CHAPTER III

JTWC STUDIES

This Chapter is a collection of studies conducted during the 1966 typhoon season. Some topics appear in their entirety. Other topics are of a continuing nature and will be completed when data becomes available.

The following is a list of the topics discussed in this Chapter:

A. USE OF COMPUTER PRODUCTS AT JTWC.

B. STATISTICAL VERIFICATION PROGRAM.

C. TROPICAL CYCLONE INTENSIFICATION RATE VERSUS SEA SURFACE TEMPERATURE AND LATITUDE.

D. TYPHOON FORMATION WITHIN THE ZONE OF THE ITC.

E. VERIFICATION OF WEATHER SATELLITE DATA.

A. USE OF COMPUTER PRODUCTS AT JTWC

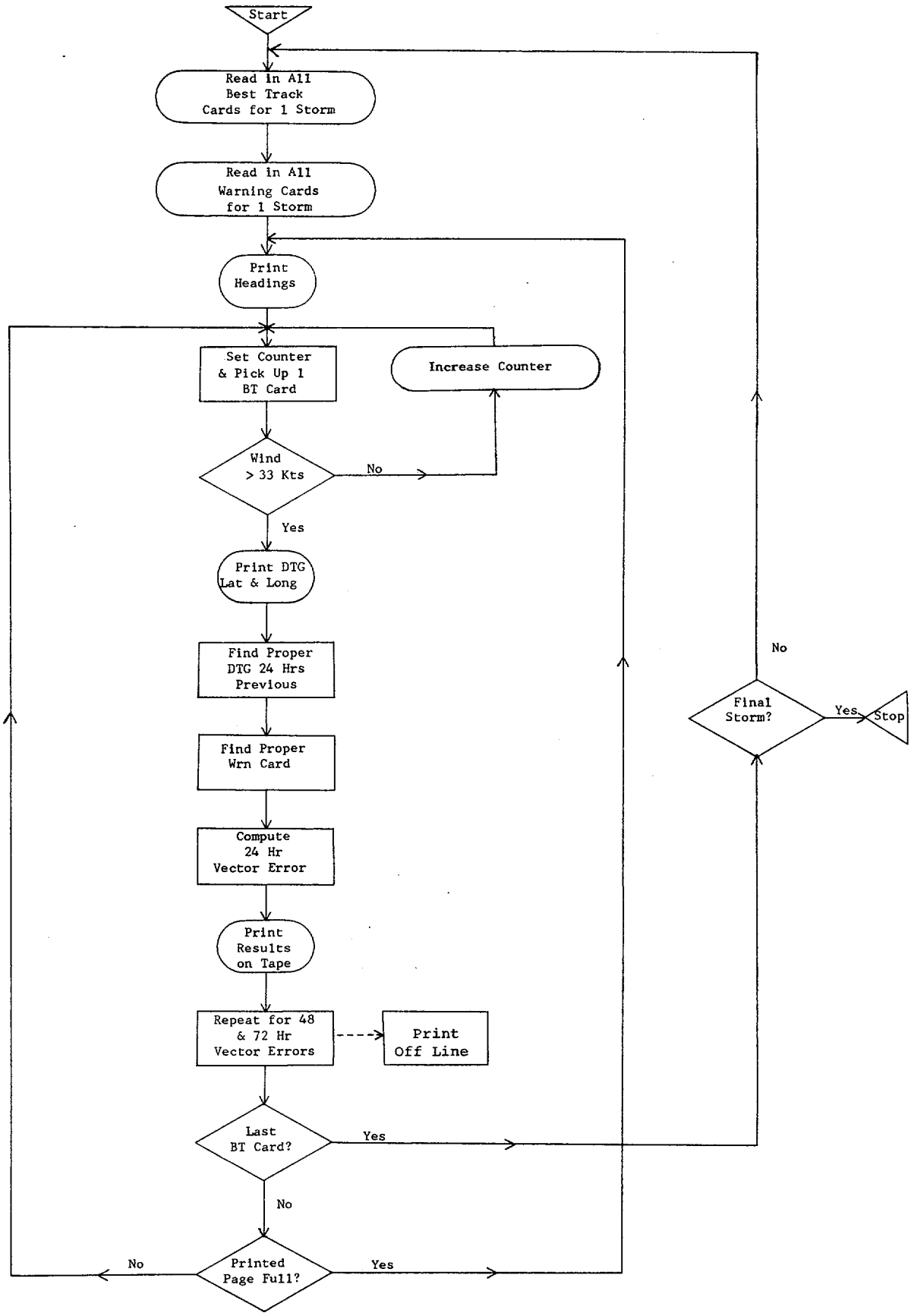
With the arrival of the CDC 3100 computer at FWC/JTWC Guam, it has become possible to partially automate the writing of the Annual Typhoon Report. The reasons for using the computer are twofold. First, to simplify the preparation of the typhoon report; and second, to build up a climatological record of past storms which can be referred to rapidly through the use of the computer. Much of the research efforts this past year were devoted to automating a large portion of the annual report.

The first step, which is being used in the present edition, is the automation of four sets of logs and the machine printing of the fix, the statistics and the verification pages for the report. The logs, which are kept on all storms, have been written to facilitate using numbered codes for all entries. The logs are double checked for accuracy and the data are cut on Hollerith machine cards. The computer programs are such that one or multiple storms may be run at any one time. The data card information is read into the computer, processed and printed for inclusion in the Typhoon report. As a by-product, a machine printout is also obtained of the delay between fix time versus its first receipt at JTWC and a fix classification of all reconnaissance flown.

It is expected that after several years of data have been compiled, these logs along with the computer print-outs will furnish the raw material for development of additional aids in forecasting typhoon formation and movement. For this reason, additional information that would prove useful in typing storms is being included on the 0000Z and 1200Z logs. This information includes the height and latitude of the 700mb trough west of the storm, the vertical extent of the storm, etc.

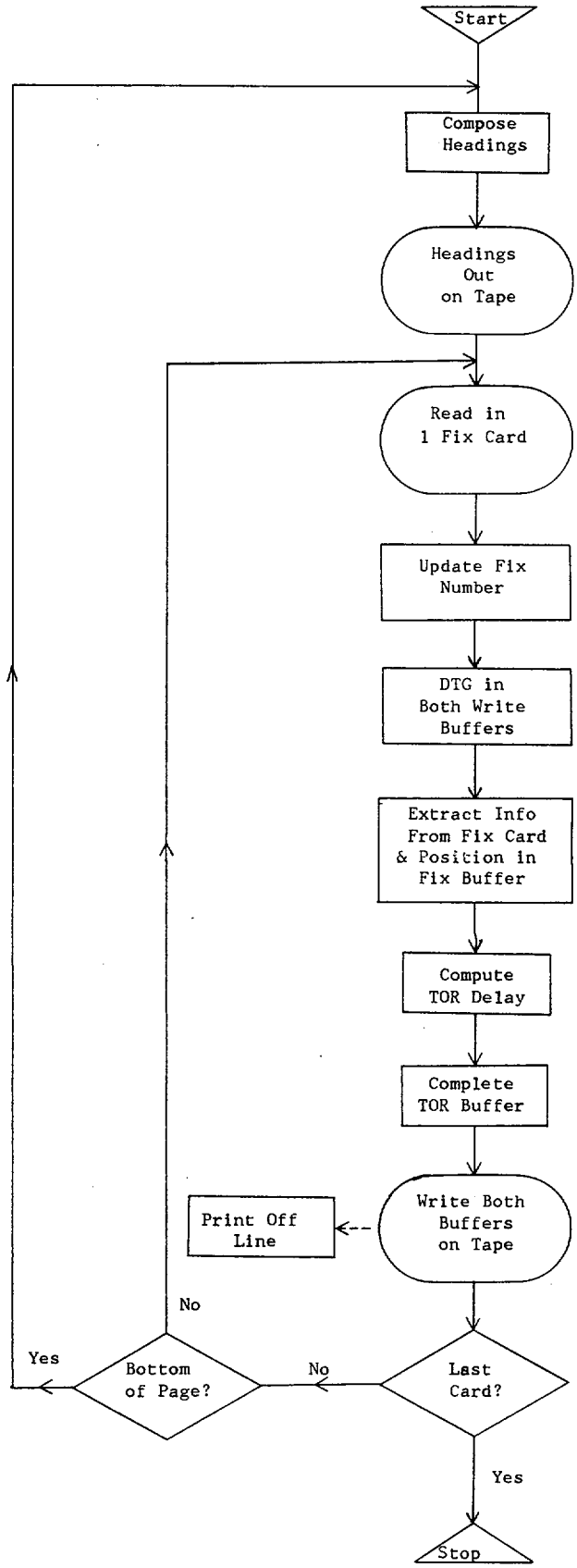
Plans for the future include automating existing objective techniques and the development of a grid type objective forecast which can be rapidly calculated by the computer.

Simplified flow diagrams for the three computer programs now being used in JTWC are depicted in figures (III-1, III-2, and III-3).



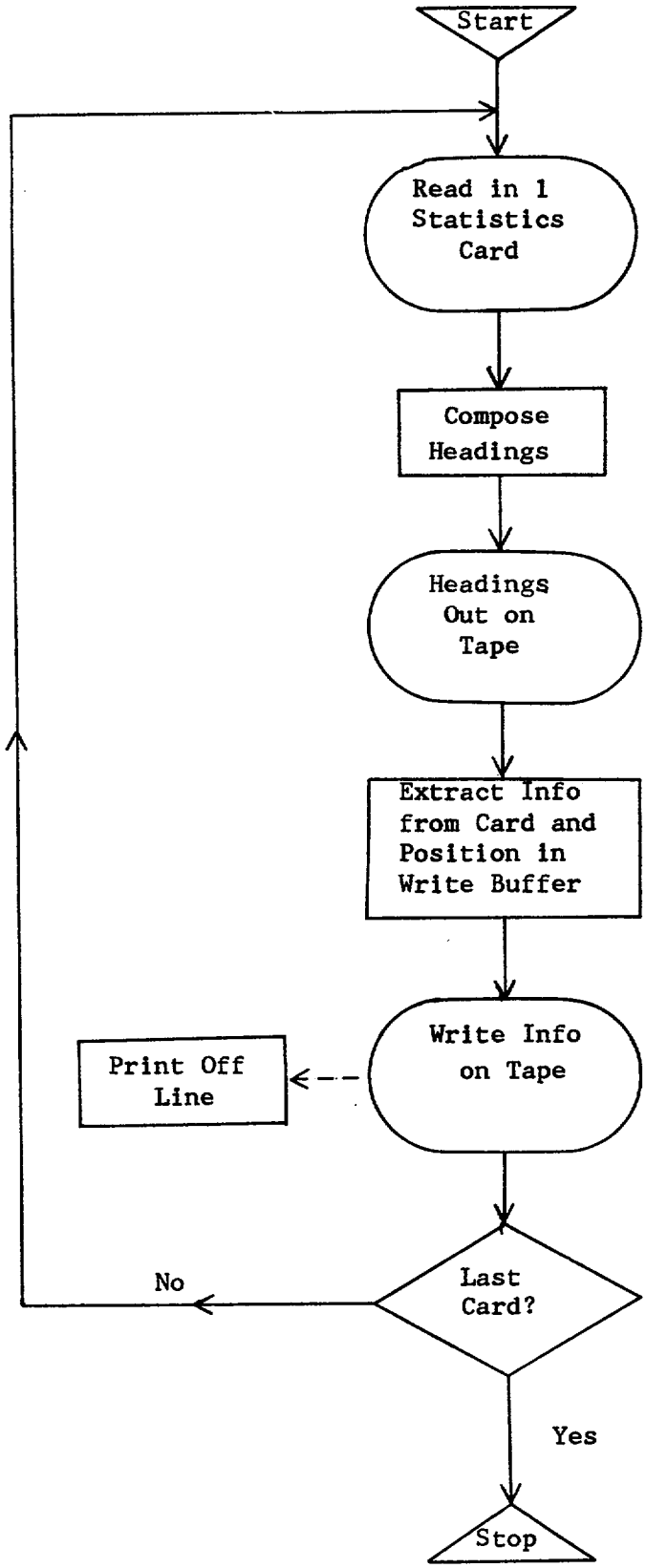
Flow Diagram for Vector Error Computation Program

Figure III-1



Flow Diagram for Fix Page Program

Figure III-2



Flow Diagram for Statistics Page Program

Figure III-3

B. STATISTICAL VERIFICATION PROGRAM

The study of R.M.S. (Root Mean Square) forecast errors initiated last year was continued this year using 1966 data.

The study provides a breakdown of forecasting errors by latitude for the 24, 48 and 72 hour forecasts (see table III-1). Two measures of dispersion were computed.

1. The R.M.S. of the Vector Error. Assuming a circular normal distribution of errors, 63% of the forecasts made should verify within one R.M.S. of the actual position and 98% within two R.M.S. (see AWS Technical Report #164, dated August 1962).

2. The R.M.S. of the right angle error (equivalent in this case to the standard deviation). Assuming a normal distribution, 68% of the forecasts should be within one R.M.S. right or left of track and 95% within two R.M.S. Since the R.M.S. of the vector error is theoretically 1.4 times greater than the R.M.S. of the right angle error for a normal circular distribution, these two figures can be used to determine the approximate shape of the "error" envelope. However, analysis of the data for the past two seasons indicate that the speed error is about 20% greater than the course error (see last column of Table III-1). The actual error envelope is therefore eliptical and oriented with the long axis coincident with the forecasted track.

A continued study of forecasting errors is planned in order to provide a better basis for command decisions involving areas threatened by tropical storms.

As a result of this study JTWC is concentrating its research efforts towards developing techniques which will reduce the error in forecasting a storm's speed of movement.

