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A descriptive summary is given of tropical revolving storms and typhoons which occurred in the Western North Pacific in 1947. Their origin and dissipation, comparison of the observations with hypotheses, and comparison of results with various forecasting techniques is given along with attempts to select the best techniques for forecasting the movement of tropical cyclones. Attention is given to the movement of cyclones when more than one is present at a time. The study of the typhoons of 1947 suggests that a new approach may be necessary to the problem of typhoon forecasting before a satisfactory solution is found.

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AIR WEATHER SERVICE
TECHNICAL REPORT 105-42

63797

REPORT ON POST-ANALYSIS OF TYPHOONS IN THE WESTERN NORTH PACIFIC, 1947.

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JULY 1949

HEADQUARTERS
AIR WEATHER SERVICE
WASHINGTON, D.C.

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Andrews Air Force Base
Washington 25, D. C.

July 1949

Air Weather Service Technical Report 105-42, "Report on Post-Analysis of Typhoons in the Western North Pacific, 1947," is published for the information and guidance of all concerned.

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Preface

In 1947 the Air Weather Service established the policy of retaining so far as feasible, officers assigned to hurricane and typhoon forecasting at their stations on a year-round, year to year basis in order to take advantage of their accumulated experience and to permit them to make post analysis studies of the storms during the "off-season." In this way the effectiveness of the tropical storm forecasting might be materially enhanced. The first report of the post-analysis studies on Atlantic hurricanes appeared in AWS Technical Report 105-37, July 1948. The present report is the first on typhoon post-analysis. Owing to the large area affected by typhoons and the probability of typhoons occurring in any month of the year, the responsibility for their forecasting is divided among several weather centrals and the personnel concerned have it as part of their general forecasting duties. The post analysis task therefore required special coordination, which was arranged by the C.O. of the 2143d Weather Wing. In the case of the Atlantic-Caribbean area, however, the single U.S.A.F. Hurricane Office at Miami is only responsible for the mission of forecasting hurricanes for USAF and Army activities and the post analysis program is entirely carried out there by the same personnel who make the forecasts.

POST-ANALYSIS OF
TROPICAL CYLCONES OF THE WESTERN NORTH PACIFIC, 1947

This report presents a descriptive summary of tropical revolving storms and typhoons which occurred in the Western North Pacific in the year 1947, their origin and dissipation, compares observations with hypotheses, compares results of various forecasting techniques, and attempts to select the best techniques for forecasting the movement of tropical cyclones. A special note is made of the movement of cyclones when more than one is present at a time. The report follows the same general form as the paper by Captains Kidd and Reed, "Typhoons of the Southwest Pacific - 1945", published in the Bulletin of the AMS, June 1946, and AWS Technical Report 105-37, "Report of the Off-Season Operations of the AF Hurricane Office 1947 - 1948."

Air Weather Service units located at Harmon AFB, Guam, Haneda AFB, Tokyo, Japan, Kadena AFB, Okinawa, Clark AFB, Manila, P.I. and Kaingwan AFB, Shanghai comprised the Typhoon Warning Network of the 2143d Air Weather Wing in 1947. The Haneda Weather Central was the Typhoon Warning Center, charged with overall direction and operation of the Typhoon Warning Network until 1 September at which time this function was transferred to Harmon Weather Central. The 514th Reconnaissance Squadron (VLR) Weather at North Guam AFB, performed reconnaissance of typhoons beginning 1 September. The material is drawn from post analysis reports made by the Typhoon Warning Network.

It should be noted that the meteorological data from the Western North Pacific for 1947 was much less than in 1945, and of course less than that available in the Carribean Area. In 1945 there were a great many ship reports and aircraft weather reconnaissance reports, as well as a network of island stations in the Western Pacific. In 1946, with the roll-up of Allied Military Forces, including their weather services and weather communications facilities, the availability of weather observations decreased to a record low. In early 1947, little improvement was apparent. But with a gradual improvement in communications, the re-establishment of upper air reports and the return of the 514th Reconnaissance Squadron on 1 September 1947, a reasonable amount of weather data became available for analysis.

There were 26 tropical cylcones of sufficient intensity to warrant the exchange of Bulletins among the stations of the Typhoon Warning Network. Of these, 19 were of typhoon intensity (Maximum winds over 65 K), and 7 of tropical storm intensity (Maximum winds over 27 knots but less than 66 K). Table I contains a record of all the tropical cyclones and a brief summary of their acterisitics. Charts one and two show the tracks of each tropical cyclone, as reconstructed by post analysis using all available data. From these records some observations on the origin, movement, and dissipation can be made.

The problem of anticipating the formation of tropical cyclones was not too difficult. Most of them were suspected several days in advance, and in all cases, they were found in sufficient time to issue forecasts to interested agencies. According to analyses made, all tropical cyclones originated at the junction of an easterly wave and the ITC, often intensified by a trough in the westerlies. In no case was one observed to form in homogeneous air mass. Formation of typhoons did not appear to be limited to island areas, from which strong convection was taking place.

Forecasting the movement of tropical cyclones was the most difficult problem encountered. No accepted method of forecasting was reliable in all cases, and using everything available, the path and rate of movement of many of the typhoons was impossible to forecast accurately. Even by post analysis, the path of Rosalind, or the deceleration of Gren is difficult to explain. To approach the problem of forecasting track and speed of movement, some new hypotheses on steering principles will be considered and the usually accepted rules examined.

The most popular method of predicting the movement of typhoons is by the use of the steering wind of the free-air current(*1). From a study of 1947 data, it was found that forecasting the movement of typhoons in the Pacific by the direction of flow of the free-air current above the typhoon is practicable only for those which do not extend above the 500-mb surface, since upper-air data above that level is very sparse, and since it is doubtful if the free-air current steers the very deep lows. Of the typhoons and tropical storms of 1947, in only 3 cases did the 700-mb wind flow apparently steer the cyclone. The 700-mb wind flow was influential when the tropical cyclone began to become extratropical. Typhoons Gwen and Jean were typical in this respect.

It was shown that no one level can be selected for steering. Some tropical cyclones have a closed circulation extending above 40,000 feet, while others were definitely only 10,000 feet high and easily steered by the 700-mb winds. Each particular tropical cyclone must be analyzed each day to find the proper level for steering.

A useful aid in forecasting the movement of typhoons is the asymmetrical distribution of wind velocities around the typhoon. The principle(*2) is this: If the wind is symmetrical, the typhoon is nearly stationary; if the wind velocity varies in the different quadrants, the typhoon will move parallel to the strongest wind and the speed of movement will be proportional to the difference between the wind speed in the strong quadrant and that of the weak quadrant. A simple explanation of this rule is as follows: In the strong quadrant, the general steering current, or movement vector, is added to the cyclonic current of the typhoon; in the weak quadrant, the general current is subtracted from the cyclonic current.

(*1) See: H. Riehl and R.J. Shaefer: The Recurvature of Tropical Storms, Journal of Meteorology, Vol. 2, no. 1-2, Sept. 1944.

(*2) Mintz: A Rule for Forecasting Eccentricity and Direction of Motion of Tropical Cyclones, Bull. Amer. Met. Soc., March 1947.

This rule can be applied to some of the typhoons of 1947, although it was not generally used by the forecaster. Many reports note the variation in the distribution of wind speed around the typhoon. Clouds and weather are also often distributed asymmetrically. Transport aircraft as well as regular reconnaissance aircraft reports remarked on this feature frequently.

This principle seems to be merely another manifestation of the steering principle: the steering current intensifies the side parallel to it, weakens the side opposed to it. However, there is an important difference in the application of the principle and therefore some of the difficulties encountered in employing the steering effect of the free-air current are avoided. No search need by made to evaluate its force. The manifestation of the free-air current is observed directly in its effect on the symmetry of the typhoon. Steering by the wind-differential method described above is considered one of the best methods available. It has a theoretically sound basis, the determining factors can be observed, often without the aid of instruments, and its verification from actual use is very high.

Another approach to the problem of movement of typhoons is the slope of the eye. It has been postulated that a low will move opposite to the slope of its vertical axis: i.e., a low sloping east will move west. (R. Sawada solved the equations of motion and derived such a relationship - unpublished). The rate of movement may be proportional to the slope of the axis. Thus, the rule would be that a typhoon whose axis slopes to the east will move west or one which slopes SW will move northeast, a vertical axis would indicate no movement or recurvature, a marked slope would indicate rapid movement, etc. Of course, the difficulty is in determining the slope accurately - little was attempted in this line in 1947; Typhoon Rosalind was the first to suggest the value of such an approach. With adequate reconnaissance, and upper-air soundings from Guam, Clark, Okinawa, Iwo and Japan, sufficient data should be available to attempt an empirical verification of this theory in future seasons.

