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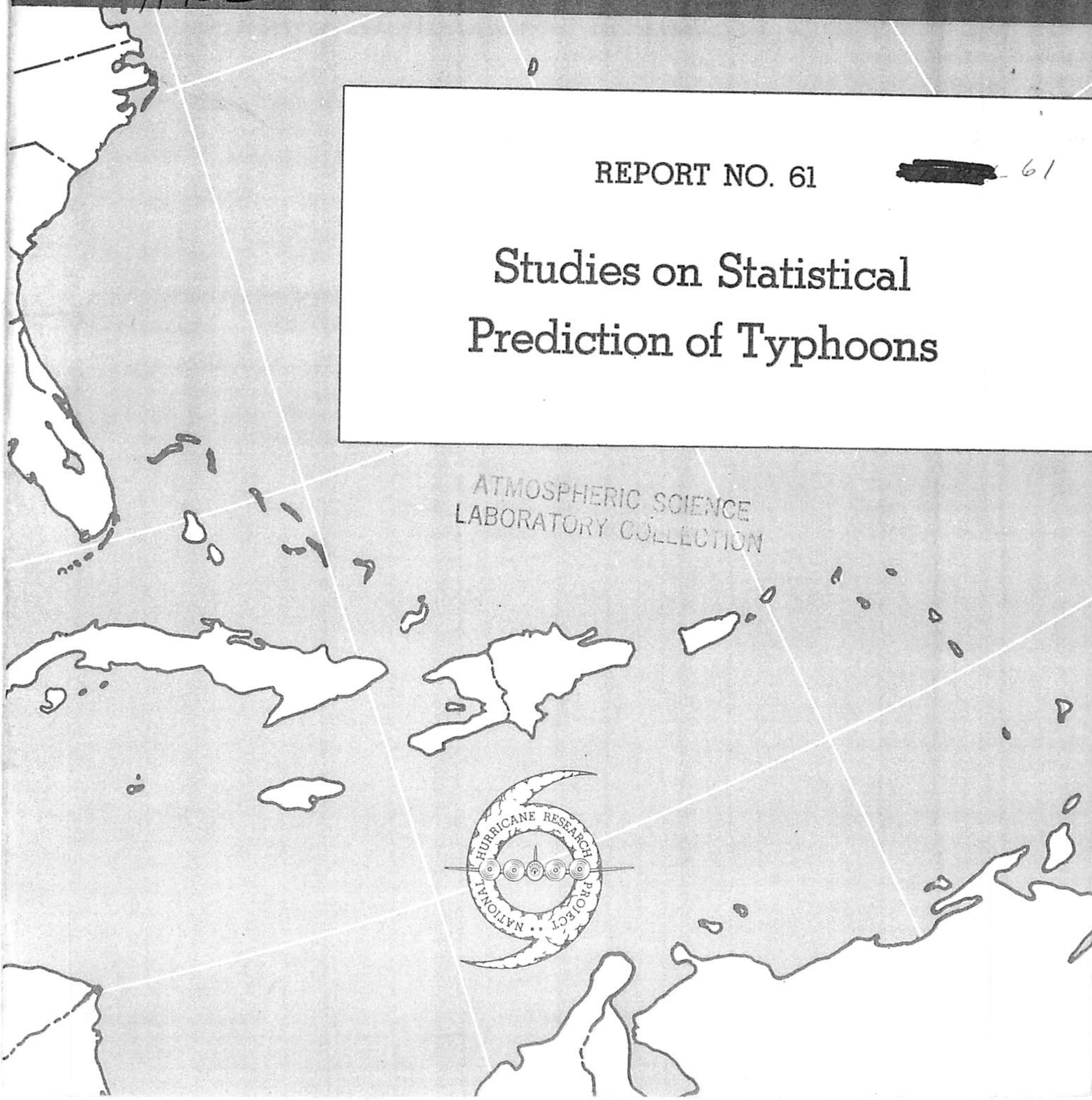

REPORT NO. 61 [redacted] 61

Studies on Statistical Prediction of Typhoons

U. S. DEPARTMENT OF COMMERCE
Luther H. Hodges, Secretary
WEATHER BUREAU
F. W. Reichelderfer, Chief

NATIONAL HURRICANE RESEARCH PROJECT

REPORT NO. 61

Studies on Statistical Prediction of Typhoons

by
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Meteorological Research Institute
Japan Meteorological Agency

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NATIONAL HURRICANE RESEARCH PROJECT REPORTS

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PREDICTION OF MOVEMENT AND SURFACE PRESSURE OF

TYPHOON CENTERS BY STATISTICAL METHODS

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1. INTRODUCTION

Forecasting the tracks and the intensities of typhoons is a very important problem in Japan, for the estimated annual mean damage amounted to some 2/3 billion dollars in the 1946-1958 census. Although synoptic forecasters can predict the movement of typhoons with moderate skill, there exists a need for more accurate forecasts. Recent advances in numerical weather prediction provide unique forecasting techniques that seem to be very promising. Another promising alternative is the statistical method of forecasting the movement of hurricanes proposed by Veigas and Miller [1]. This paper summarizes a statistical study of the movements and the central surface pressures of typhoons by means of the Veigas-Miller screening procedure.