	1. R.M.S. OF VECTOR ERROR (MI)	2. .707 x R.M.S. OF VECTOR ERROR (MI)	3. STANDARD DEVIATION OF RIGHT ANGLE ERROR (MI)	PERCENT VARIATION $(\frac{2-3}{2})$
24 HOUR				
TOTAL	165	117	71	19
UNDER 20N	131	93	58	11
20N-30N	166	117	75	13
ABOVE 30N	240	170	79	41
UNDER 35N	159	112	70	16
ABOVE 35N	281	199	106	39
48 HOUR				
TOTAL	332	235	160	12
UNDER 20N	197	139	98	9
20N-30N	354	250	191	4
ABOVE 30N	433	306	163	38
UNDER 35N	320	226	163	8
ABOVE 35N	505	357	113	59
72 HOUR				
TOTAL	513	363	229	21
UNDER 20N	260	184	108	30
20N-30N	521	368	258	16
ABOVE 30N	695	491	299	27
UNDER 35N	495	349	224	18
ABOVE 35N	694	491	297	39

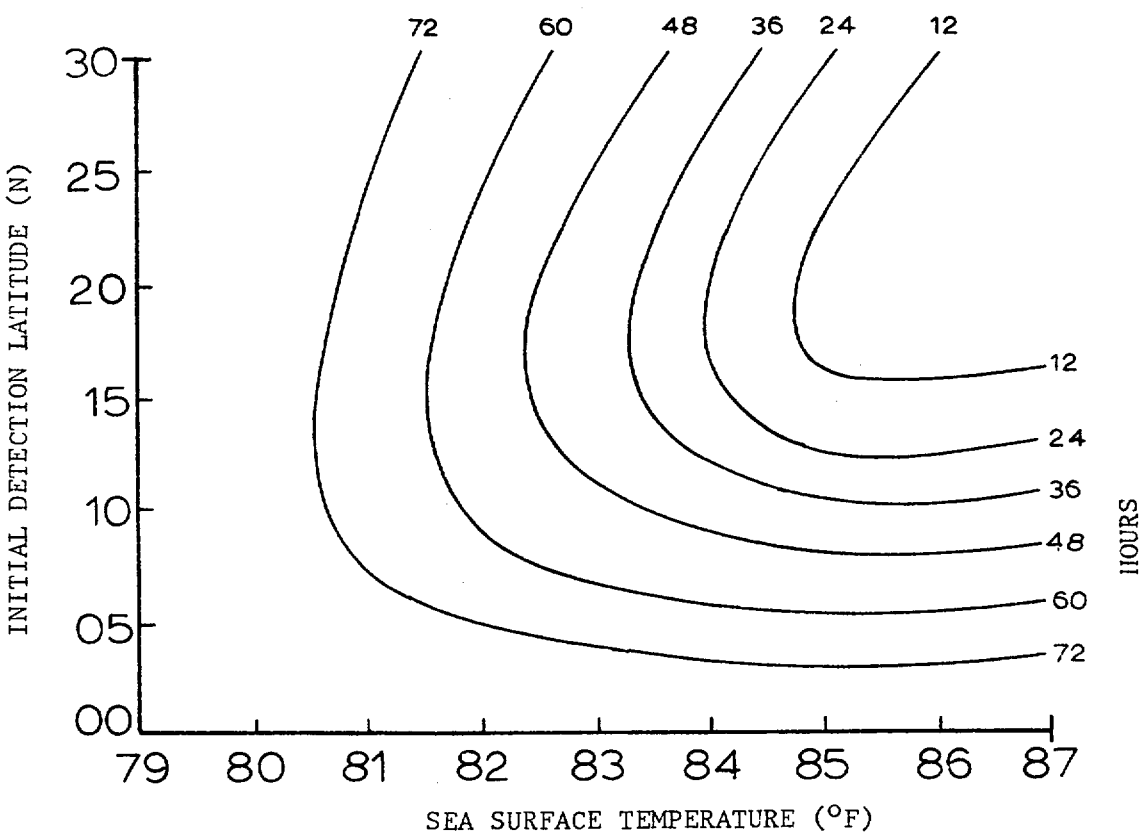
TABLE III-1

C. TROPICAL CYCLONE INTENSIFICATION RATE VERSUS SEA SURFACE TEMPERATURE AND LATITUDE

A study was made this past year to determine the effect, if any, the sea surface temperature and latitude have on the time required for a tropical depression to attain tropical storm intensity. Data for 56 typhoons and tropical storms from 1965 and 1966 were processed and a fair correlation was shown to exist which indicates a more rapid rate of intensification occurs as both latitude and sea surface temperature increase. The relationships are by no means perfect because other meteorological considerations such as the amount of low level feed of moist warm air into the cyclone, the degree of high level divergence over the cyclone, etc., also have a direct influence on intensification rates. Figure III-4 is a smooth graph, summarizing the results of the study.

Further evaluation concerning the validity of the graph as a forecasting tool will be made during the 1967 typhoon season.

Figure III-4 Smooth Analysis of the Intensification Time in Hours



D. TYPHOON FORMATION WITHIN THE ZONE OF THE ITC

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54th Weather Reconnaissance Sq.
Guam, Mariana Islands

A study of the early development of typhoon MARIE, which was generated during the latter portion of October 1966, revealed that this storm formed within the zone of the ITC without any easterly wave inter-action. Satellite pictures of the storm area including infra-red read-out during the night-time hours were compared with conventional and reconnaissance data. This comparison suggested a model of typhoon formation distinct from those storms originating as a result of the intensification of easterly waves. The model is shown in figure III-5. Four separate stages of development are defined in relationship to 700mb streamlines.

Stage I — In Stage I outflowing air from anticyclones of the northern and southern hemisphere converge near the equator along an asymptote conventionally referred to as the Intertropical Convergence Zone (ITC). Cloudiness forms primarily on the southern side of the convergence asymptote.

Stage II — In Stage II an elongated trough is formed between the northern and southern hemispheric anticyclones. Formation of the trough is attributed to the reduction of pressure through the release of latent heat of condensation which occurred as a result of forced convection necessitated by the Stage I configuration. Cloudiness as in Stage I and in the typical easterly wave pattern remains dominantly south and east of the trough axis. The trough area may contain occasional embedded closed circulations. However, maximum sustained surface wind speeds will normally not exceed 30 knots.

Stage III — In Stage III vortices generated within the trough area of maximum relative vorticity have further developed. The trough has moved northwestward around the northern hemispheric anticyclone where super-position of the ITC trough with the polar trough has been achieved. At this time a transfer of energy from the westerlies to the easterlies is possible, increasing wind speeds (and hence cyclonic vorticity) northwest of the storm center. Rapid intensification follows as tropical storm intensities are attained.

TYPHOON DEVELOPMENT WITHIN THE ZONE OF THE ITC

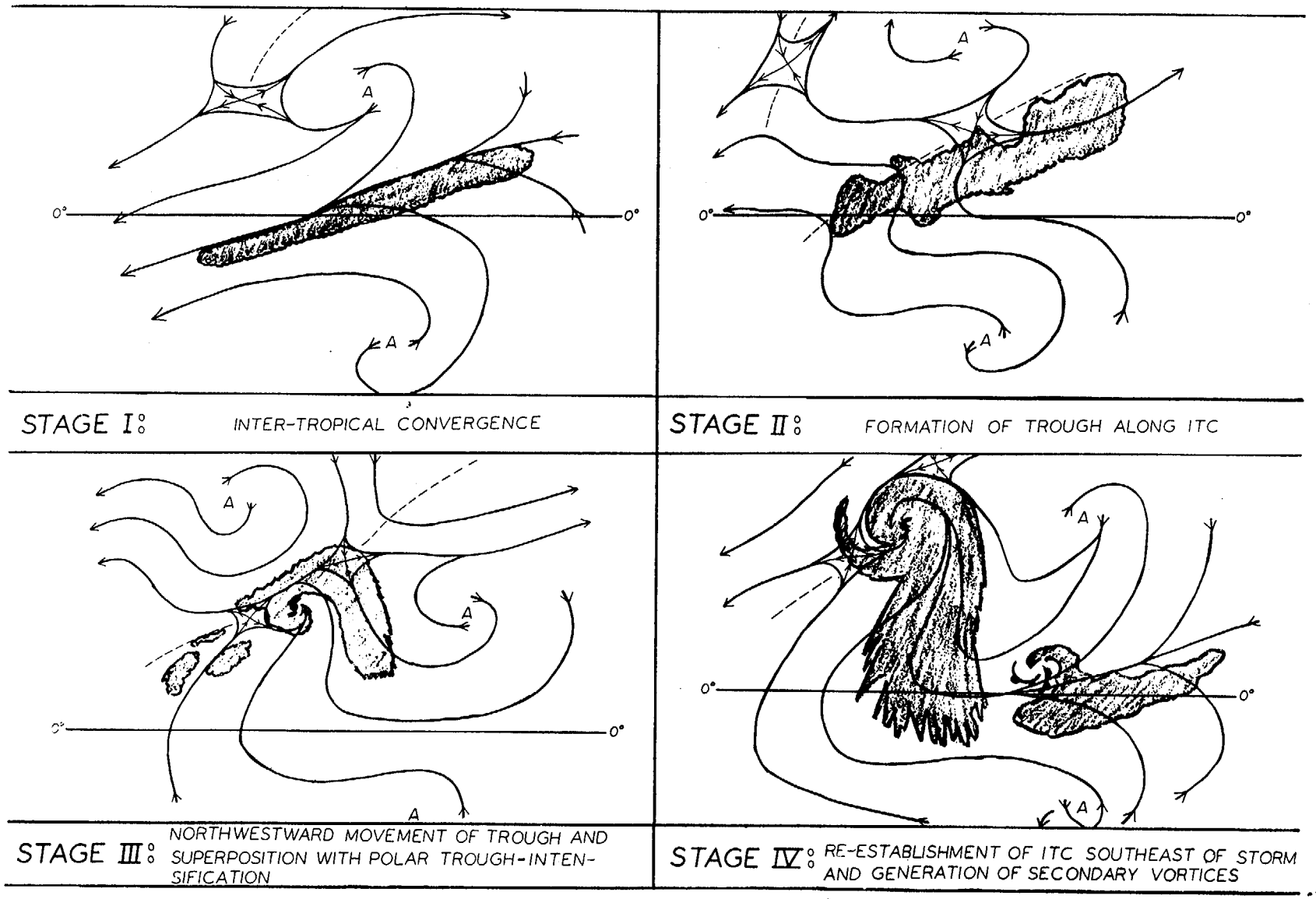


Figure III-5

Stage IV — As the storm reaches typhoon intensity it continues its generally northwesterly movement around the northern hemispheric anticyclone and the ITC is reformed at lower latitudes. With the re-establishment of the ITC in the wake of the original storm the cycle of formation has been completed. The stage is now set for the establishment of a new ITC trough and the generation of vortices in a manner similar to the development of the original storm.

It should be noted that this model is similar in many respects to the model of typhoon development from an easterly wave configuration (figure III-6). Both models depend upon the generation of vortices within a trough. Intensification of an easterly wave, as in the ITC model, is commonly attributed to polar trough interactions. Vortices developing within the ITC trough, when viewed by satellite, frequently assume an appearance similar to the stages of development of an easterly wave. Such similarities undoubtedly account for the many confused analyses and mistaken inferences which have led to opposing interpretations of the same phenomena. However, the over-all pattern of each type of development when viewed by satellite is quite different. Wave-like disturbances have a notable absence of peripheral cloudiness in their immediate vicinity (see figure III-7, which shows an easterly wave in the Gulf of Mexico); whereas ITC cloudiness is connective and elongated over long distances more or less parallel to the equator (see figure III-8, which shows a polar front and ITC near 10 N). Disturbances developing on the ITC protrude perpendicular to the main band as shown in the schematic model in Stage IV (figure III-5). Surveillance satellites such as the ATC (Advanced Technology Satellite) hovering great distances above the earth provide integrated pictures over large areas so that it should be an easy matter to differentiate between the separate types of development.

Further research and accumulation of additional examples will be necessary to verify the general applicability of this model. Of particular interest is the question regarding the percentage of cases that result from either ITC or easterly wave development in comparison to the total. The typical upper-air pattern over the ITC in each of the various stages is also an item of interest that may be crucial with respect to the development problem. Recognition and documentation of these major characteristics will be an important step toward improved analyses and forecasts of the future.