Extrapolation, climatology, and surface pressure-pattern ("synoptic") were also investigated as methods of forecasting the direction and speed of movement of typhoons. Extrapolation was found to be useful, if applied to good data, especially either in the early or late parts of the season. Extrapolation was a very poor method of forecasting in those cases in which the present and past position of the typhoon were inaccurate, and also poor during July, August and September when the tracks are most erratic. Another difficulty in using extrapolation in forecasting the rate of movement was that many of the typhoons (notably Gwen, Kathleen, and Rosalind) did not accelerate upon recurving, the supposedly normal behavior.

Climatology was especially useful in 1947. In many instances climatology was the only aid available, and late in the season during November and December, the typhoons followed the tracks of climtological expectancy well. Of course, some difficulties were encountered in using climatic data available. Tracks shown in different publications do not agree. Those shown in H.O. 219, "Climatology, Asiatic Station", appear to be incorrect, especially the average tracks shown for November, December and January. Although climatology given in "Typhoon Tracks Supplement to Weather Guides for Long Range Planning", prepared by the War Advisory Council on Meteorology, U. S. Weather Bureau, March 1944, covers a period of approximately 20 years, it apparently does not include all the possible track variations.

The use of the surface synoptic map in evaluating steering was found quite useful, since the most data was available for these maps. It might be said that, insofar as the upper-air situation can be estimated from the surface map, the use of the surface map is successful. It must also be kept in mind here is that the surface synoptic pattern is influenced by the typhoon. (see case of Rosalind.)

The study of the typhoons of 1947 suggests that a new approach may be necessary to the problem of typhoon forecasting before a satisfactory solution is found. Throughout the year it was apparent that typhoons are not wholly dependent upon external forces for steering; their own energy is an important factor in their course and character. It is generally agreed that this energy is derived from the condensation of water vapor. In the case of typhoons, a large amount of latent energy is converted to kinetic energy at the condensation level. What happens at the condensation level during the formation, life, and dissipation of a typhoon?

The conventional rule that typhoons dissipate rather rapidly after moving north of 30°N lat., held up well in 1947. Only Donna, Gwen, Kathleen, and Rosalind had any significant life north of 30°N and these weakened rapidly upon reaching and passing that latitude. An examination of climatic records for Japan also verifies that typhoons almost never retain the severity experienced at lower latitude stations such as Iwo Jima and Okinawa, upon reaching Honshu. (*4) This finding is somewhat different than for the eastern coast of the U.S., where hurricanes sometimes remain intense well above 30°. A possible explanation of this difference lies in the curvature of the coastline of SW Honshu. It will be noted that the SE coast of the islands has a definite convex curvature. It has been suggested that low pressure systems approaching a convex coast line tend to weaken. (*3)

An interesting difference between the storm behavior in the Western North Pacific and the Carribean Area is that frequently typhoons originate in the wake of other typhoons. Four of those in 1947 were formed in this manner. Three of these followed in the trough formed by the previous typhoon; one, Elnora (November) did not follow the path of Dora, the preceding typhoon. This phenomenon is rare in the case of Atlantic hurricanes.

(*3) Carpenter: Cyclogenetic Arcs on the Pacific Coast, Bull. Amer. Met. Soc., Feb. 1945.

(*4) Takahasi: Typhoon in Japan, Geophysical Mag. Vol XVII, No. 1-2, March 1948.

TABLE

VERIFICATION OF FORECASTING

DATE AND NAME OF TROPICAL CYCLONE	ORIGIN	POSITION OF RECURVATURE	POINT OF ENTRY ON LAND
1. ANNA 18-20 March	Junction of easterly wave and ITC.	None	7 degrees north
2. BERNIDA 13-16 May	Junction of easterly wave and ITC	N to NE at 28N 131.4E.	None
3. CAROL 16-22	ITC.	None - NW movement.	
4. EILEEN 17-19 July	ITC. Strong Southwesterly monsoon.	18 N 110E	Hainan
5. FAITH 26-31 July	ITC	24N 122.5E	None
6. GWEN 4-7 August		30N 129E & 34E 132E	None.
7. HELENA 12-13 August	Junction of easterly wave and ITC	None	None.
8. INEZ 26-30 August	Junction of easterly wave & ITC	None - General NW movement.	Northern Formosa & China coast.

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TECHNIQUES ON TYPHOONS OF 1947

EXTRAPOLATION	CLIMATOLOGY	STEERING LEVEL	SURFACE SYNOPTIC SITUATION	REMARKS
Good for direction, fair for rate.	Poor - only 1 or 2 tracks similar to this.	No data	Good for direction of movement	
Good for rate of movement & direction	Track similar to one in May 1923		Good for direction of movement followed PT 1	
Good both for rate & direction	Fair for track except about 60% recurve near 20N 121E.		First indications were that it would recurve into PT - Okay for short range.	
Fair	Good, Several similar tracks.		Fair - no problem	
None.	Poor. Change in both rate & direction several times.	Poor-nothing quite like this.	Poor	
Poor. Change in rate made extrapolation incorrect	Poor, last curvature was directly across usual track	Fair-little data-some indication this typhoon was shallow. 700mb may have steered.	Good, followed Polar trough	The rapid dissipation may have been due to curvature of Jap coast.
Fair, no problem	Excellent		Good	
Fair, path somewhat irregular.	Good-Track was most probable.		? Not conclusive. High pressure not very strong.	

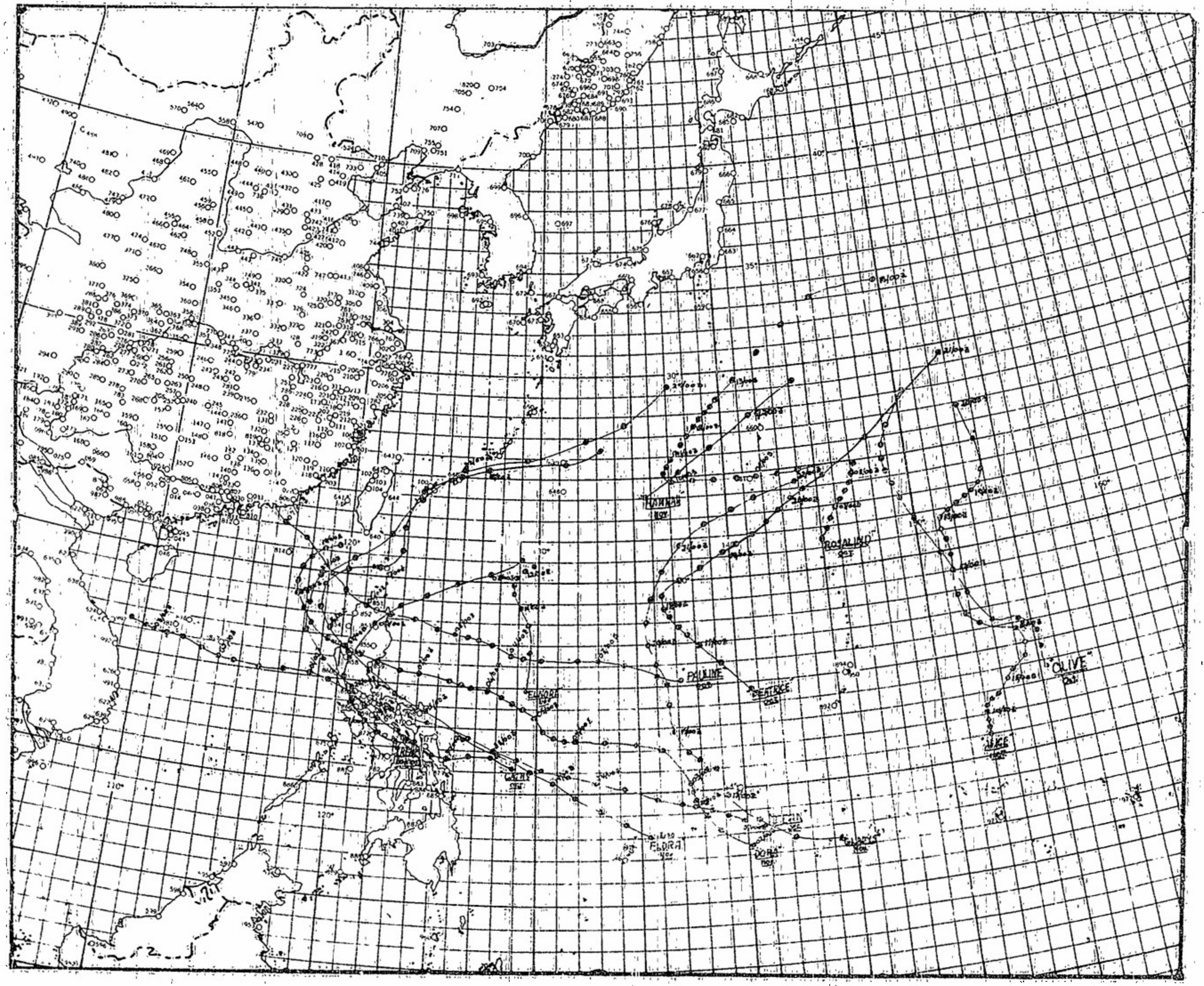
DATE AND NAME OF TROPICAL CYCLONE	ORIGIN	POSITION OF RECURVATURE	POINT OF ENTRY ON LAND
9. JOYCE 8-10 September	Junction of ITC & easterly wave.	NW to N at 23.5N 123E.	None.
10. KATHLEEN 10-15 Sept	Junction of ITC & easterly wave.	15.5N 135.5E	Tokyo
11. LAURA 14-17 September	In wake of Kathleen.	30N 150E	None.
12. MILDRED 22-25 Sept	Junction of ITC & easterly wave	General WNW movement.	Crossed Central Luzon.
13. NANETTE 29-Sept, 2 Oct	Junction of easterly wave and surface trough.	None.	Crossed south of Formosa & entered China Coast, South of Amoy.
14. OLIVE 2-5 October	Junction of ITC & easterly wave.	25N & 149E.	None.
15. PAULINE 2-7 October	Junction of easterly wave & ITC	WNW to NW movement entire history.	Northern tip of Luxon & China Coast at 27.5N.
16. ROSALIND 6-14 Oct.	Wake of Typhoon Olive.	NNE to W at 29N 146E-W to NE at 30N 137 E.	None.

