km) of each other begin to rotate about one another. When intense tropical cyclones are within about 400 nm (741 km) of each other, they may also begin to move closer to each other.

MAXIMUM SUSTAINED WIND - Highest surface wind speed averaged over a one-minute period of time. Peak gusts over water average 20 to 25 percent higher than sustained winds.

RAPID DEEPENING - A decrease in the minimum sea-level pressure of a tropical cyclone of 1.25 mb/hr for 24-hours (ATR 1971).

RECURVATURE - The turning of a tropical cyclone from an initial path toward the west or northwest to a path toward the northeast.

SIGNIFICANT TROPICAL CYCLONE - A tropical cyclone becomes "significant" with the issuance of the first numbered warning by the responsible warning agency.

SUPER TYPHOON/HURRICANE - A typhoon/hurricane in which the maximum sustained surface wind (one-minute mean) is 130 kt (67 m/s) or greater.

TROPICAL CYCLONE - A non-frontal low-pressure system of usually synoptic scale developing over tropical or subtropical waters and having a definite organized circulation.

TROPICAL CYCLONE AIRCRAFT RECONNAISSANCE COORDINATOR - A USCINCPACAF representative designated to levy tropical cyclone aircraft weather reconnaissance units within a designated area of the PACOM and to function as coordinator between USCINCPACAF and the appropriate typhoon/hurricane warning center.

TROPICAL DEPRESSION - A tropical cyclone in which the maximum sustained surface wind (one-minute mean) is 33 kt (17 m/s) or less.

TROPICAL DISTURBANCE - A discrete system of apparently organized convection - generally 100 to 300 nm (185 to 556 km) in diameter - originating in the tropics or subtropics, having a non-frontal migratory character, and having maintained its identity for 12- to 24-hours. It may or may not be associated with a detectable perturbation of the wind field. As such, it is the basic generic designation which, in successive stages of intensification, may be classified as a tropical depression, tropical storm or typhoon (hurricane).

TROPICAL STORM - A tropical cyclone with maximum sustained surface winds (one-minute mean) in the range of 34 to 63 kt (17 to 32 m/s) inclusive.

TROPICAL UPPER-TROPISPHERIC TROUGH (TUTT) - A dominant climatological system (upper-level trough) and a daily synoptic feature, of the summer season over the tropical North Atlantic, North Pacific and South Pacific Oceans.

TYPHOON/HURRICANE - A tropical cyclone in which the maximum sustained surface wind wind (one-minute mean) is 64 kt (33 m/s) or greater. West of 180 degrees they are called hurricanes. Foreign governments use these or other terms for tropical cyclones and may apply different intensity criteria.

WALL CLOUD - An organized band of cumuliform clouds immediately surrounding the central area of a tropical cyclone. The wall cloud may entirely enclose or partially surround the center.

APPENDIX II

NAMES FOR TROPICAL CYCLONES

Column 1	Column 2	Column 3	Column 4
ANDY	ABBY	ALEX	AGNES
BRENDA	BEN	BETTY	BILL
CECIL	CARMEN	CARY	CLARA
DOT	DOM	DINAH	DOYLE
ELLIS	ELLEN	ED	ELSIE
FAYE	FORREST	FREDA	FABIAN
GORDON	GEORGIA	GERALD	GAY
HOPE	HERBERT	HOLLY	HAL
IRVING	IDA	IAN	IRMA
JUDY	JOE	JUNE	JEFF
KEN	KIM	KELLY	KIT
LOLA	LEX	LYNN	LEE
MAC	MARGE	MAURY	MAMIE
NANCY	NORRIS	NINA	NELSON
OWEN	ORCHID	OGDEN	ODESSA
PEGGY	PERCY	PHYLLIS	PAT
ROGER	RUTH	ROY	RUBY
SARAH	SPERRY	SUSAN	SKIP
TIP	THELMA	THAD	TESS
VERA	VERNON	VANESSA	VAL
WAYNE	WYNNE	WARREN	WINONA

NOTE:

Names are assigned in rotation, alphabetically. When the last name (WINONA) has been used, the sequence will begin again with "ANDY".