FORMATIVE STAGES OF TROPICAL CYCLONE DEVELOPMENT

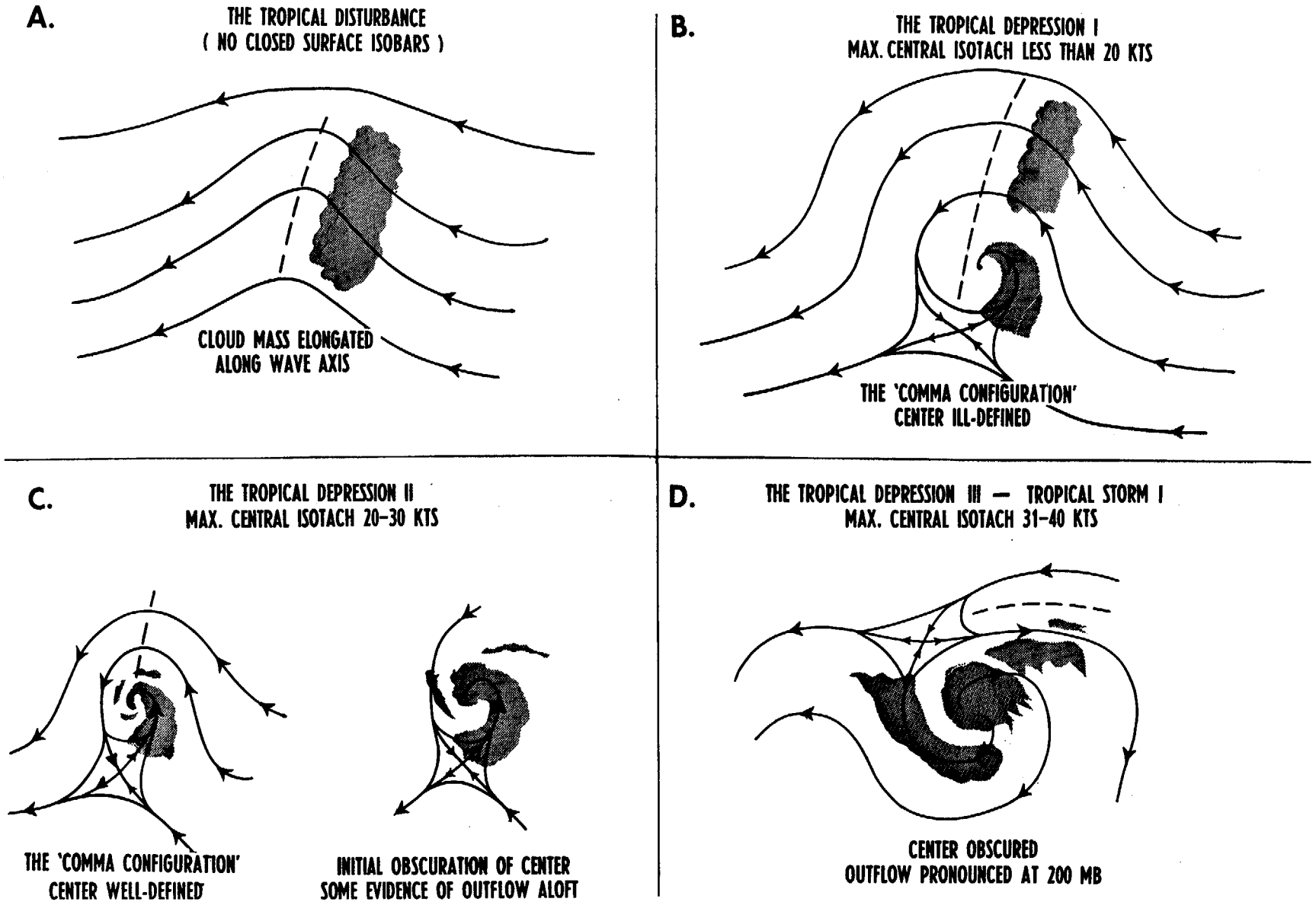
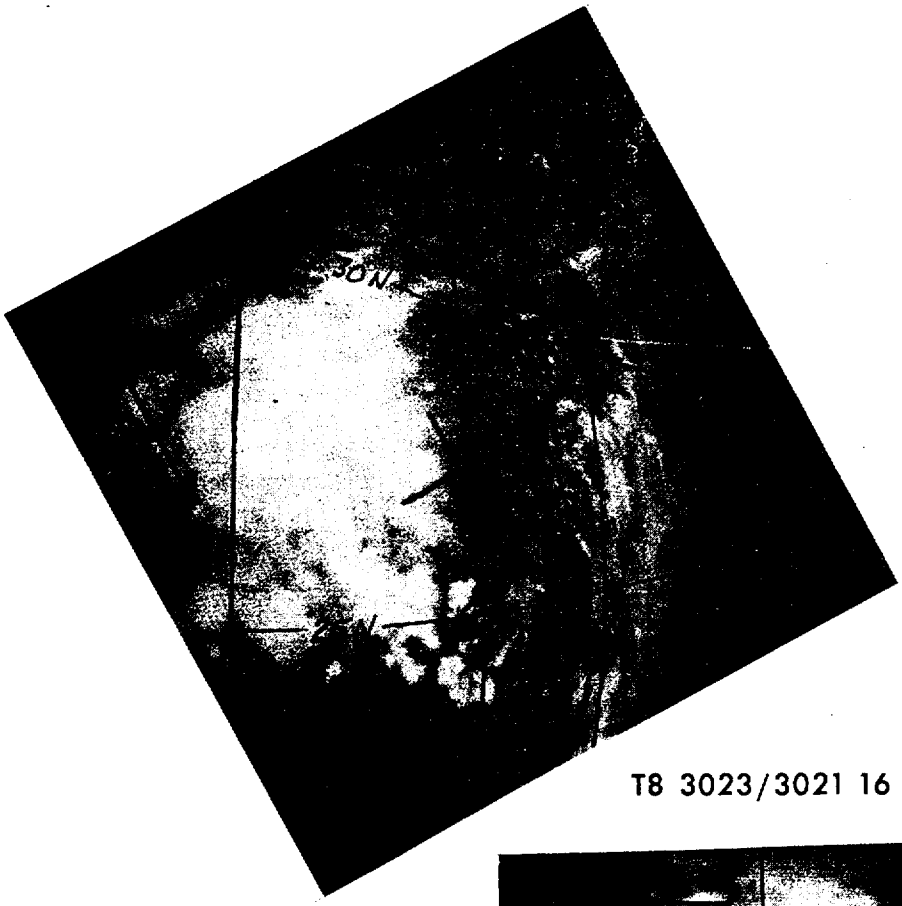


Figure III-6



T8 3023/3021 16 JULY 1964 1903Z

Figure III-7

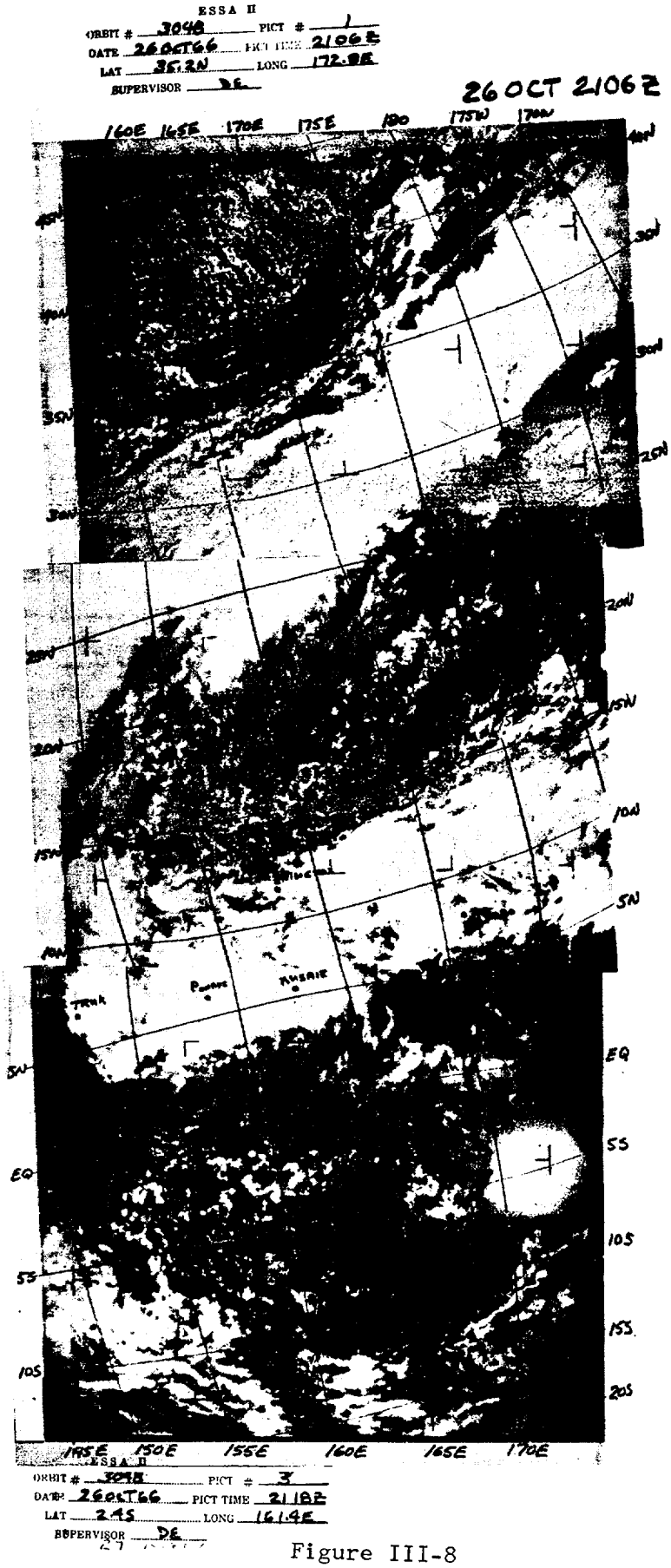

ESSA II
ORBIT # 3048 PICT # 1
DATE 26OCT66 PICT TIME 2106Z
LAT 35.2N LONG 172.9E
SUPERVISOR DE
26 OCT 2106Z
160E 165E 170E 175E 180 175W 170W
40N
35N
30N
25N
20N
15N
10N
5N
EQ
5S
10S
15S
20S
145E 150E 155E 160E 165E 170E
ESSA II
ORBIT # 3048 PICT # 3
DATE 26OCT66 PICT TIME 2118Z
LAT 24S LONG 161.4E
SUPERVISOR DE

Figure III-8

E. VERIFICATION OF WEATHER SATELLITE DATA

With the launching of the operational weather satellite, it has been anticipated that this new meteorological observation tool would be able to locate and identify tropical cyclones in data-sparse regions of the Pacific Ocean and thus aid in the prediction of typhoon movement and intensity. To a large extent this has been realized. There is no doubt that satellite cloud pictures have aided in the locating of tropical cyclones and have also given an estimate of the maximum wind speed of the storms.

FWC/JTWC, through the APT ground station equipment, has begun to utilize the information received from ESSA II and NIMBUS weather satellites launched in 1966 to locate tropical cyclones and estimate their maximum wind speeds. The question of whether or not the satellite data could locate the center of the storms with sufficient accuracy to satisfy certain recon requirements was investigated. A verification program was started in 1965 and continued throughout this past season using National Environmental Satellite Center (NESC) data. It was noted that there was an elapsed time of about 11 hours between picture time and time of receipt of the NESC bulletin at FWC/JTWC, so that in most cases, the information did not have nearly as much value as that received from the local APT equipment. The following is a comparison of position and wind errors for 1965 and 1966 of the NESC bulletins:

POSITION ERROR

	1965	1966
NUMBER OF CASES	75	71
AVERAGE POSITION ERROR	81 nm	49 nm
MEDIAN POSITION ERROR	55 nm	39 nm
RANGE OF POSITION ERROR	0-425 nm	5-219 nm

WIND SPEED ERROR

	1965	1966
NUMBER OF CASES	61	59
AVERAGE WIND ERROR	17 kts	18 kts
MEDIAN WIND ERROR	11 kts	13 kts
RANGE OF WIND ERROR	0-60 kts	0-83 kts

In comparing the two years, there was an improvement in accuracy of the storm location while the accuracy of the estimated wind speeds remained the same. The improvement in the location of the storms can probably be attributed to the direct view of the earth by the satellites in 1966 as compared to the angled view of the previous TIROS satellites.

The satellite locations of the storms were verified against the "best track" plots of the individual storms.

ESSA II and NIMBUS transmit daytime cloud pictures while only NIMBUS transmits nighttime infrared data. Graphs of the frequency of position errors of the satellite data are shown in figures III-9 through III-12. A summary of the position errors of data taken from weather satellite pictures received at FWC/JTWC follows:

POSITION ERRORS OF WEATHER SATELLITE DATA

	ESSA II & NIMBUS DAY	NIMBUS NIGHT	COMBINED DAY & NIGHT
NUMBER OF CASES	104	65	169
AVG POSIT ERROR	65 nm	96 nm	78 nm
MEDIAN POSIT ERROR	55 nm	82 nm	65 nm
RANGE POSIT ERROR	5-255 nm	10-398 nm	5-398 nm

It is interesting to note that location errors are not much greater than the average grid error.

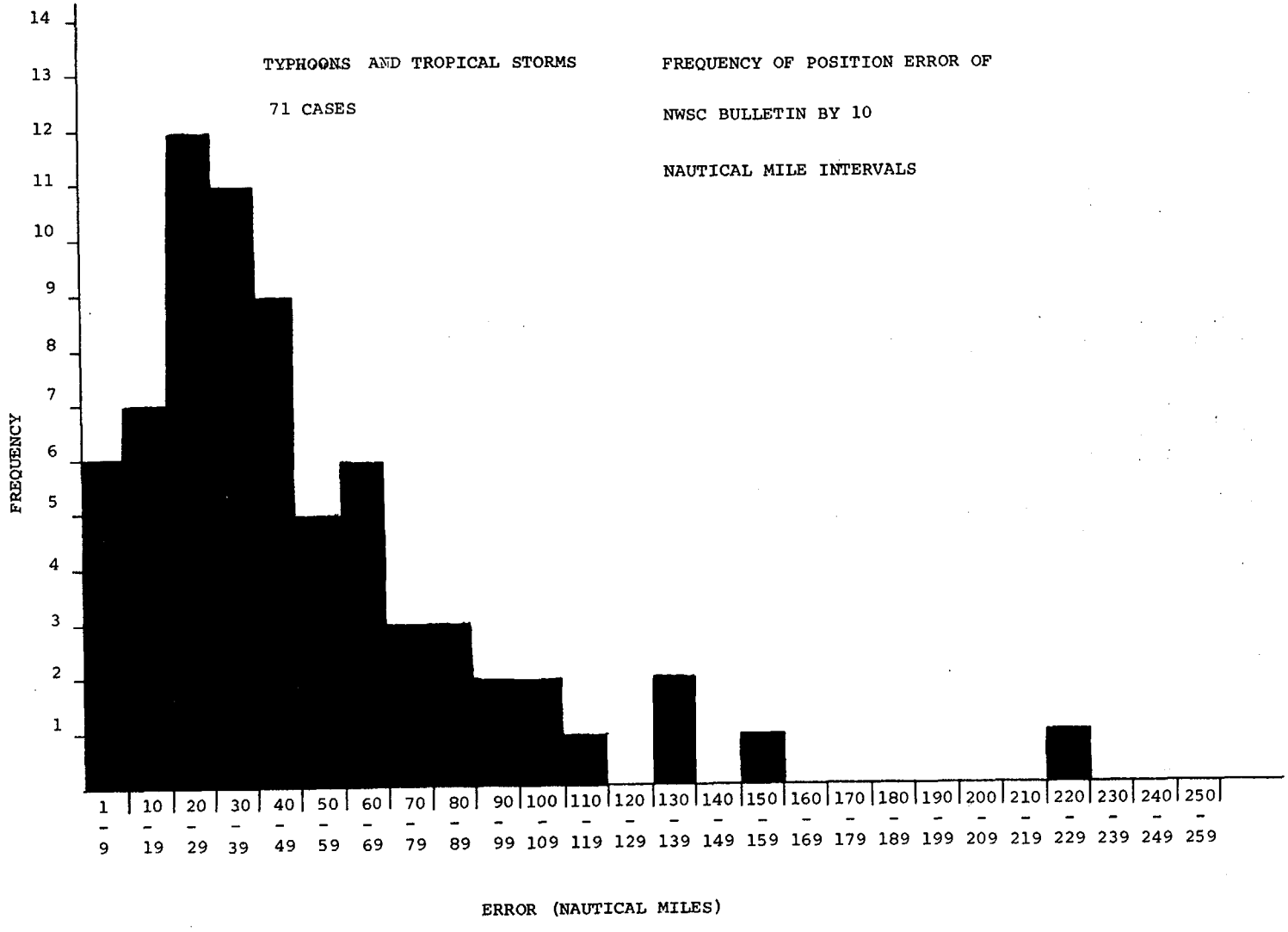

TYPHOONS AND TROPICAL STORMS
71 CASES
FREQUENCY OF POSITION ERROR OF
NWSC BULLETIN BY 10
NAUTICAL MILE INTERVALS
FREQUENCY
14
13
12
11
10
9
8
7
6
5
4
3
2
1
1 - 9
10 - 19
20 - 29
30 - 39
40 - 49
50 - 59
60 - 69
70 - 79
80 - 89
90 - 99
100 - 109
110 - 119
120 - 129
130 - 139
140 - 149
150 - 159
160 - 169
170 - 179
180 - 189
190 - 199
200 - 209
210 - 219
220 - 229
230 - 239
240 - 249
250 - 259
ERROR (NAUTICAL MILES)