EXTRAPOLATION	CLIMATOLOGY	STEERING LEVEL	SURFACE-SYNOPTIC SITUATION	REMARKS
Fair	Fair-Track was most probable.		Fair, dissipated upon reaching PT.	
Fair.	Good- Most probable tr ck.	700mb only chart available followed upper level trough prob. was steered by high level winds.	Good, fell into PT.	Did not accelerate after passing 30 degrees north - slowed down.
Good	Poor, outside the usual tracks.		Followed in wake of Kathleen.	Formed in wake of Kathleen.
Good	Poor, this track is rare for the season.	Followed 700 mb flow well.	Good, warm high to the north.	
Fair	Anything can happen		Poor, did not follow trough.	
Fair, except at the beginning	Poor, outside the normal limits of clime.	Fair, by 700mb level, closed there	Fair, followed in trough.	
Good for direction, fair for rate.	Fair-most recurve however.	Not by 700 mb level.	Fair, good high to the north, no trough passed.	
Unsatisfactory	Nothing quite similar especially part east of Iwo.	Not steered by 700mb level	This was the only clue. High pressure blocked NE movement.	

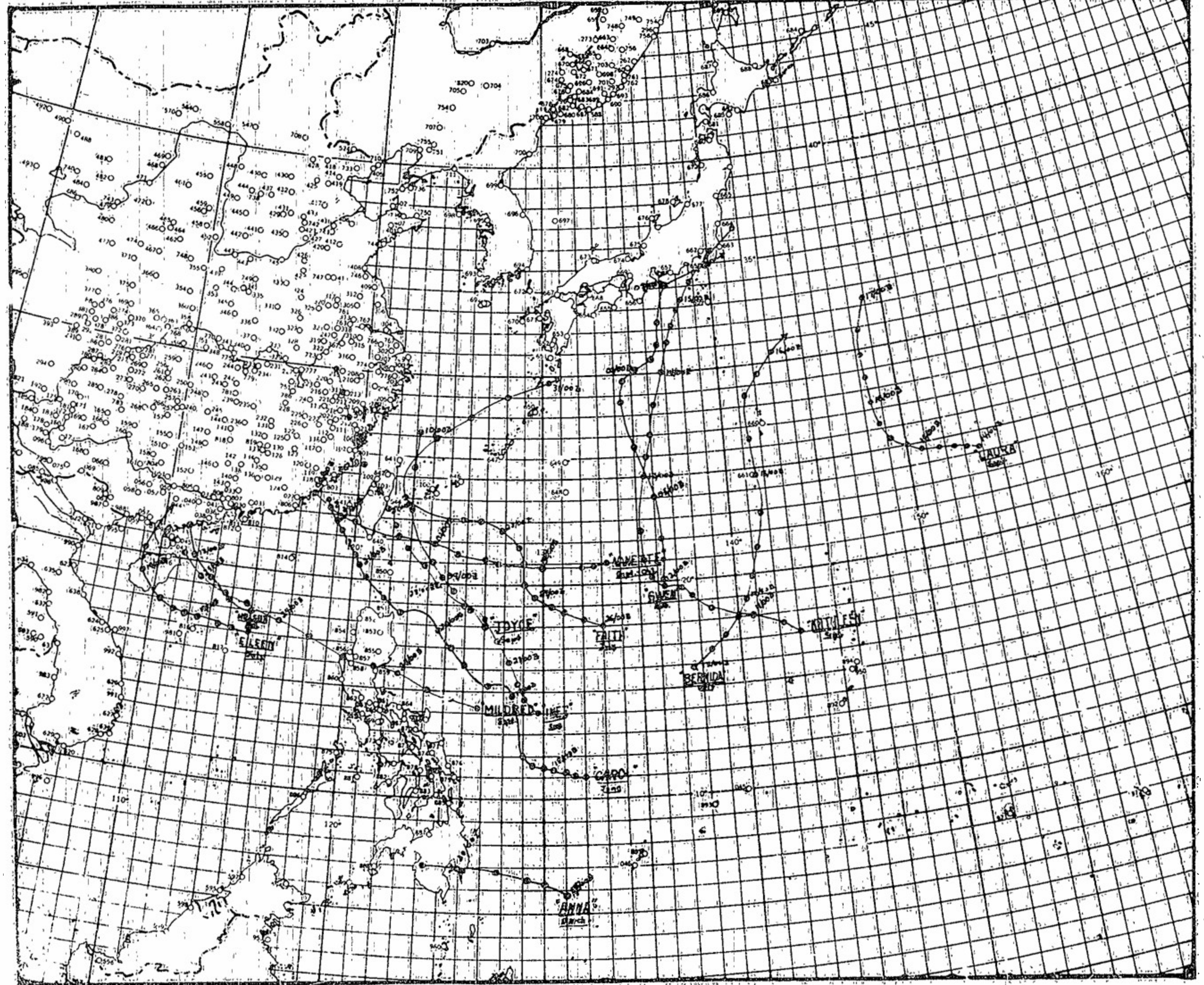
DATE AND NAME OF TROPICAL CYCLONE	ORIGIN	POSITION OF RECURVATURE	POINT OF ENTRY ON LAND
17. ALICE 13-20 October	Junction of easterly wave & ITC	None.	None
18. BEATRICE 17-21 Oct.	First noticed on 700mb level.	19N 137E.	None.
19. CATHY 29 Oct - 3 Nov.	Junction of easterly wave & ITC.		12N 126E.
20. DORA 2-10 November	First noticed on 700mb chart.	NN to NE at 24N at 118E.	Central Luzon.
21. ELNORA 10-11 Nov.	Wake of Dora.	20N 131N to NE.	None.
22. FLORA 13-18 Nov.	Junction of ITC & easterly wave.	19N 119E NW to NE.	Central Luzon
23. GLADYS 17-22 Nov.	Junction of easterly Wave & ITC.	18 N 136E.	None.
24. HANNAH 22-23 November	Wake of Gladys	18 N 136E.	None
25. IRENE 30 Nov-3 Dec.	Junction of easterly wave, westerly trough & ITC.	20 N 121E.	Southern P.I.