Source: CINCPACINST 3140.1 (series)

APPENDIX III

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TROPICAL DEPRESSIONS — TYPHOONS/SUPER TYPHOONS
TROPICAL CYCLONE RESEARCH — METEOROLOGICAL SATELLITE

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

ANNUAL PUBLICATION SUMMARIZING THE TROPICAL CYCLONE SEASON IN THE WESTERN NORTH PACIFIC, BAY OF BENGAL AND THE ARABIAN SEA, AND SOUTH PACIFIC AND SOUTH INDIAN OCEANS. A BEST TRACK IS PROVIDED FOR EACH SIGNIFICANT TROPICAL CYCLONE. A BRIEF NARRATIVE IS GIVEN FOR ALL TYPHOONS AND SELECTED TROPICAL CYCLONES IN THE WESTERN NORTH PACIFIC AND NORTH INDIAN OCEAN. ALL RECONNAISSANCE DATA USED TO CONSTRUCT THE BEST TRACKS ARE PROVIDED. FORECAST VERIFICATION DATA AND STATISTICS FOR THE JOINT TYPHOON WARNING CENTER (JTWC) ARE SUMMARIZED.

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BLOCK 18 (CONTINUED)
TROPICAL CYCLONE BEST TRACK DATA
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CLIMATOLOGY/PERSISTENCE TECHNIQUES
TROPICAL CYCLONE FIX DATA

1986 ANNUAL TROPICAL CYCLONE REPORT ERRATA SHEET

CHANGES FOLLOW.

1. Page iii - Add "Special thanks to Mr. Charles Mauck for his assistance with data reduction."

2. Page iv - TROPICAL CYCLONE - "(13) TY ABBEY" should read, "(13) TY ABBY".

3. Page vi - "CPA Closest Point to Approach" should read, "CPA Closest Point of Approach".

4. Page vi - "HATRACK" should read "HATTRACK".

5. Page vi - definition for "INJAH" should read, "North Indian Ocean Component of TYAN".

6. Page 2, under Section 4. ANALYSES, paragraph 2, in line 5 - delete "six" and replace with "three". On the next line delete "29,000 feet (8,839 m)" and replace with "31,000 feet (9,448m)".

7. Page 5, paragraph under Section 1. GENERAL, last line - "1985" should read, "1986".

8. Page 7, Figure 2-2 - arrow is missing that indicates NOAA9 operations extended through December.

9. Page 10, last paragraph - "Tables 3-1 through 3-6" should read, "Tables 3-1 through 3-4".

10. Page 26, expanded section of best track - the missing DTG should be 180000Z.

11. Page 52, Figure 3-08-2 - text of caption should be switched with caption under Figure 3-08-5 on page 53 and visa versa.

12. Page 81, first line - delete "digitally".

13. Page 106, Figure 3-18-2 - surface pressure report "09" at position 17.1N 154.3E should read, "009". Pressure report "08" at position 14.5N 154.5E should read, "008", and "8" at 17.8N 150.8E should read "008".

14. Page 117, Figure 3-21-1 - on the image the labelling "IDA" should read "HERBERT" and "JOE" should read, "IDA".

15. Page 133, Figure 3-25-1 - in first line of caption delete "passed south" and insert "was approximately 500 nm (926 km) southeast".

16. Page 146 - Best track for TC03A should appear on page 150.

17. Page 147, Figure 3-01B-1 - on the image the labelling "TC06S" should read "TC04S".

18. Page 150 - Best track of TC01B should appear on page 146.

19. Page 151, Figure 3-03A-1 - in line 2 of the caption delete 'Cyclone'.

20. Page 151, Figure 3-03A-1 - image should be rotated clockwise ninety degrees for proper orientation.

21. Page 171, in Section titled Tropical Cyclone Prediction Research - Delete lines 19 through 24.

22. Page 171, in Section titled Automated Tropical Cyclone Forecasting System, second paragraph - after line 2 insert the following text:

'tropical cylone warning procedure. New forecasters
can gather valuable hands-on experience of the
warning procedure during their training period.'

Then add three additional blank lines before the start of the next Section titled, Tropical Cyclone Inner Regional Circulation Classification.

23. Page 172, Section titled Tropical Cyclone Condition Setting Aid - after line 7, which ends with 'evasion action that', delete the next 3 lines and add the following:

'would be unwarranted at lower risk levels. A rule
for deciding such actions can be derived on an
expected outcome basis (e.g. cost/benefits ratio).
The CHARM model is now being adapted for seven North
Pacific sites: Pearl Harbor, Guam, Subic Bay, Buckner
Bay, Yokosuka, Sasebo, and Pusan.'

24. Page 186, definition of TYPHOON/HURRICANE - in line 3 delete 'West' and insert 'East'.

25. Page 189 - in Sadler, J. C. reference 'NAVENVPREDRSCHFACO' should read, 'NAVENVPREDRSCHFAC'.

26. Page 191 - 'NOCD, DIEGO GARCIA (20' should read, 'NOCD, DIEGO GARCIA (2)'.