Figure III-9

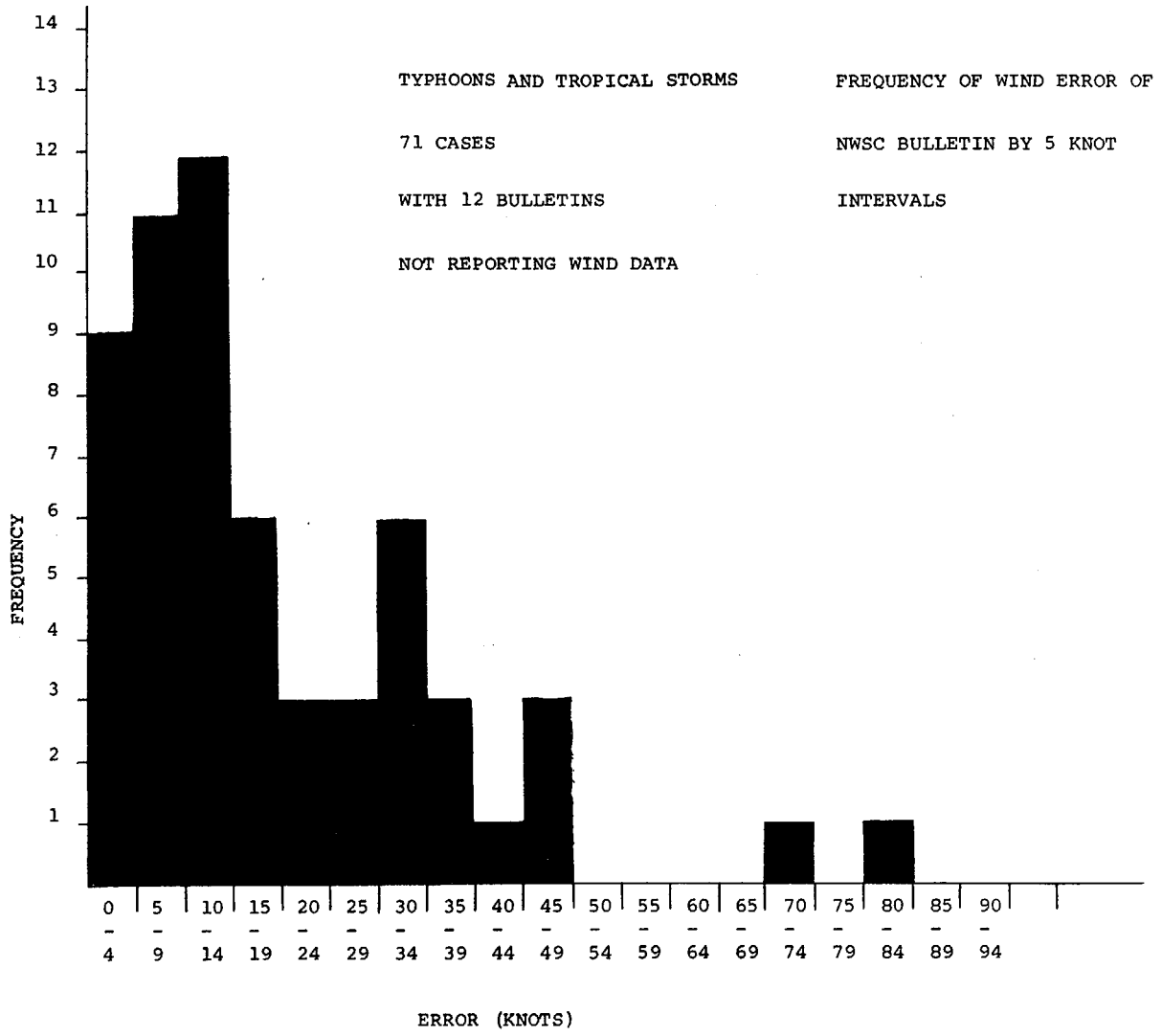


Figure III-10

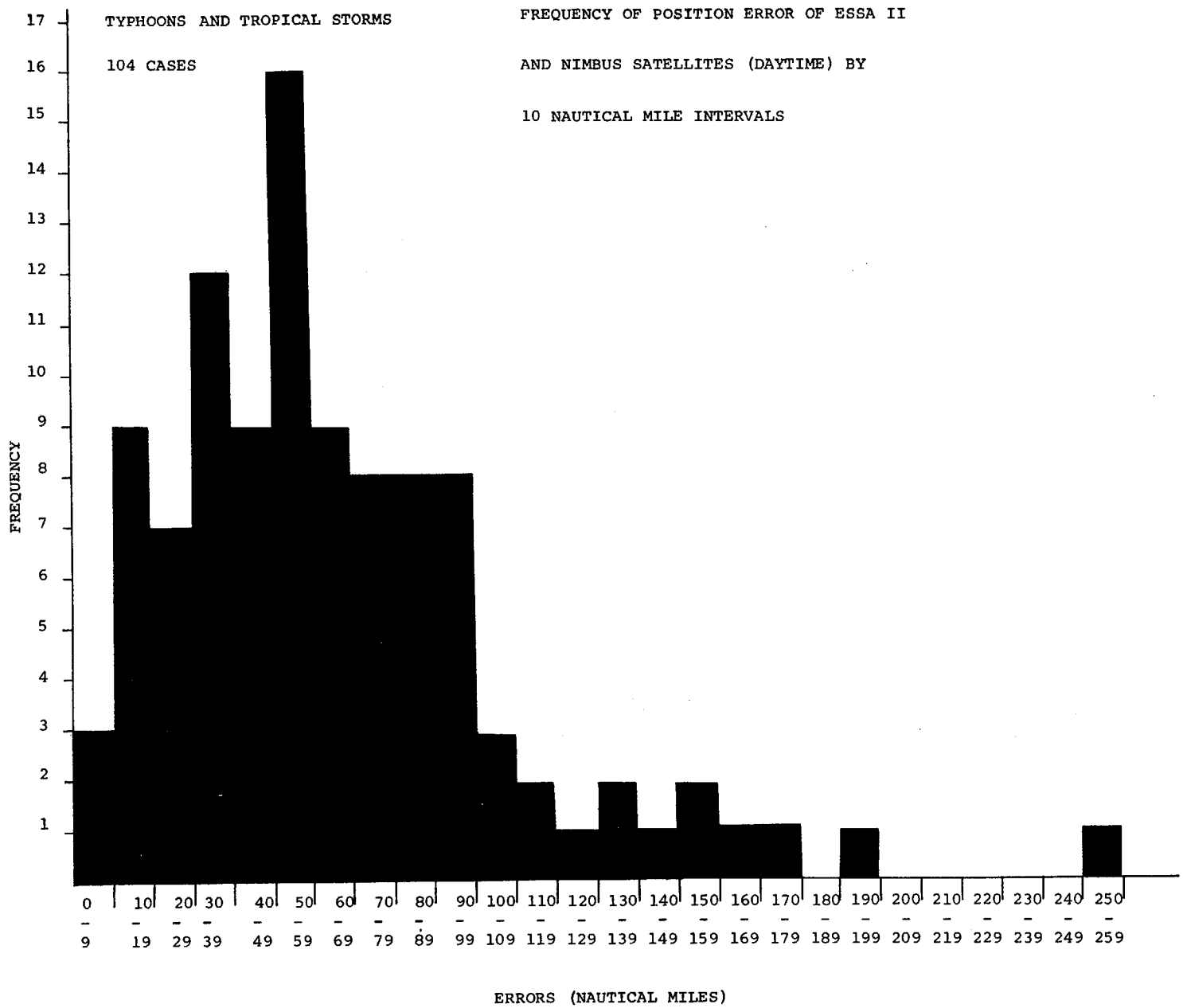


Figure III-11

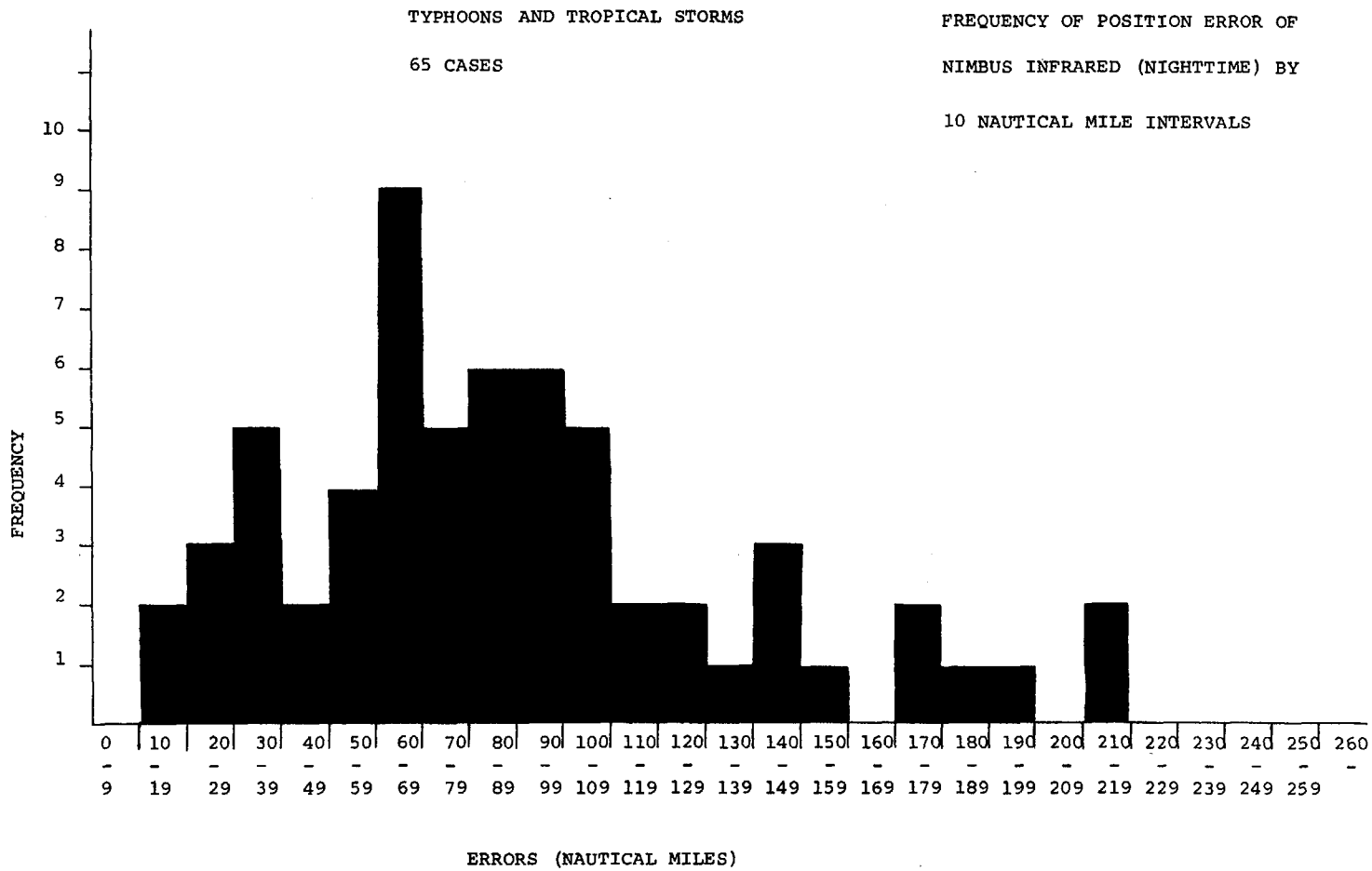
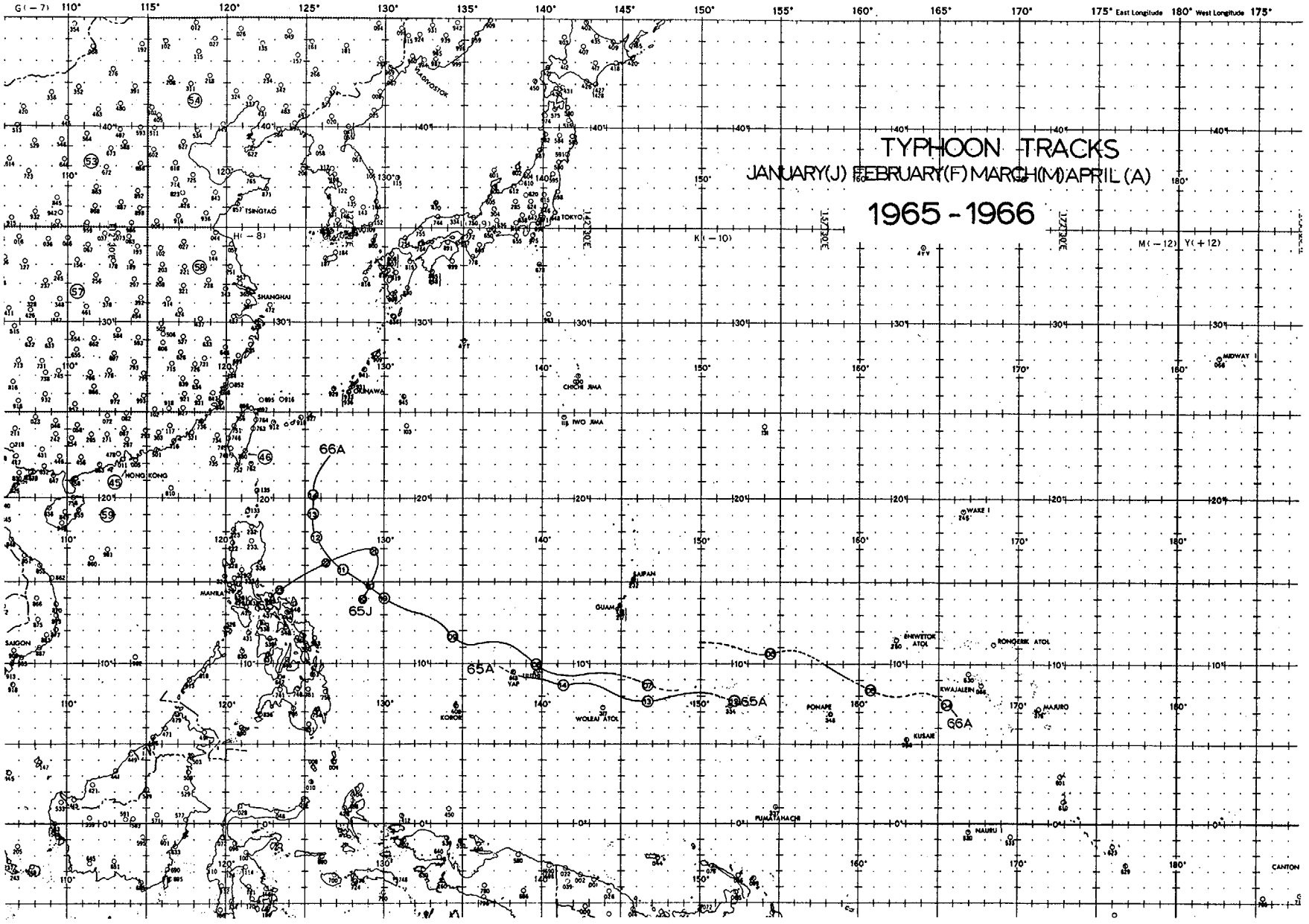