EXTRAPOLATION	CLIMATOLOGY	STEERING LEVEL	SURFACE SYNOPTIC SITUATION	REMARKS
Poor, minor variations in whole track	Poor.	700mb was of some help.	Good, followed a trough in the trough.	
Fair	Fair	Primarily apparent at 700 mb.	Fair, followed in wake of Alice.	
Fair.	Good, most probable course.		Good, high to north.	
Poor	Good, most probable.	Poor, did follow 700mb trough.	Fair.	
Poor.	Fair.		Did not follow wake of Gladys but did the FT.	
Good until recurvature.	Poor, very few recurves after crossing Luzon.	Poor at 700 mb, lack of data.	Poor.	
Fair.	Fair, only small percentage.		Good, followed trough made by Flora.	
Fair	Good	Good by 700 mb level	Good, followed trough of Gladys.	
Fair	Poor, exception to usually path		Good, followed trough.	

DATE AND NAME OF TROPICAL CYCLONE	ORIGIN	POSITION OF RECURVATURE	POINT OF ENTRY ON LAND
26. JEAN 22-29 December	Junction of ITC, westerly trough & shear lines.	NW to NE at 23 N 118 E.	Central P. I.



"HANNAH"
"ROSALIND"
"PAULINE"
"BEATRICE"
"CLIVE"
"FLORA"


LAURA
KATHLEEN
BERMUDA
ANNETTE
GLEN
FAITH
JOYCE
MILDRED
INEZ
CARO
EILEEN
ANNA

EXTRAPOLATION	CLIMATOLOGY	STEER-ING LEVEL	SURFACE SYNOPTIC SITUATION	REMARKS
Fair	Good, followed most probable course.	700 mb showed recurvations.	Good, strong high to north until recurvature.	

NARRATIVE HISTORIES OF 1947 TYPHOONS

ANNA - MARCH

Tropical storm Anna was the first of the year, and existed from 18 to 20 March. It was formed at the junction of an easterly wave and the ITC about 360 nautical miles east southeast of Davao, moved toward Davao and dissipated over Mindanao. Little data was available for analysis, but from all indications, the storm was of little significance.

BERNIDA - MAY

Typhoon Bernida was the first important tropical cyclone of the year. A strong easterly trough with an associated "wave" on the ITC, passed Guam on 9 May giving Guam 12 to 18 hours of severe weather including thunderstorms and about 2 inches of rainfall.

The easterly trough was retarded and intensified by a westerly trough in the vicinity of 141°E, giving severe weather enroute Guam to Manila and Guam to Okinawa. The easterly trough continued to move westward, stagnating on the Guam to Manila route 10 May between 130 and 136° E, with continued severe weather.

A general widespread low area resulted along the ITC, centered near 12°N, 136°E during 11 May. The persistance of the low area caused the Navy Weather Reconnaissance Squadron at Guam to fly a mission into it early on 13 May. Bernida was first found by this reconnaissance near 16°N, 137.5°E at 130000Z and moved rapidly northward under the influence of a rather deep polar trough which was intensifying over eastern Honshu.

The 140000Z May Navy reconnaissance reports gave a fair location of Bernida near 18°N, 140°E with probable typhoon intensity indicated at that time.

The point of acceleration of Bernida appeared to be near 19.5°N, 141°E. The reconstructed path indicated change of velocity from 10-11 knots to 15-18 knots after that position had been reached.

Bernida reached maximum intensity between the 14th and 15th during which time it passed just to the east of Iwo Jima with highest wind speeds near 80 knots in gusts.

During its entire history, Bernida remained relatively small in area with the most intense belt of winds in the eastern quadrants.

A turning point for Bernida was reached early on 16 May to the north of Iwo Jima. The reconstructed path indicates a change from northerly to northeasterly track at this time. There was rapid dissipation of the typhoon circulation shortly after this turning point was reached.

CAROL - JUNE

Typhoon Carol was first noted on the 0000Z synoptic map of 16 June as a tropical disturbance on the intertropical front in the vicinity of 10°N and 130°E. The disturbance continued to develop during the day and night of the 16th and 17th, and the Navy reconnaissance mission flown on the morning of 17 June gave a fair fix at 11.0°N and 132.0°E. Winds reported by the reconnaissane mission revealed that Carol had increased to storm proportions. Maximum winds near the center at this time were estimated at 45 knots, with winds over 27 knots extending over a radius of 150 nautical miles.

Reconnaissance on the morning of 18 June located Carol at 11.6°N and 130°E. During the afternoon and night of the 18th and 19th, Carol recurved into a more northerly direction, accelerated and was found by reconnaissance on the morning of June 19 to be at 14.9°N, 128.3°E. Maximum wind velocity near the center had increased to 65 knots.

The afternoon reconnaissance mission on 19 June placed Carol at 15.3°N, 127.2°E, indicating a new curvature towards the west.

Reconnaissance on the 20th accurately located Carol at 18°N, 123°E and winds were found to have increased to 100 knots near the center. Winds over 65 knots extended to a radius of 150 miles, and over 27 knots to a radius of 250 miles. Thus, reconnaissance information tends to substantiate a rather erratic path, a path which would have been extremely difficult to forecast by extrapolation. Furthermore, deceleration was noted after the typhoon had reached maximum intensity (100 knots) on the 20th of June, accompanied by lessening intensity until, at the time it began its northerly course, it had completely dissipated.

DONNA - JULY

Kadena first detected what appeared to be a closed low on the 0000Z surface synoptic chart of 6 July 1947 at 15.3°N and 133.7°E. The low persisted on subsequent charts, moving 300 degrees true at 12 knots until 061800Z, when it was centered at 17.2°N and 130.4°E. At this time it began to recurve and accelerate, moving 330 degrees true at 14 knots, and in the next twelve hours it accelerated even more and continued to recureve, moving 350 degrees true at at approximately 20 knots.

A maximum wind speed of approximately 40 knots near the center was estimated.

By 100000Z surface weather reports indicated that the cyclone had dissipated in the mountains northeast of Osaka.

Although small in size and intensity, Donna brought heavy rains to Kyushu and Southern Honshu, causing considerable flood damage.

EILEEN - JULY

Presence of a tropical disturbance along the equatorial front over the South China Sea, was first indicated by a strong flow in the monsoon current along the western coast of Luzon, P.I. on 17 July. The intensity of the disturbance as observed by a Navy weather reconnaissance flight on 17 July, was rather weak, with the strongest winds near 30 knots in the southeast quadrant.

Eileen, as the storm was named, moved westward along the equatorial front at an estimated speed of eight knots. Lack of reports in the vicinity of the storm after 17 July prevent accurate comments relative to the wind speeds. It is believed that little change occured in the intensity of storm during it's westward movement.

Upon reaching the island of Hainan on the 19th, Eileen curved to the north. Passage over this island weakened the storm; it accelerated and passed into South China during the evening of 19 July.

FAITH - JULY

The existence of this storm was first suspected when winds and pressures at Palau, Ulithi, and Parece Vela indicated that a closed circulation might have developed around a low area centered at 15°N and 135°E on the 240600Z map. The ITC was in a pronounced trough in the area for several preceding maps, and for several subsequent ones it was still doubtful whether a depression or storm actually existed.

During the first section of its history the storm, beginning at 20.5°N and 125.8°E at 270600Z, moved in a smooth curve to the NW and WNW. It is estimated that the maximum wind velocity on the 27th was only 35 knots.

From 281200Z thru 291200Z, no definite center of circulation could be detectedbut the cyclone apparently moved due west to 23.5°N and 122.5°E at which point it regenerated rapidly.

Beginning at the point of regeneration, storm Faith moved rapidly NNE then NE in 18 hours to 28.6°N, 126.6°E, where it was centered at 301200Z. The storm attained maximum intensity with the maximum wind velocity of 50 knots at 200400Z, at which time the storm was centered at 26.7°N and 123.9°E. At this time the storm also attained maximum size, winds over 27 knots covering an area of 225 nautical miles radius.

After curving to the NE, this storm decelerated slightly instead of accelerating as is usually the case. The storm was considered extratropical upon reaching 30°N, 130.5°E.

GWEN - AUGUST

Typhoon Gwen, the next of the season, proved to be interesting for it's eccentric movement. It is believed that the speed of Typhoon Gwen was exceptional and could not have been anticipated, for the synoptic situation was not abnormal. The typhoon moved at 31.6 knots during one six-hour period.

This tropical cyclone was first noticed at 1500I on 4 August at 20.0°N, and 136.3°E and the movement of 040 degrees true at 10 knots.

Maximum winds of ninety knots were reported in the typhoon on the 5th of August, the highest attained at any time.

By 061200Z Gwen began moving to the north more rapidly, and at 070000Z began recurving to the northeast at a speed of about 20 knots, passing about 60 miles south of Tokyo at 070600Z. By that time Gwen had weakened in intensity so that the maximum winds near the center were only 35 knots. At the time the storm passed south of Tokyo, Haneda reported winds of 20 mph with a few gusts to 35 mph, with rain showers, then very rapid clearing as the wind shifted into the north.

HELENA - AUGUST

Tropical storm Helena was first suspected to be forming when an easterly wave moved across the Philippine area and developed a closed cyclonic circulation just to the northwest of Manila as indicated by the surface reports from the 0000Z synoptic map for 12 August. Navy Reconnaissance found the storm to be 18.1°N and 116.3°E at 120200Z, and Air Force Reconnaissance found it at 18.6°N and 115.3°E at 120300Z, which indicated a northwesterly movement at 10 knots. Maximum winds at this time were estimated to be 55 knots with winds over 27 knots extending to a radius of 150 nautical miles.

Due to lack of any weather data from China during the next 24 hours, the positions given were very inaccurate, and even by post-analysis the movement of the storm cannot be accurately determined.

INEZ - AUGUST

Typhoon Inez was first found to be forming in the area around 14°N, 132°E on 25 August. A weak-low circulation had been present over that area for 48 hours previous to the formation of the typhoon. An easterly wave moved into this weak cyclonic circulation area and began the development of the typhoon along the intertropical front.

Typhoon Inez moved NW at 8 knots to 10 knots. The high pressure area over Japan began increasing in intensity, causing the typhoon to change its NW movement at 10 knots to WNW at 12 knots.

Typhoon Inez followed a fairly regular curve on a true heading of from 325 degrees gradually becoming 330 degrees to 340 degrees as it moved across the China Mainland. The path was slightly shifted as the center passed across Northern Formosa and again as it struck the China Coast.

Maximum intensity of the typhoon is believed to have reached 100 knots. The typhoon dissipated rapidly beginning at 301200Z and became extratropical upon crossing the China Coast.

A strong possibility exists that the center of the typhoon was split into two separate centers as Inez moved over Formosa, the main center being forced north whereas the secondary center formed to the south and west where it was difficult to analyze owing to the pronounced influence of the thermal low pressure area over Southern China.

JOYCE - SEPTEMBER

The existence of this storm was first suspected when surface winds reported by the ship located at 18°N and 132°E at 0600Z on 5 September showed a northeast flow of force four.

Although there was a well-defined trough-line through this area, a closed circulation did not show-up again until twelve hours later (on the 060000Z map).

Even though the ship report and inflight reports still showed a closed circulation, it was not until the 080500Z and 080530Z Navy Reconnaissance reports had been received that a definite center was located and the intensity, 27 knots, was known.

The few in-flight reports from Okinawa indicated very little "weather" was associated with depression Joyce.

On the 9th of September, the low showed indications of increasing in intensity.

When the storm reached 20°N at approximately 090000Z, it began to recurve slowly north-northwestward at 11 knots. Maximum wind at this time was approximately 32 knots, the maximum intensity reached; the storm affecting an area of only 50 miles radius.

KATHLEEN - SEPTEMBER

Typhoon Kathleen was probably the most widely publicized of the year. In its final stages, it passed along the southeast coast of Honshu near Tokyo causing considerable damage in central Honshu. Rainfall reports from stations in the mountains around Tokyo were: Mito 12.26 inches, Maebaski 15.40 inches, Hakone 21.21 inches and Chichibu 24.04 inches. Final reports indicate that 1030 people lost their lives in the resulting floods.

Kathleen first appeared as a low area on the intertropical front in the vicinity of 18°N and 143°E. A definite but weak circulation was discernable, defined by synoptic reports from Iwo Jima, Ulithi, and Saipan and by scattered in-flights from the area. At the same time the surface winds at these islands developed a consistent above normal velocity and the cloud pattern of a storm gradually took shape, although transient aircraft reported only light to moderate weather until the night of 10 September.

By 100600Z, Saipan's pressure had fallen to 1006.2 mb. Latest reports from transient aircraft had indicated significant deterioration of conditions through the critical zones. A C-46 arriving at Guam from Iwo Jima reported heavy rain and extreme turbulence. This report and a thirty knot southwest wind at 10,000 feet on Guam's 101600Z rawin were conclusive indications that the system was more than a zone of strong activity on the intertropical front.

Increasingly squally weather closed Iwo Jima, and this persistent condition of wide spread bad weather throughout the eastern semi-circle of the storm, with practically nothing abnormal to the west, suggested the possibility of double center. This was never established by actual observation however. (The phenomena of unequal distribution of severe weather was frequently observed in later typhoons, and tends to verify the hypothesis that a typhoon will move parallel to the most intense sector).

Although the center of the storm at this time was only approximately 360-400 miles due south of the coast of Southern Honshu and Shikoku, no where did the three-hourly pressure changes show the falling tendency that might normally be expected if the typhoon was moving in that direction. To the west, over China and Manchuria, a well-developed high-pressure center existed. There were large pressure rises over Korea and Eastern China and fairly large rises over western Honshu. The 700-mb chart showed a trough aloft paralleling the West Coast of Japan, over the eastern half of the Japan Sea, moving slowly but steadily eastward. These facts coupled with northerly latitude of the typhoon seemed to indicate that while the typhoon center would pass close to Tokyo it would tend to recurve towards the northwest, accelerate, and weaken.

Instead of accelerating the typhoon slowed its movement. This condition lasted for about 24 hours, after which the normal expected acceleration did set in and typhoon Kathleen moved off to the northeast, the center passing a very short distance south of Tokyo at 151030Z.

LAURA - SEPTEMBER

The Synoptic pattern at the time of origin of Laura was dominated by Typhoon Kathleen which was three hundred nautical miles south of Nagoya. Laura was first suspected when the 111800Z synoptic map carried two high surface-wind reports, three hours apart, from a transient surface vessel near 26°N and 158°E. The velocities were Beaufort eight and showed a ninety degrees cyclonic shift which established a well-developed storm center at approximately 24°N and 156.5°E. This area was watched very closely for the next two days and finally by 13 September there were some indications that Laura did actually exist and a reconnaissance aircraft was dispatched to the area. From this flight the existence of Laura was definitely established. The influence of Kathleen and the flow around a rather strong high which was centered over the western Aleutians indicated a west northwest movement.

A Navy reconnaissance plane was able to get a good fix on the disturbance for 150600Z.

Recurvature began near 25°N and 150°E. Typhoon Laura thereupon followed the trough left by its predecessor Kathleen, moved on NE out to sea and became extratropical in nature.

MILDRED - SEPTEMBER

First indications of the formation of typhoon Mildred were persistant easterly force four and five winds at a weather ship located at 18°N and 132°E beginning with the 201200Z surface map. During this early period an easterly wave moved into the area and intensified the development of the low pressure area, which was indicated roughly near 130°E along the ITC.

The first definite information that a typhoon existed was a Navy reconnaissance report which located the center at 14.3°N and 126.5°E.

After initial detection of the typhoon, a fairly steady travel at 290 degrees was followed toward Luzon.

Upon approaching Luzon, the terrain apparently weakened the circulation and maximum winds which had been indicated as roughly 70 to 100 knots now decreased to 50 knots.

After leaving Luzon the storm continued at decreased intensity with maximum winds near 50 knots and finally decreased to 35 knots maximum near the China coast.

A movement of approximately 290 degrees at 12 to 16 knots characterized the entire history of Mildred. This movement is reasonably well explained by a careful re-analysis of the 700-mb chart during this period. A closed high circulation, centered near Okinawa steered Mildred along its southern periphery in a 290-degree direction.

NANETTE - SEPTEMBER & OCTOBER

An easterly wave which passed Guam on 25 September, moved west into a sharp, stationary, surface trough just east of the weather ship at 18°N, 132°E. This trough was oriented NNE-SSW. After entering this trough, the easterly became stagnant and was finally dropped from the surface map analysis and replaced by a trough line in the same area.

At this time Nanette lay on the west edge of a sharp upper-level (700-mb) trough, roughly lying along the 132° meridian. Apparently Nanette was too far west to be caught and recurved to the north or northeast by this trough. The next synoptic influence considered was a large surface high over China, in view of which a northwest movement was forecast.

No further reconnaissance information became available to definitely fix the track that Nanette would follow until 292200Z. The definite fix established by reconnaissance at 292200Z established a westward movement at 5-6 knots.