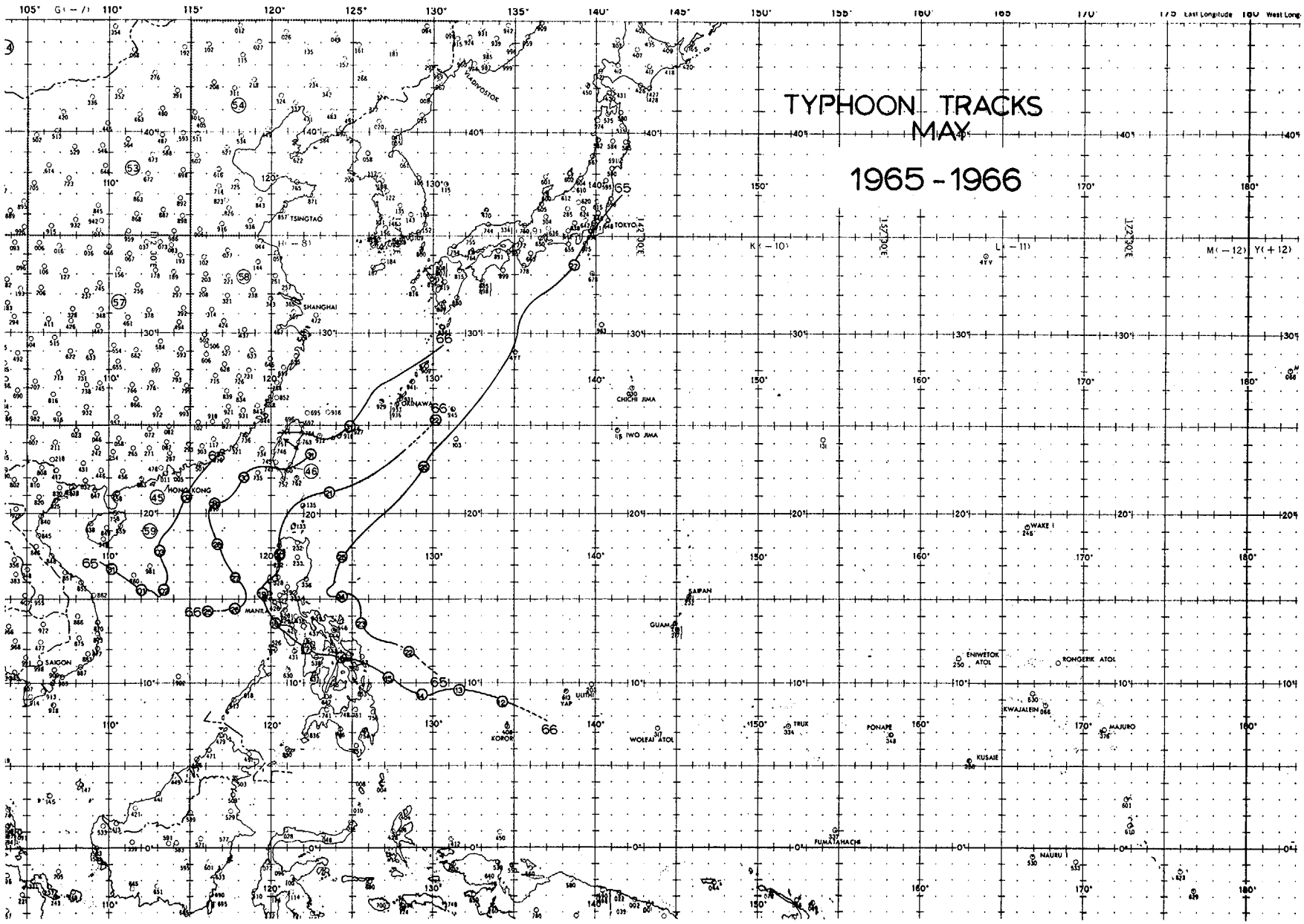
Figure III-12

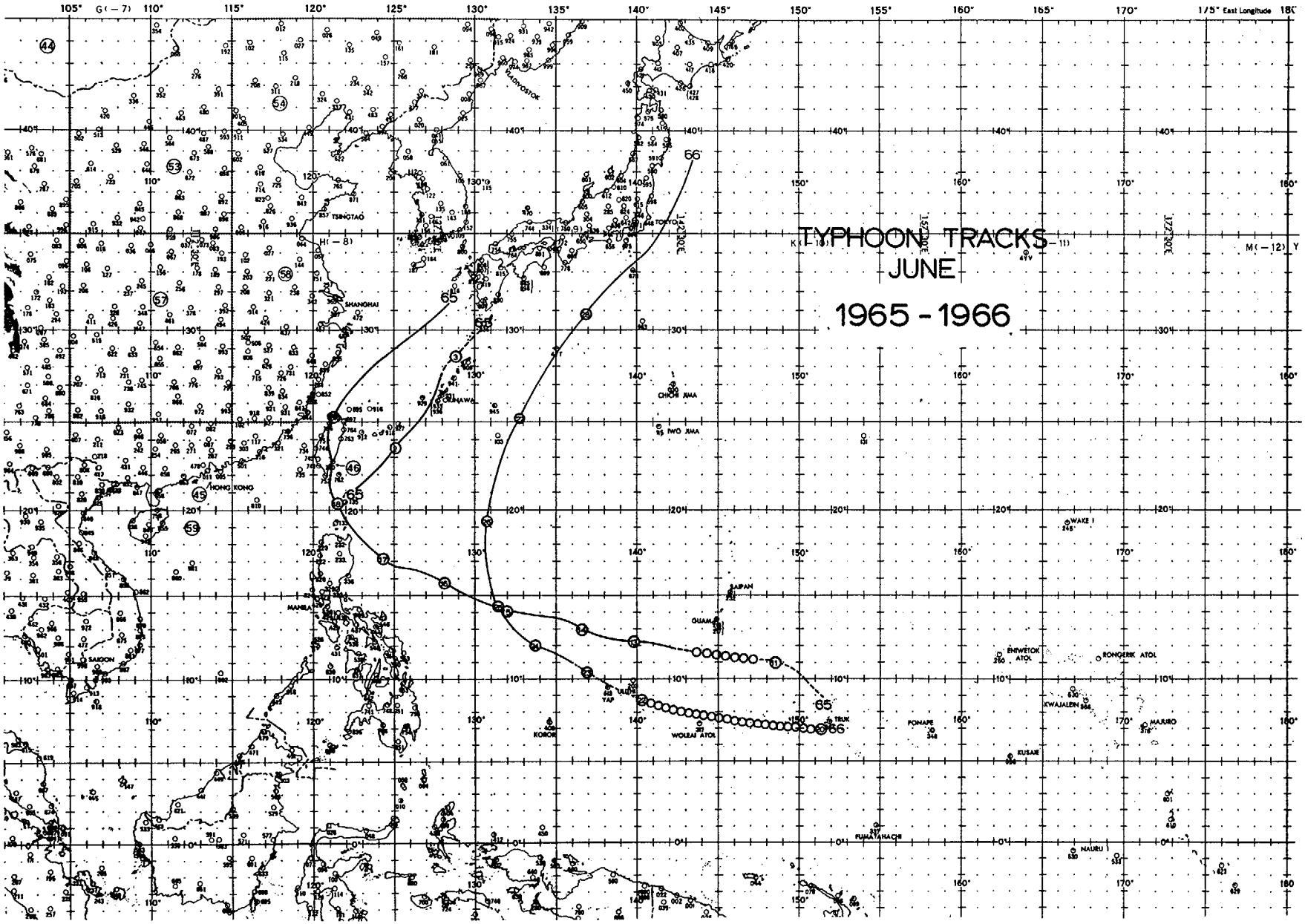
TYPHOON TRACKS

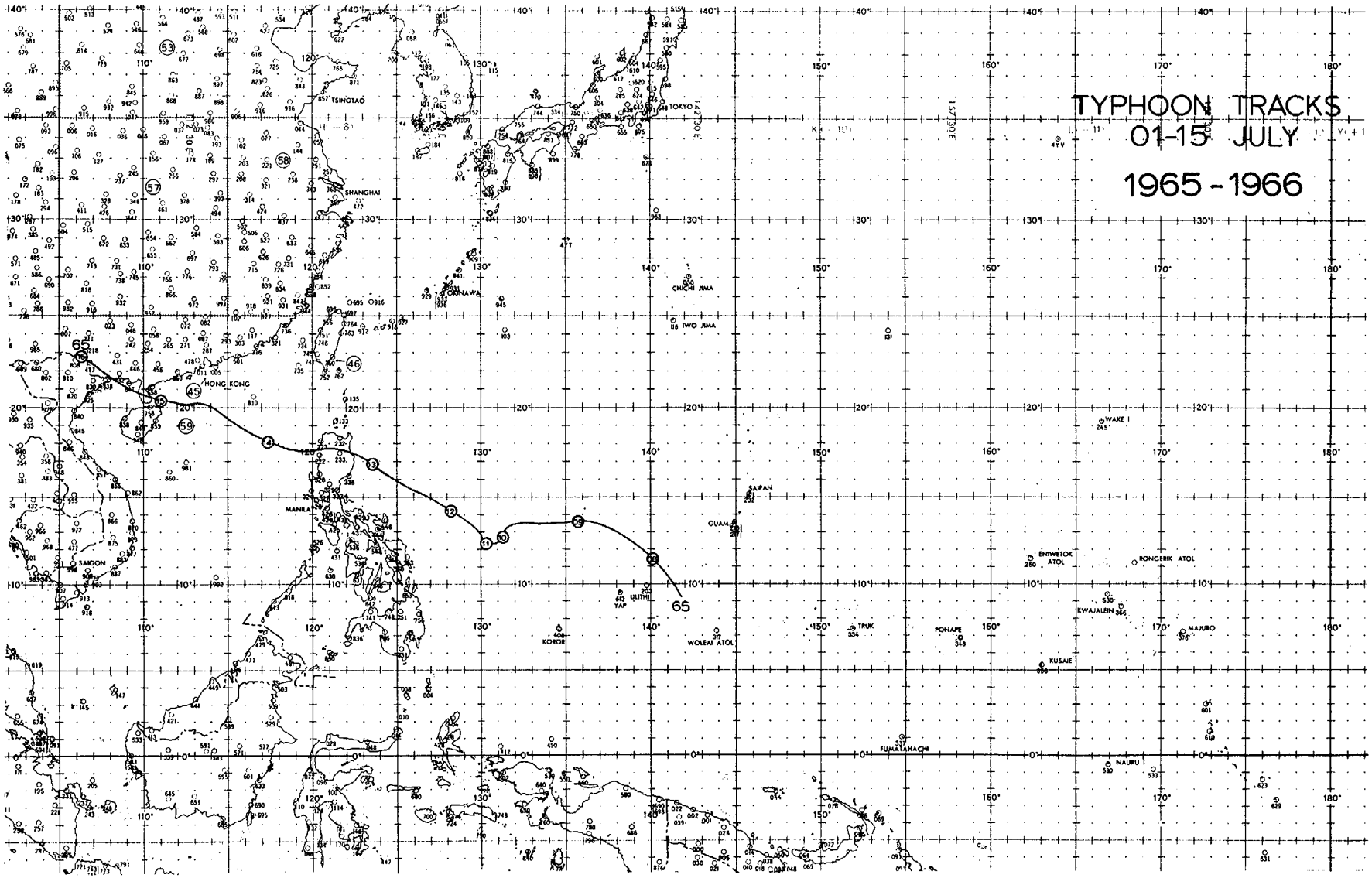
1965-1966

Storm tracks from 1953 through 1964 have been discontinued this year due to the extreme crowding that has occurred. Tracks for the 1965-1966 seasons are included in this report. For all tracks, by month, prior to 1965 see prior Typhoon Reports.