Although Nanette continued the westerly course, it apparently accelerated rapidly after the reconnaissance fix at 292200Z (20.5N 131.7E), for the next reconnaissance fix at 300600Z (from Okinawa) located the center at 21.1N 127.7E. This was an average velocity of 28 knots for this period in contrast with the previously indicated velocity of 5-6 knots. For the next six-hour period, Nanette immediately decelerated to an average velocity of 7-8 knot. **Movement with** a gradual recurvature to a west north-westerly direction. The blocking effect of the 17,000-ft mountain on Formosa caused considerable weakening. After recurvature movement was variable at 13-20 knots.

The intensity of Nanette remained fairly constant during its track toward Formosa with maximum winds 80 to 90 knots, but after passing Formosa, the effect of the land areas within its circulation became very evident and it rapidly decreased to depression intensity with 25 knot winds as it reached the China coast.

OLIVE - OCTOBER

The area near the stationary weather ship at 11°N, 156°E first became suspicious on 1 October. The ship reported westerly force three and four surface winds. At 010000Z, a dissipating easterly wave was indicated as having passed the weather ship and the intertropical convergence zone was analyzed as being just north of the ship. Another easterly wave was approaching from the east. On the 010600Z surface map, the ship reported a pressure of 1003.9 mb which appeared to be abnormally low, however, the Harmon Weather Central had been previously advised by the Navy that the reported pressures at this ship were consistently two milibars low. In spite of this, the area was still watched with suspicion. On the 011800Z surface map, the winds at the ship increased to force six and a closed 1005-mb isobar could now be drawn in this area. In-flight reports from Kwajalein were showing considerable weather and their reported winds, together with winds at the ship, indicated that a depression was probably located north of the Kwajalein-Guam route. A small closed-low circulation was now analyzed on the 700-mb chart also.

On the 020000Z map, a well-defined closed low near 13°N, 156°E was evident. The Air Force reconnaissance plane located a storm center at approximately 13.3°N, 155.0°E at 020300Z. A west-northwest movement at ten knots was forecast due to the presence of a high-pressure ridge, oriented east-west, north of Olive at both the surface and 700-mb levels.

A reconnaissance fix at 040035Z by the Navy bore out the forecast 330-degree movement, but the storm had accelerated and averaged 20 knots during the 20 hours since the previous fix.

No further reconnaissance on Olive was accomplished. After leaving the area near the weather ship at 11°N, 156E, the only information on which the position could be determined and movement forecast was synoptic reports from Iwo Jima and a few reconnaissance fixes. To further complicate matters, an extensive surface trough hung back south of the storm area as far south as 10°N and the upper-air circulation at the 700-mb level indicated an elongated low centered somewhere south of the surface position. This condition modified the significance of Iwo Jima's synoptic reports and presented an extremely difficult problem in determining Olive's position after 040035Z. It also became evident on the 031600Z map that an extensive upper-air circulation had developed over typhoon Pauline and was blocking the westward movement of Olive.

Olive recurved to a northerly and finally a northeasterly direction as it approached the belt of westerlies north of 30°.

Actual verifications of the intensity of Olive during its history were very sparse and obtained almost entirely from reconnaissance reports. In the early stages, 40 to 45 knot winds were established definitely, and later, the Navy reconnaissance at 040035Z reported 100-knot winds.

PAULINE - OCTOBER

First indication of the formation of typhoon Pauline was a shallow low pressure area centered near 14°N, 141°E on the 010000Z surface synoptic map. It was centered over the ITC at the foot of an easterly wave. Beaufort force three and four surface winds and considerable intermittent rain and shower activity characterized the area.

At the time of origin of Olive, the 700-mb upper-level chart showed a closed-low circulation centered near 12°N, 135°E, southwest of the surface low position. A trough line on this chart extended SSW from a point east of Japan to three degrees northwest of Parece Vela or roughly nine degrees NNW of the low center associated with Pauline. Pauline already had a closed circulation, and at that time did not appear likely to be caught and recurved by the trough.

Pauline moved all the way to the northern tip of Luzon at 10.3 knots. Actually the velocity varied between 8 and 16 knots for short intervals, as nearly as could be determined. The northwesterly direction was then followed until Pauline entered the China coast one hundred miles northeast of Hong Kong.

Since Pauline had an extensive, well-developed circulation at the 700-mb level, steering rules were of little value for forecasting during its histor. Pauline was too far south and west to be recurved by the upper-level trough NNE of it at the time of its origin and no future trough developed having the orientation or extent required to recurve a cyclone with an extensive upper-level circulation such as associated with Pauline.

The surface intensity of Pauline increased gradually from 40 knots at 020600Z to 100 knots at 050600Z. It maintained the latter intensity until it passed into the northern tip of Luzon at 051800Z, after which it decreased to 70 to 75 knots due to the weakening effects of the land.

ROSALIND - OCTOBER

Although typhoon Rosalind did not receive the publicity accorded to Kathleen, from a meteorologist's point of view, Rosalind was by far the most interesting. The narrative history submitted by the Typhoon Warning Network is quoted in part:

"The origin of Rosalind is rather obscure due to the fact that it developed in a trough associated with tropical cyclone Olive at a time when the position and movement of Olive itself were somewhat uncertain. Reconnaissance on Olive was extremely meager immediately prior to the time it was dropped as having become extratropical, so there is a definite possibility that it stagnated in the are: east of Iwo instead of moving away to the northeast, and was later re-discovered and identified as Rosalind.

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"Two things support the belief that Olive actually moved out. First, the extensive surface trough which developed south of Olive could have been the indication of the formation of a second center (Rosalind). Second, reports from a ship at 40°N, 170°E on the eighth indicated the approach and passage of a well-developed wave on a cold front. The nature of these reports and the fact that no history of this low was indicated by past maps, led to the conclusion that this low was the remnant of Olive, now extratropical.

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"Whatever it's beginnings, Rosalind was a fully-developed typhoon when the first Bulletin was issued. It's movement was to the north-northeast at a very slow pace, about 4.5 knots, a velocity which characterized it for the first four Bulletin positions determined by Harmon Weather Central. This was in accord with the existing synoptic patterns at the surface and aloft, both of which showed troughs to the northeast and north respectively which offered likely paths for the typhoon to follow.

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"Bulletin No. 4(070000Z) had been based on reconnaissance information, but after that time reconnaissance was highly unsatisfactory. A fix was obtained for Bulletin No. 10 (080600Z), and succeeding Bulletins based on reconnaissance were numbers 18,21,22,23 and 26. All others centered the typhoon by extrapolation and land and ship reports.

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"As an average this gives an acceptable one fix per day, but the distribution was such that there were two periods of approximately 36 hours and another of 48 hours during which no definite fix was obtained.

"Rosalind continued its north-northeast movement until 080600Z, but decelerated and became nearly stagnant by that time. In retrospect, this stagnation and the subsequent abrupt inverse recurvature with westward movement for the following 48 hours might be explained by the presence of a migratory anticyclone which was moving into a position due north of Rosalind as the typhoon reached its 080600Z position. At the time, this blocking action probably was not anticipated since the typhoon was intense and the high was only moderate (Maximum pressure about 1023mb). Furthermore, since a surface trough still existed to the northeast, and the latitude of upper westerlies had been reached, a normal recurvature would appear to have been more likely than the reverse one which occurred. Be that as it may, a normal recurvature did not occur until this anticyclone had moved off, and a new trough had come into position to receive Rosalind.

"The next reconnaissance position, at 100600Z, placed the center at 25.3°N, 137.2°E. Land reports previous to this time had, of course, indicated the abnormal turn of the typhoon, but forecasts synoptic with Bulletins 9 through 14 were wide of the mark. The reconnaissance indicated that the typhoon was beginning to recurve (again) in the vicinity of 137°E. In other words, only land (Iwo Jima) and ship reports were available in fixing the center at any time from 030600Z, when it was 240 miles east of Iwo Jima, to 100600Z, when it was 230 miles west-northwest of Iwo Jima.

"During this critical interval the center passed immediately south of Iwo Jima, where the surface wind reached a maximum of 140 mph (with gusts to 160 mph) from the east-northeast at 082100Z, and a minimum pressure of 28.48 inches (976.3 mb) occurred at 082140Z. Damage to the Iwo Weather Station and equipment involved portions of quonset roofs blown off, the east wall of the hydrogen shack blown away, the anemometer blown down from its platform, and the ceiling light projector when the central tower on which it was mounted collapsed.

"As remarked before, the advent of a new surface trough to the north signaled the final very sharp recurvature to the northeast, but even here the movement had an abnormal phase. Instead of decelerating and recurving simultaneously, then accelerating as soon as the recurved path was established, a maximum deceleration amounting practically to stagnation occurred well after the recurving was complete and a more or less straight course was once more established. Even post-analysis fails to produce any satisfactory explanation of this.

"After 121200Z the typhoon behaved normally, moving northeast and accerlerating into the mean polar trough.

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"If we proceed step by step thru Rosalind's development, using at each step only the information and tools available to the forecaster at that step, we find that the tools and technique were, at least in this case, inadequate.

"It is believed that use of the steering principle offers the greatest chance of success in typhoon forecasting. Yet, neither the surface map nor the 700-mb chart, the charts rapidly available to the forecaster, can be used in this procedure. On them the pressure fields consist predominantly of closed systems and no general trajectory is apparent. Too, the method of analysis which bases the 700-mb analysis to a great extent on the surface analysis constitutes a vicious circle. A perusal of the maps during Rosalind shows this.

"Of prime importance to the forecaster during the life of a typhoon are:

"1. Its center at the surface and the inclination of its axis. This information is necessary for predicting velocity and intensity, and their derivatives.

"2. The relativepositions of air masses immediately surrounding it, i.e., temperature, humidity, stability and wind fields at several levels thru and above the disturbance. This information is necessary for predicting velocity, intensity, their derivatives, extent and intensity of cloud, precipitation and wind fields, and also aids in selecting levels at which the steering principle can be used.

"3. In lower latitudes, the height of the discontinuity between lower easterlies and overlying westerlies, and their relative intensities. This information is necessary in using the steering principle, providing vertical extent of the disturbance is known.

It is believed that without synchronous observations at least low enough to evaluate accurately surface weather elements over the area of the closed circulation, and at least high enough to evaluate weather elements at a level where the closed circulation "opens" to a trough aloft, it will be impossible to forecast abnormalities in behavior of these storms with any degree of accuracy."

ALICE - OCTOBER

First indications of the formation of a tropical cyclone were detected in the area northeast of Truk on the October 111800Z surface map. An easterly wave through the area was also a factor favorable for the development of a tropical cyclone.

A reconnaissance mission located a small closed center at 11°N, 152.5°E, at 130400Z.

Reconnaissance fixes for the 13th and 14th of October established a northerly movement, which was supported by continued positive pressure tendencies in the Marianas and by the pattern of 700mb, which during this interval was dominated by southerly flow between the low area of typhoon Rosalind to the northwest and weak lobe of the semi-permanent Pacific High to the northeast.

From 16 October to 18 October, the typhoon moved in a fairly regular manner towards the north at a speed of 8 to 10 knots.

The next major perturbation in the path of the disturbance occurred in the thirty hours following 180000Z. The actual path appears to have been east-northeast with speed decreased to 3 or 4 knots. It appears that this period of quasi-stagnation may have resulted from a rather fine balance between upper-level and low-level influences; that is, Alice may have reached a vertical development just short of that necessary to overcome completely the blocking effect of the surface high, and yet sufficient for the upper-level trough not only to overcome the prevailing easterly flow around the southern periphery of that high, but in fact to cause a slight eastward drift. However, the small amount of both surface and upper-air data available precluded verification of this conjectural analysis.

After 190000Z the disturbance began to accelerate and weaken, and a good Air Force reconnaissance fix at 200200Z indicated that the central winds were decreasing in velocity and the typhoon was rapidly becoming extra-tropical.

Forecasting on typhoon Alice was almost entirely on the basis of the overall synoptic patterns at the surface and 700-mb levels, and on successive fixes determined by aircraft reconnaissance. Although the disturbance attained typhoon force and had maximum winds of 100 knots or more for two thirds of its history, it never covered a large area, 200 miles being the maximum radius of storm-force winds. Because of this tight pattern it's circulation never affected the winds in the Marianas or Bonins areas, which were dominated by the flow around the less intense but more extensive Beatrice to the west. Since there was no reflection of the disturbance on either the wind flow or the pressures in these islands, these synoptic reports served only the negative purpose of indicating where the typhoon was not going.

BEATRICE - OCTOBER

On the 15th of October, a depression was suspected near 12°N and 137°E. A westerly trough aloft was moving into the area in question, which caused the surface low to deepen.

It was impossible to get a definite fix on the storm center or a good indication of its speed and direction of movement, either by reconnaissance reports or surface information. At no time during Beatrice's history was it a sufficiently strong storm to describe a well-defined central circulation on the surface. This storm was, in reality, mainly an upper-air circulation and only partially reflected on the surface. At nearly all times during the storm's history the 700-mb chart showed a low aloft with winds in excess of 50 knots and a fairly well-defined center.

CATHY - OCTOBER

On the 27th of October, the 0000Z surface map showed a possible low in the vicinity of Ulithi. On the two succeeding maps, pressure falls in that general area necessitated the closing of a 1005-mb isobar. The synoptic situation at the time Cathy began forming constituted a favorable condition for the formation of a depression. There was an easterly wave moving along the intertropical zone of convergence, and a trough aloft (above the easterly wave) on the 700-mb chart.

A reconnaissance mission departed Guam at 2000Z on the 27th to investigate the suspected area, but found no definite storm center. A Navy reconnaissance mission departed Manila the 29th of October and located the center of the storm at 11.3°N and 128.7°E. Maximum winds near the center were found to be 70 knots over a radius of 25 miles with winds greater than 27 knots over a radius of 275 miles.

Upon entering the Philippine Islands, Cathy slowed down and for an eighteen-hour period moved at the rate of eight knots. During the slowing down process the storm curved into the northwest and decreased in intensity while moving across the Philippine Islands. By the time the center reached Manila Bay (1100Z 31 Oct), passing directly over Cavite, the maximum winds had decreased to 50 knots, and the radius of winds greater than 27 knots had decreased to 100 miles. At this point Cathy recurved into the west northwest and passed over the China Sea at a speed of 12 knots.

Navy reconnaissance on the first of November showed that Cathy had intensified as it entered the China Sea. The wind had increased once more to typhoon strength reaching a maximum of 70 knots near the center, with winds of 65 knots over a radius of 25 miles. The storm then followed a path of 290 degrees at 10 knots, finally moving onto the Central Indo-China coast at 17°N.

DORA - NOVEMBER

The development of a depression was suspected on 1 November 1947 because of the indications on the 0400Z 700-mb chart, on which a well-defined low was analyzed with two closed contour lines. The 0600Z surface map on this date showed a good cyclonic circulation with a closed 1005-mb isobar.

On the morning of 2 November reconnaissance reports from the Navy indicated a tropical cyclone of typhoon intensity.

First indications were that this tropical cyclone would move NNE in the 700-mb trough and 24-hour pressure changes.

An Air Force reconnaissance mission, at 0530Z on 3 November, proved that the forecast for a continued north-northeast movement was in error. The 700-mb chart for 3 November, 1600Z showed that the trough that was present on the 0400Z chart had filled rapidly and moved to the east leaving the storm to curve back into the northwest. This error in forecasting is attributed to the lack of sufficient upper-air data to properly forecast the filling and deepening of upper-air systems.

Until this time, Dora was a relatively small typhoon with winds in excess of 27 knots confined to a radius of less than 200 miles. Winds in excess of 65 knots covered an average radius of 50 miles.

The Air Force and Navy reconnaissance missions on the 3rd and 4th of November showed indications of intensification, and deceleration. The speed dropped from 13 knots to 4 knots during the succeeding 42 hours.

On the 5th of November at 0100Z a Navy reconnaissance mission relocated the center at 13.8°N and 130°E. This same reconnaissance mission indicated a considerable decrease in maximum winds.

On the morning of 6 November a Navy reconnaissance mission revealed that Dora had regenerated to typhoon intensity with winds reaching a maximum of 75 knots. The speed of the typhoon had increased to 8 knots. Maximum intensity was reached on the morning of 7 November, when the winds near the center were found to be 100 knots by Navy reconnaissance. Movement was west-northwest at 9 knots. Dora crossed central Luzon during the night of 7 November, retaining a maximum wind velocity of 80 knots throughout its course over land. As the typhoon passed over the East China Sea from Lingayen Gulf, it began to recurve into the northwest and the rate of movement slowed to about 5 knots. Recurvature into the north continued until a direction of north-northeast was attained. The component of westerly movement ceased near 19.5°N and 117.6°E. The final position of Dora as reported by Clark Field was 20.7 degrees north and 118.6 degrees east at 0000Z 10 November. At that time the maximum winds had decreased to 50 knots and continued degeneration was indicated.