TYPHOON TRACKS
JANUARY(J) FEBRUARY(F) MARCH(M) APRIL (A)
1965 - 1966
66A
65J
65A
65A
66A
VLADIVOSTOK
TSINGTAO
SHANGHAI
TOKYO
OKINAWA
CHICHI JIMA
IWO JIMA
HONG KONG
MANILA
SAIGON
SAIPAN
GUAM
YAP
KOROR
WOLEAI ATOL
PONAPE
KUSAIE
ENIWETOK ATOL
RONGERIK ATOL
KWAJALEIN
MAJURO
WAKE I
MIDWAY I
NAURU I
PUMATAHACHI
CANTON
East Longitude
West Longitude


TYPHOON TRACKS
MAY
1965 - 1966
TSINGTAO
SHANGHAI
HONG KONG
MANILA
SAIGON
OKINAWA
TOKYO
CHICHI JIMA
IWO JIMA
SAIPAN
GUAM
ULITHI
YAP
KOROR
WOLEAI ATOL
TRUK
PONAPE
KUSAIE
ENIWETOK ATOL
RONGERIK ATOL
KWAJALEIN
MAJURO
NAURU
FUMATAHACHI
WAKE I
East Longitude
West Long


TYPHOON TRACKS
JUNE
1965 - 1966
VLADIVOSTOK
TSINGTAO
SHANGHAI
HONG KONG
MANILA
SAIGON
OKINAWA
TOKYO
CHICHI JIMA
IWO JIMA
SAIPAN
GUAM
YAP
ULUPI
KOROR
WOLEAI ATOL
TRUK
PONAPE
KUSAIE
ENIWETOK ATOL
RONGERIK ATOL
KWAJALEIN
MAJURO
NAURU
FUMATAHACHI
WAKE I
65
66


TYPHOON TRACKS
01-15 JULY
1965 - 1966
TSINGTAO
SHANGHAI
TOKYO
OKINAWA
CHICHI JIMA
IWO JIMA
HONG KONG
MANILA
SAIGON
SAIPAN
GUAM
YAP
ULITHI
KOROR
WOLEAI ATOL
TRUK
PONAPE
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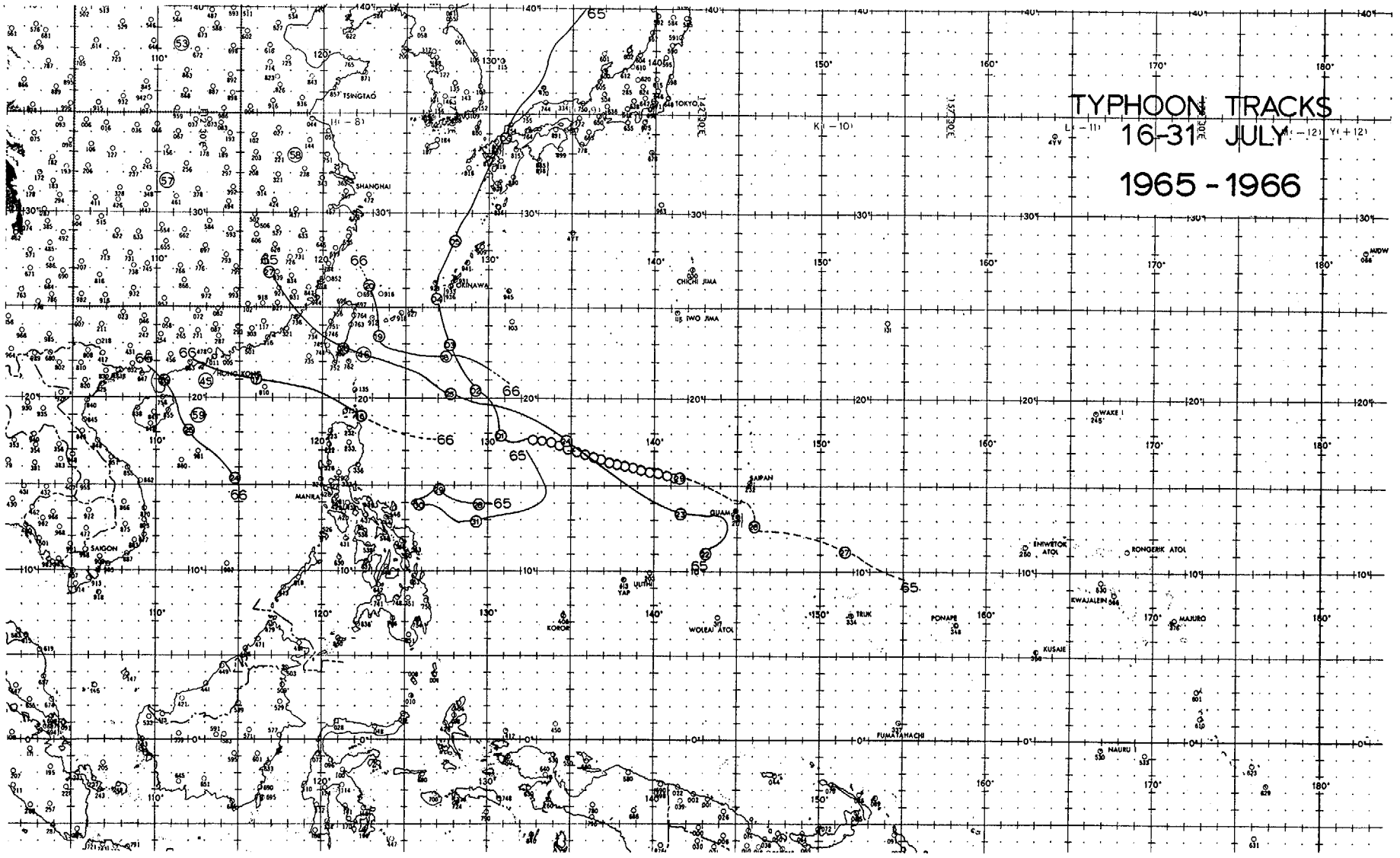
RONGERIK ATOL
KWAJALEIN
MAJURO
KUSAIE
WAKE I
NAURU I
FUMATAMACHI
65


TYPHOON TRACKS
16-31 JULY
1965 - 1966
TSINGTAO
SHANGHAI
TOKYO
OKINAWA
CHICHI JIMA
IWO JIMA
HONG KONG
MANILA
SAIGON
SAIPAN
GUAM
YAP
ULITHI
KOROR
WOLEAI ATOL
TRUK
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KUSAIE
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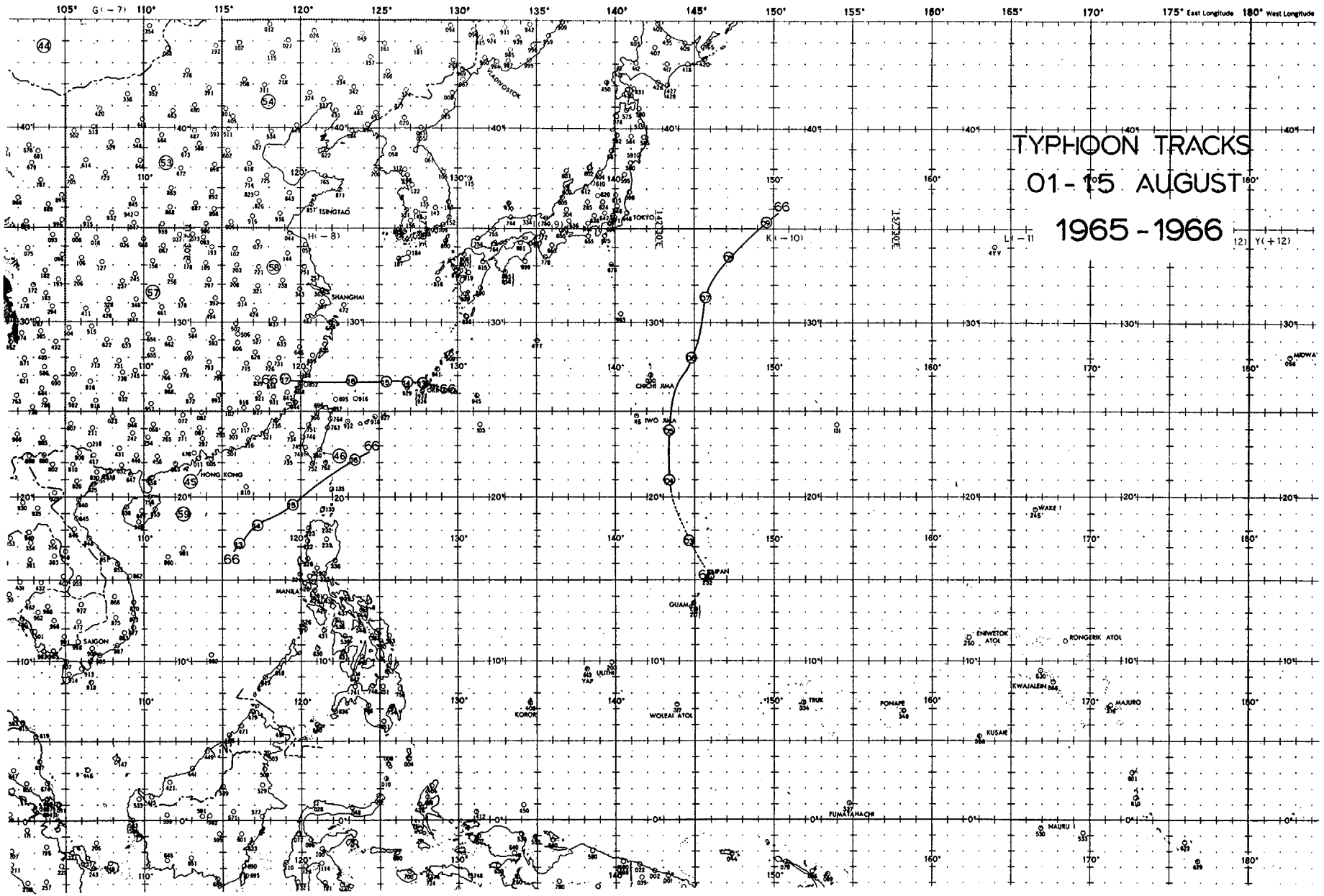
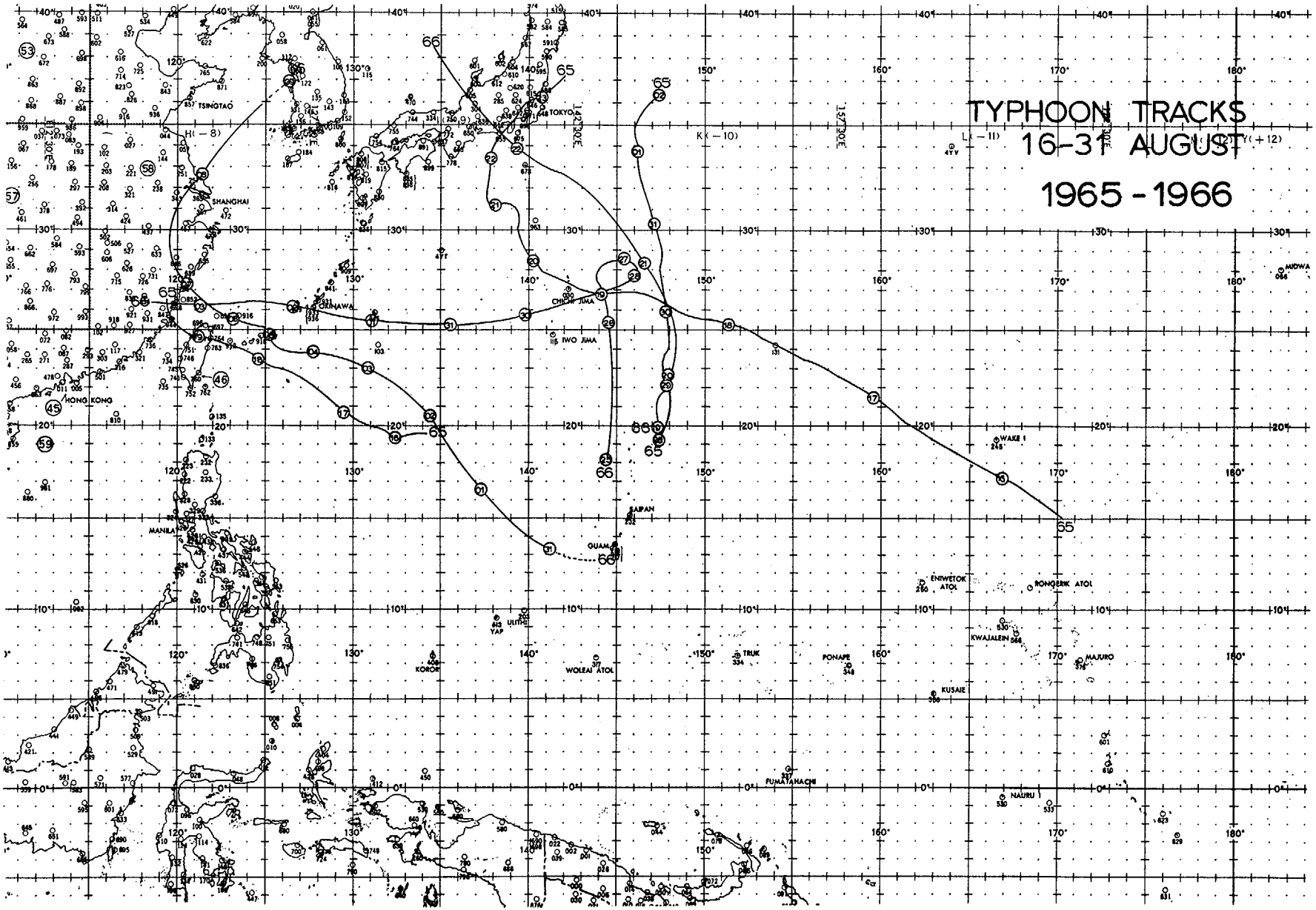
MAJURO
WAKE I
NAURU
MIDW


TYPHOON TRACKS
01-15 AUGUST
1965-1966
105° G(-7) 110° 115° 120° 125° 130° 135° 140° 145° 150° 155° 160° 165° 170° 175° East Longitude 180° West Longitude
H(-8)
K(-10)
L(-11)
Y(+12)
VLADIVOSTOK
TSINGTAO
SHANGHAI
TOKYO
CHICHI JIMA
IWO JIMA
HONG KONG
MANILA
SAIGON
SAIPAN
GUAM
ULITHI
YAP
KOROR
WOLEAI ATOL
TRUK
PONAPE
KUSAIE
ENIWETOK ATOL
RONGERIK ATOL
KWAJALEIN
MAJURO
WAKE I
MIDWAY
FUMATAHACHI
NAURU
66


TYPHOON TRACKS
16-31 AUGUST
1965 - 1966
TSINGTAO
SHANGHAI
OKINAWA
HONG KONG
MANILA
TOKYO
CHICHI JIMA
IWO JIMA
SAIPAN
GUAM
YAP
ULITHI
KOROR
WOLEAI ATOL
TRUK
PONAPE
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ENIWETOK ATOL
RONGERIK ATOL
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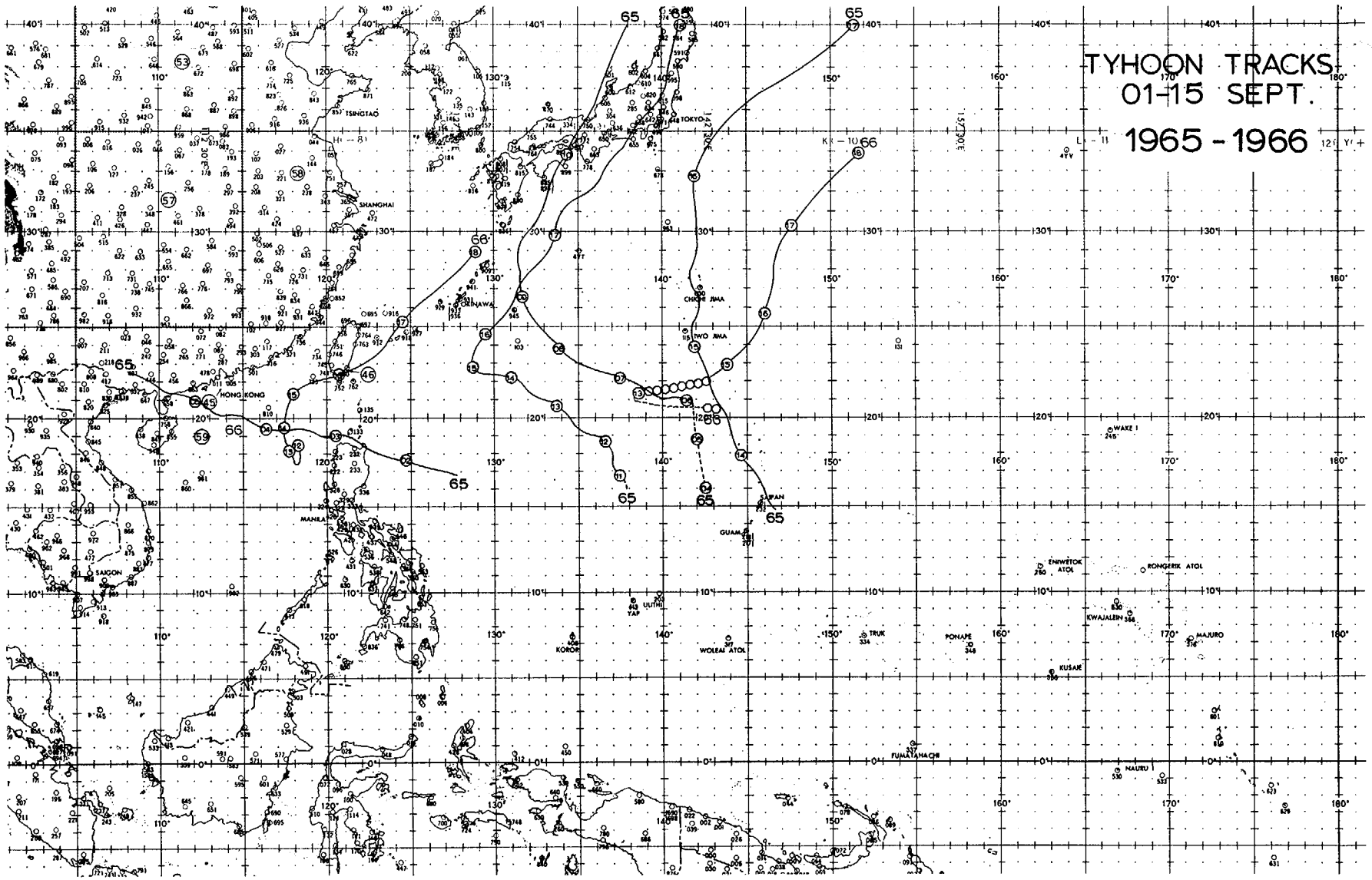
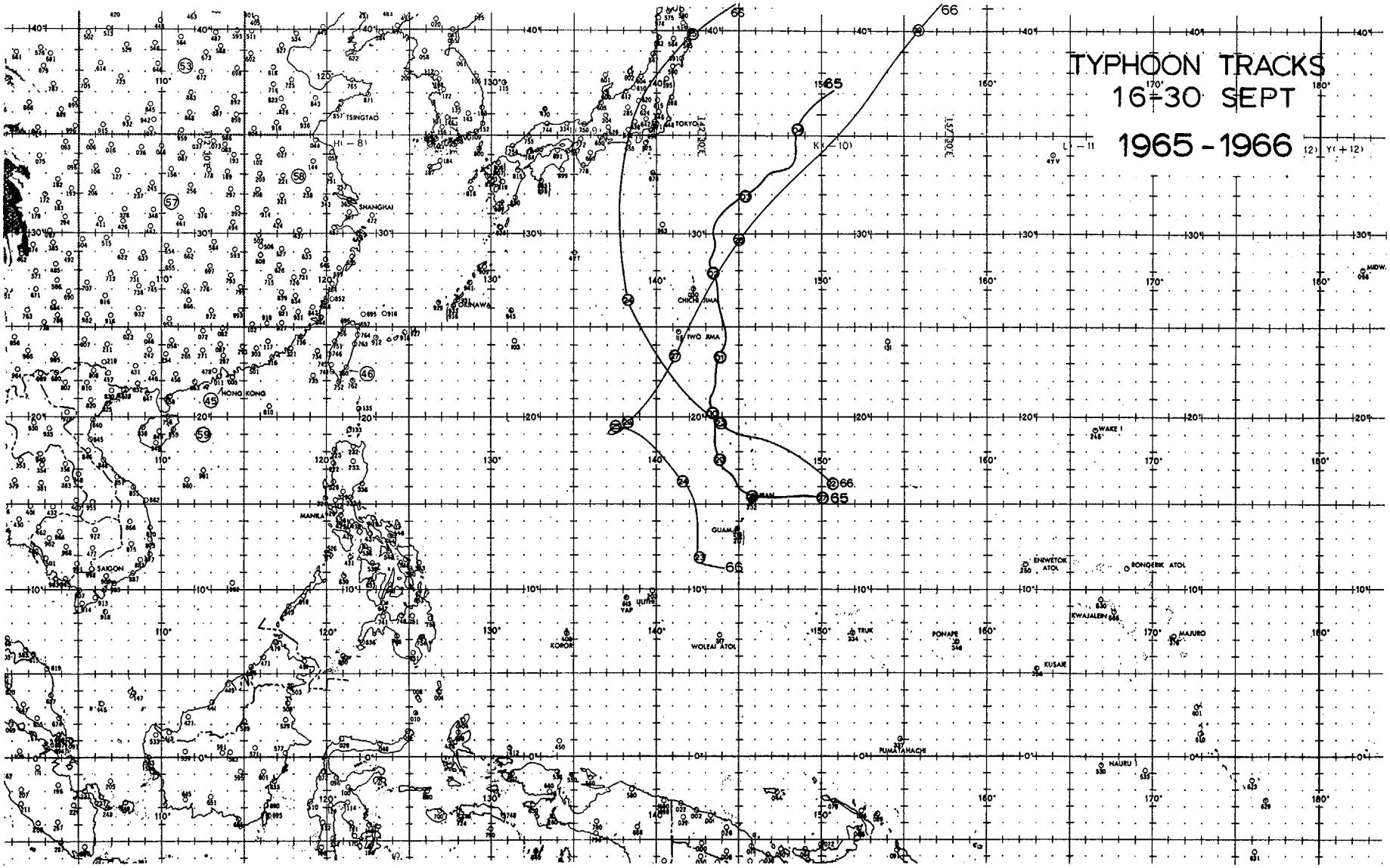
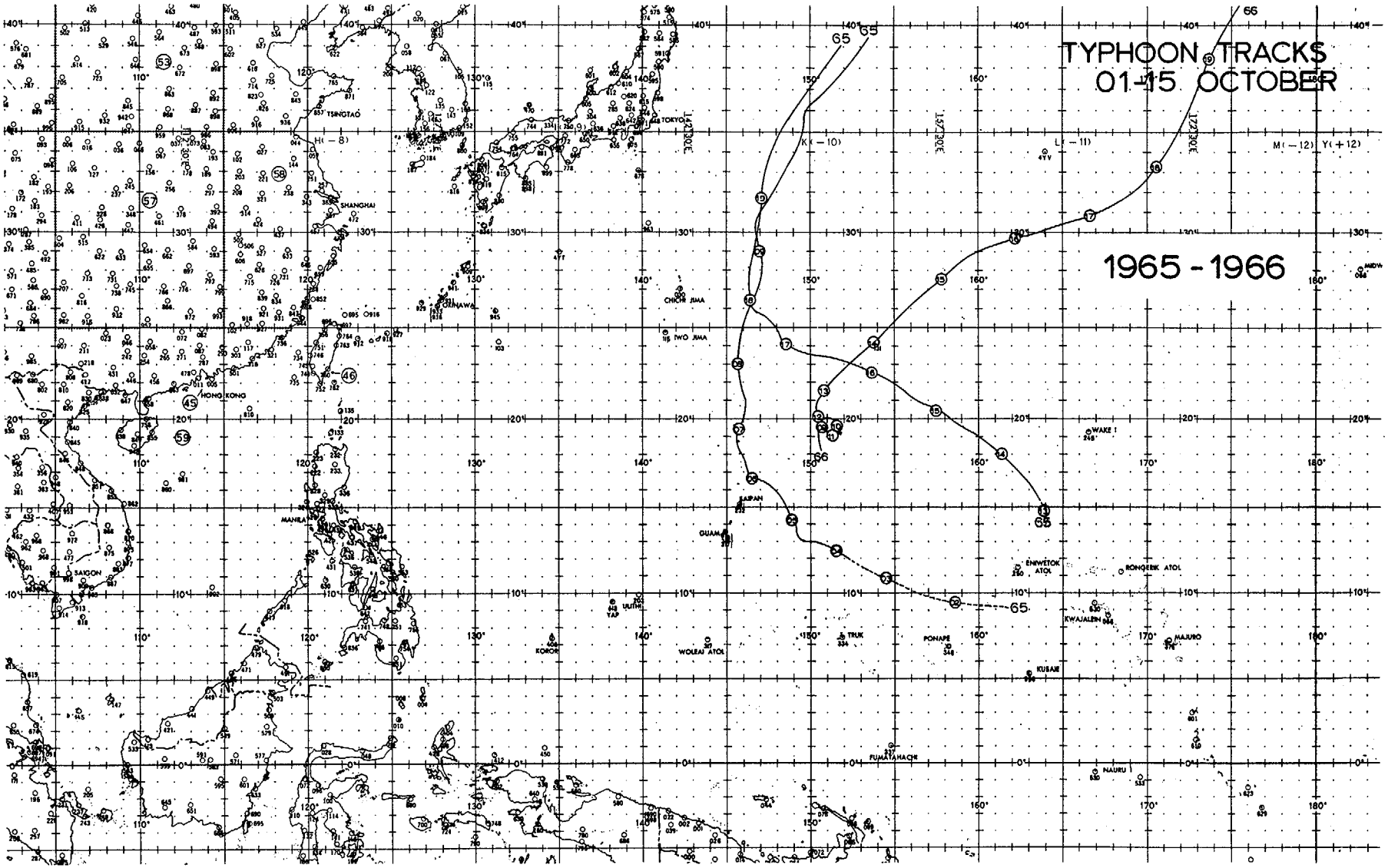
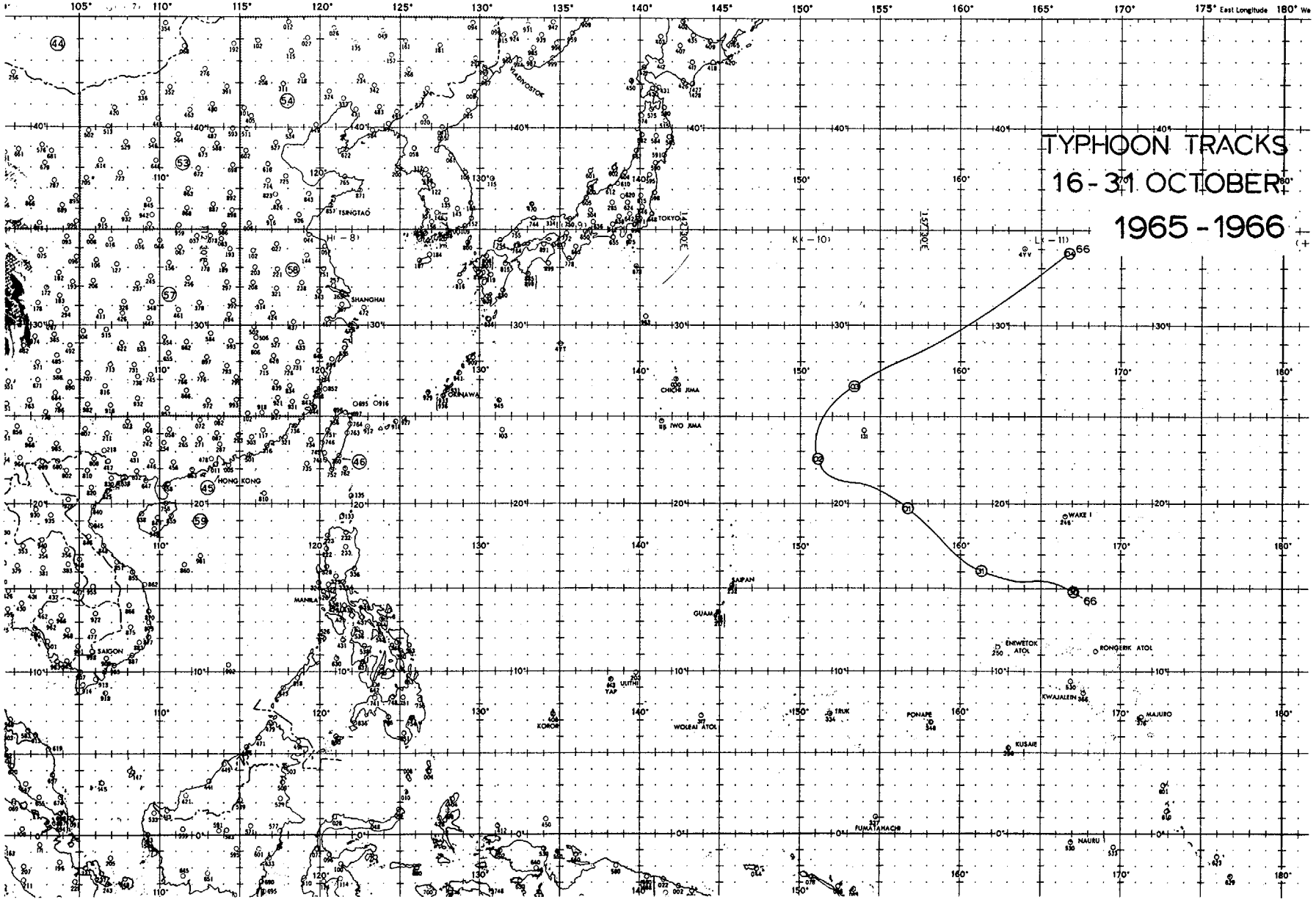
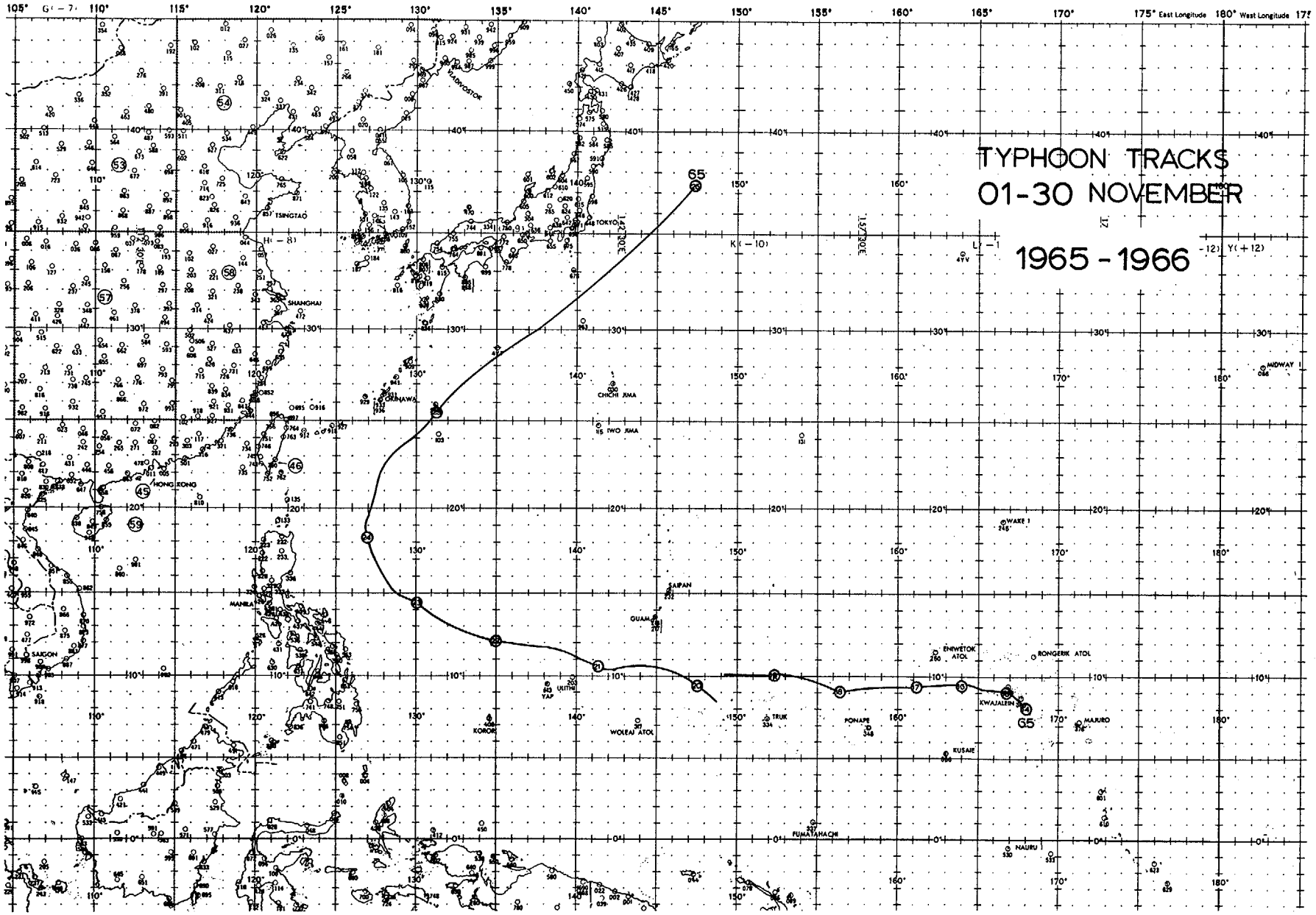
NAURU
FUMATAHACHI
WAKE I
MIDWA