ELNORA - NOVEMBER

The first evidence of Elnora's existence was report of Beaufort force eight surface winds from the east with heavy rain from the weather ship 18°N and 132°E at 2100Z on 9 November. A Navy reconnaissance aircraft investigation of the area established the reality of the storm.

The synoptic situation at this time was not dominated by any particularly strong systems. The intertropical front was drawn up northeast of Luzon behind tropical cyclone Dora, which was weakening and becoming extratropical about 600 nautical miles northwest of the new disturbance. North of Dora and oriented east-west across Formosa, was the Polar Front with associated weak waves, and over China lay a weak high cell.

It was expected that Elnora would follow in the wake of Dora, but instead it took the most direct route towards the polar trough. At 111800Z near 25°N, Elnora slowed to 5 knots preparatory to recurving northeastward into the polar trough and eighteen hours later this recurving together with the transformation into an extratropical low had been accomplished.

At no time in its short life did Elnora approach typhoon intensity. Maximum winds never exceeded 45, and reconnaissance aircraft reported only weak and shallow circulation around an indistinctly defined center.

FLORA - NOVEMBER

On the 11th of November 1947, the first indications of the formation of a possible tropical disturbance in the vicinity of 8°N and 142°E were detected. Aircraft reconnaissance reports for 12 November showed good wind shift lines but no definite center or cloud pattern. Navy reconnaissance located the storm center at 8°N and 135.5°E at 0000Z on the 13th, with flight level winds of 120 knots.

Flora's origin was typical of a large number of tropical cyclones in the West Pacific area. She formed at the foot of an easterly wave along the intertropical front. The 700-mb chart was not instrumental in detecting the formation of Flora, because of the lack of adequate coverage of upper-air reports in the area in which this storm originated.

Flora moved in a west northwesterly direction at about 12 knots with an average maximum wind velocity of 100 knots. In the vicinity of 11°N and 129.5°E, the storm began to accelerate and decrease in intensity. On the morning of the 15th, the typhoon entered the Philippine Islands area over the Island of Samar, and gradually curved into a northwesterly direction. The rate of motion and maximum winds decreased, gradually becoming fourteen and seventy-five knots, respectively as the center passed across central Luzon and entered the Northern Lingayen Gulf at 1800Z on the 15th of November. After passing into the East China Sea, the typhoon began to recurve more sharply to the north and continued to decelerate, with maximum winds decreasing to seventy knots.

A change of direction into a north-northeast direction was detected by the hourly weather reports received from Formosa and the Southern China coastal areas.

As the weakened storm moved northeast and into the trough along the Ryukyus, it intensified considerably, and showed signs of containing frontal activity.

At 180000Z, the storm center was approximately 60 miles southeast of Naha, giving Okinawa winds of 50 knots with gusts to 60 knots. The Siberian high pressure center area over Northeast China was invading the East China Sea and Japan on 18 November causing an eastward movement of the polar trough and consequently a northeastward movement of the storm center as it traveled away from the Ryukyus.

GLADYS - NOVEMBER

In its early stages the embryonic tropical cyclone Gladys existed as a vague sort of low area associated with the intertropical trough south of the Guam-Kwajalein course. Some easterly-wave activity existed in the stronger than normal trade-wind flow north of the trough, but though the area was watched as a likely region for storm development no significant pressure falls or circulation patterns were observed.

The disturbance apparently developed as a true closed circulation in the synoptically blank area between Truk and Ulithi, south of Guam, but being initially of small diameter, had no revealing influence on these surrounding stations until the 170000Z map.

A strong easterly flow existed north of the center at 700-mb level moving Gladys 290 degrees at 13 knots.

Gustiness at Ulithi reached a maximum of 60 knots with the passage of Gladys south of there at 172230Z.

The western most point of the path, 18.0°N., 135.7°E, was reached by 200600Z. On the surface the storm was nearing the diffuse southwestern end of the polar front and its associated trough which lay with a northeast-southwest orientation across Iwo Jima. Aloft the westerly trough remained strong, and both of these factors dictated continued recurvature of the storm to the north and eventually northeast.

Passage south of Iwo occurred near 211800Z, with equally weather and surface winds up to 40 knots at Iwo. After 220000Z the circulation around Gladys was no longer detectable.

HANNAH - NOVEMBER

Tropical cyclone Hannah developed in a strong, extensive surface trough southeast of preceding tropical cyclone Gladys. On the 211300Z surface map, Gladys was located eighty miles south-southeast of Iwo Jima and indicated as an extratropical wave on a frontal system. The front extended from Gladys into the southwest and Hannah was shown as a second extratropical wave on this same front located near 19°N, 136E in the trough southwest of Gladys. A closed-low circulation was analyzed on the upper-air chart (700-mb level) centered at approximately 17°N and 135°E, southwest of the surface low.

A Navy reconnaissance mission fixed the center of the typhoon at 24.1°N, 135°E at 220515Z which indicated Hannah had moved due north from the position analyzed twelve hours previously. This same reconnaissance mission reported an eye, five miles in diameter and winds over 100 knots north and east of the center, which established tropical cyclone characterisitics for Hannah. The cyclone was beginning to acquire extratropical characteristics at this time due to its northerly position for this season and the presence of a polar air mass to the northwest from which air mass discontinuities would form. Hannah moved off to the NE without further incident.

IRENE - NOVEMBER

Irene was first noticed at 0600Z on 30 November 1947 and was a small tropical storm both in extent and intensity and also of relatively short duration.

The synoptic conditions contributing to the formation of the storm were a typical situation. The nucleus of the tropical cyclone, in its initial stag of development, was a weak cyclonic circulation at the 'foot of an easterly trough along the intertropical zone of convergence. The cyclone probably would not have reached storm proportions if it had not been for another factor that was introduced to the already potential tropical cyclone area. The other factor that led to the intensification of the easterly wave and the subsequent development of Irene was a westerly trough that extended down into the easterl flow.

It was evident, even in the initial stages, that the cyclone could not develop to any great extent because of the presence of a large continental polar high that was moving across China, which should preclude any movement farther north than the northern tip of the Philippines.

After reaching the Island of Tables at 1800Z on 30 November, the storm began recurvature to the north and the maximum winds increased to 40 knots. The curvature continued through 1 December, with the rate of movement increasing to 14 knots and the maximum winds to 45k by 1800Z 1 Dec 1. By 0000Z on 2 December, the movement had become 050 degrees at 17 knots. The maximum winds decreased to 30 knots during the passage of the storm over the mountains of northern Luzon.

The curvature of the storm into the north and eventually the northeast, as mentioned above, was easily predicted because of the development and subsequent deepening of a trough in the China Sea.

After passing out to sea from the northeast tip of Luzon on the afternoon of 2 December, Irene began to assume extratropical characteristics as a cold front invaded the storm area from the north.

JEAN - DECEMBER

Two shear lines and a westerly trough were dominating the Southwestern Pacific area previous and subsequent to the 20th of December. The pressure gradient was strong from Guam to Iwo Jima, giving rise to a fairly strong northeasterly flow, while the gradient south of Guam was comparatively weak. The southwestern extremity of a dissipating shear line with an east-northeast, west-southwest orientation was located at 7°N and 151°E, while a second and still active shear line was located five degrees south of Iwo Jima. Both shear lines had the same orientation. A westerly trough, in the easterly flow, between the two shear lines, was located three degrees east of Guam at 201800Z. The trough was shallow, but extended sufficiently far south to induce a cyclonic perturbation on the intertropical zone of convergence at 8°N and 147°E. Through the combined effects of these synoptic conditions a nucleus was found that later led to the development to Typhoon Jean.

The first good fix on the storm center was determined by Air Force reconnaissance at 2223Z, on the 23d of December, locating the center at 9.3°N and 137.3°E at 230000Z.

During the 24 hour period following origin, the storm had not developed to the point of formulating a well-defined cloud or wind pattern. The absence of these tropical storm characterisitcs caused erratic "center reporting" by reconnaissance planes during the first 24-hour period.

Tropical Cyclone Jean gained typhoon intensity by 221200Z. At 220700Z a Navy reconnaissance plane estimated the maximum surface winds near the center to be 90 knots.