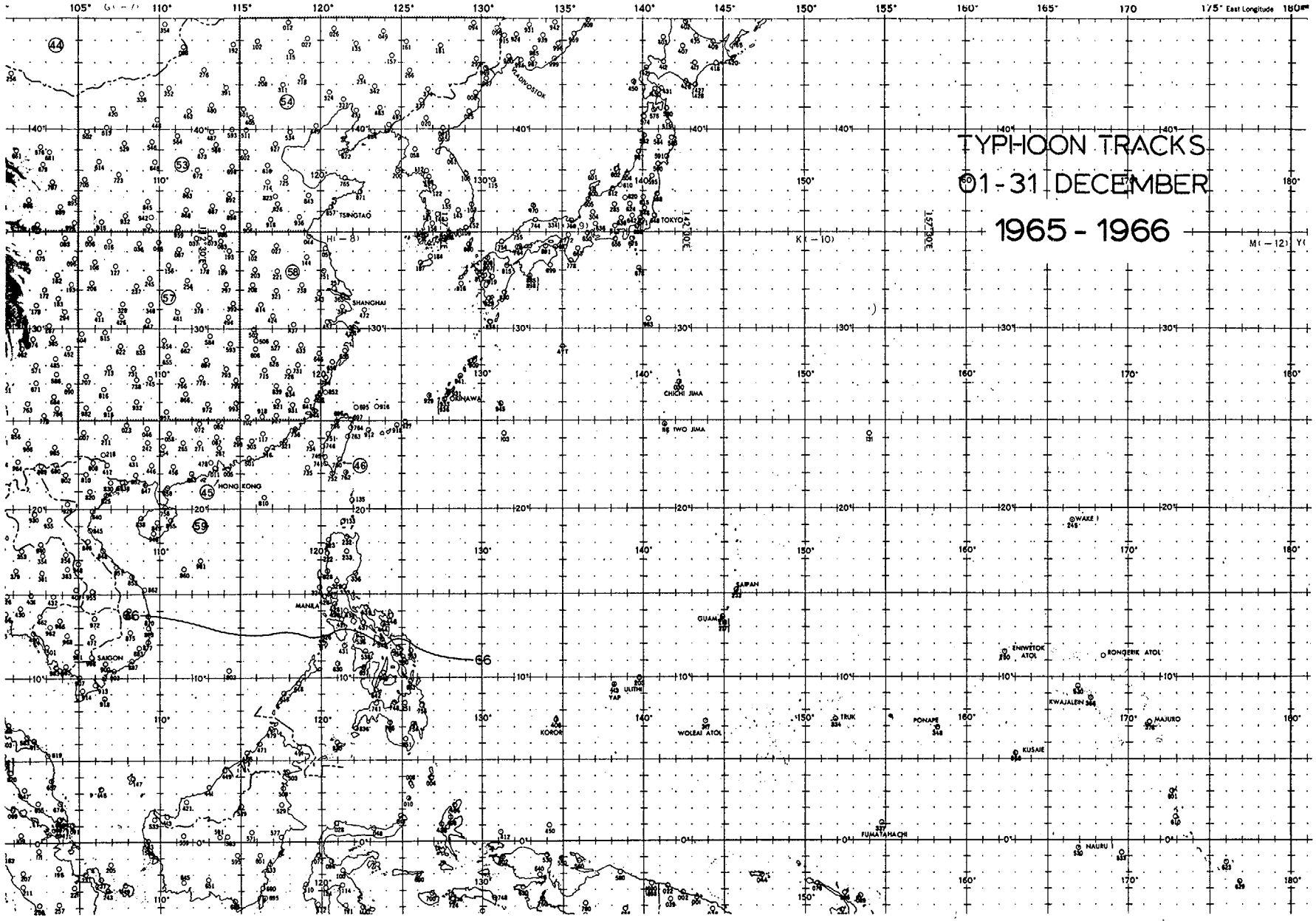

TYHOON TRACKS
01-15 SEPT.
1965 - 1966
TSINGTAO
SHANGHAI
HONG KONG
MANILA
SAIGON
OKINAWA
TOKYO
CHICHI JIMA
IWO JIMA
SAIPAN
GUAM
WAKE I
ENIWETOK ATOL
RONGERIK ATOL
KWAJALEIN
MAJURO
KUSAIE
PONAPE
TRUK
WOLEAI ATOL
KOROR
YAP
ULITHI
FUMATAHACHI
NAURU


TYPHOON TRACKS
16-30 SEPT
1965 - 1966
TSINGTAO
SHANGHAI
TOKYO
OKINAWA
CHICHI JIMA
IWO JIMA
HONG KONG
MANILA
SAIGON
GUAM
YAP
ULITHI
KOROR
WOLEAI ATOL
TRUK
PONAPE
PUMATAHACHI
KUSAIE
KWAJALEIN
MAJURO
ENIWETOK ATOL
RONGERIK ATOL
WAKE I
NAURU
MIDW.


TYPHOON TRACKS
01-15 OCTOBER
1965 - 1966
TSINGTAO
SHANGHAI
TOKYO
OKINAWA
CHICHI JIMA
IWO JIMA
HONG KONG
MANILA
SAIGON
SAIPAN
GUAM
ULITHI
YAP
KOROR
WOLEAI ATOL
TRUK
PONAPE
KUSAIE
ENIWETOK ATOL
RONGERIK ATOL
KWAJALEIN
MAJURO
WAKE I
FUMATAHACHI
NAURU
MIDW
H(−8)
K(−10)
L(−11)
M(−12)
Y(+12)
65
66


TYPHOON TRACKS
16 - 31 OCTOBER
1965 - 1966
105° 110° 115° 120° 125° 130° 135° 140° 145° 150° 155° 160° 165° 170° 175° East Longitude 180° We
VLADIVOSTOK
TSINGTAO
TOKYO
SHANGHAI
OKINAWA
CHICHI JIMA
IWO JIMA
HONG KONG
MANILA
SAIGON
SAIPAN
GUAM
YAP
ULITHI
KOROR
WOLEAI ATOL
TRUK
PONAPE
FUMATAMACHI
KUSAIE
KWAJALEIN
MAJURO
ENIWETOK ATOL
RONGERIK ATOL
WAKE I
NAURU
66
66


TYPHOON TRACKS
01-30 NOVEMBER
1965 - 1966
175° East Longitude
180° West Longitude
VLADIVOSTOK
TSINGTAO
TOKYO
SHANGHAI
OKINAWA
CHICHI JIMA
IWO JIMA
HONG KONG
MANILA
SAIGON
SAIPAN
GUAM
ULITHI
YAP
KOROR
WOLEAI ATOL
TRUK
PONAPE
KUSAIE
ENIWETOK ATOL
RONGERIK ATOL
KWAJALEIN
MAJURO
FUNATAHACHI
NAURU
WAKE I
MIDWAY I
65


TYPHOON TRACKS
01 - 31 DECEMBER
1965 - 1966
VLADIVOSTOK
TSINGTAO
TOKYO
SHANGHAI
CHICHI JIMA
BIG TWO JIMA
HONG KONG
MANILA
SAIGON
SAIPAN
GUAM
WAKE I
ENIWETOK ATOL
RONGERIK ATOL
KWAJALEIN
MAJURO
KUSAIE
PONAPE
TRUK
WOLEAI ATOL
KOROR
ULITHI
YAP
FUMATAHACHI
NAURU
175° East Longitude

TYPHOON FREQUENCY

10 YEAR PERIOD

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL TOTAL
1957	1			1	1	1	1	2	5	3	3		18
1958	1				1	2	5	3	3	3	1	1	20
1959				1			1	5	3	3	2	2	17
1960						2	2	8		4	1	1	19
1961			1		2	1	3	3	5	3	1	1	20
1962				1	2		5	7	2	4	3		24
1963				1	1	2	3	3	3	4		2	19
1964					2	2	6	3	5	3	4	1	26
1965				1	2	2	4	3	5	2	1		21
1966				1	2	1	3	6	4	2	0	1	20
AVE	.3	.0	.1	.7	1.3	1.3	3.3	4.3	3.5	3.1	1.6	.9	20.4