It should be remarked that longitude and latitude are expressed in degrees and tenths, surface pressure in millibars, and height of the 700-mb. surface in meters, throughout this paper.

2. REGRESSION EQUATIONS IN TERMS OF THE 700-MB. MAP FOR THE MOVEMENT AND THE CENTRAL SURFACE PRESSURE OF TYPHOONS IN THE WESTERN NORTH PACIFIC

Typhoons located in the entire western North Pacific were analyzed. Here the area discussed was confined to the North Pacific from 0° to 34°N. and from the coasts of China, Formosa, and the Philippines to 180°E., excluding the Southern China Sea. To obtain the pressure pattern in terms of the 700-mb. map relative to the typhoon center, the author took the height values at 91 grid points which were provided by intersections of 5° longitude and 5° latitude circles as shown in figure 1.

Regression equations were derived for the fully-developed typhoons which occurred in the 4-year period 1957-1960. The number of typhoon data samples was: 1957, 88; 1958, 91; 1959, 71; 1960, 69, and the total number was 319.

The set of possible predictors was 99, as follows:

h_1, h_2 ---- h_{91} ; 91 700-mb. height values at chart time,

λ_0, λ_{-12}, λ_{-24}; east longitude of typhoon center at chart time, 12 hours prior to chart time, and 24 hours prior to chart time.

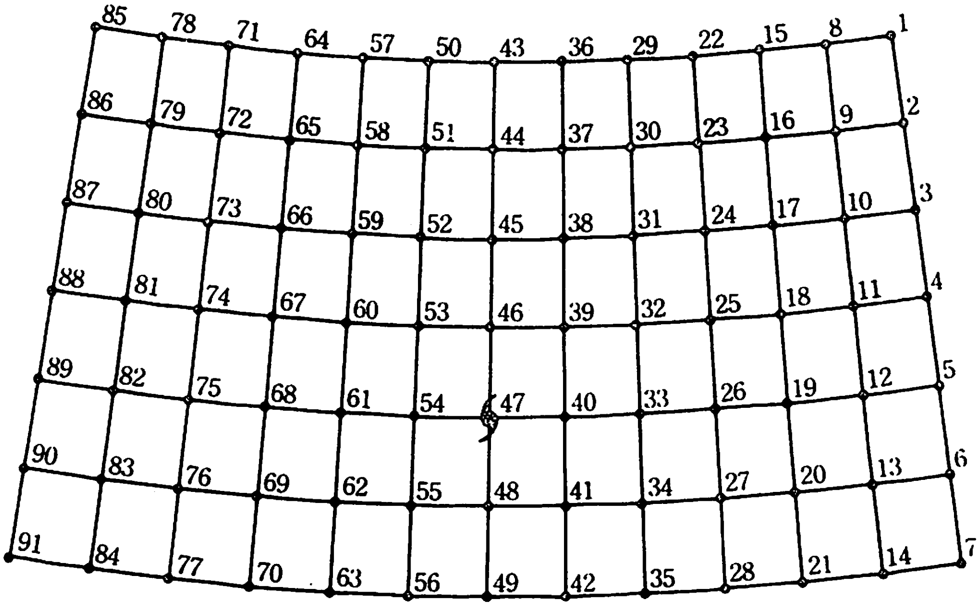

Figure 1. - Grid used for reading 700-mb. pressures relative to center of typhoon.

ϕ_0, ϕ_{-12}, ϕ_{-24}; north latitude of typhoon center at chart time, 12 hours prior to chart time, and 24 hours prior to chart time.

p_{-12}, p_{-24}; central pressure 12 hours prior to chart time, and 24 hours prior to chart time.

The set of predictands was as follows:

$\lambda_{12})_{pred.}$, $\lambda_{24})_{pred.}$; predicted east longitude of typhoon center 12 hours after chart time and 24 hours after chart time.

$\phi_{12})_{pred.}$, $\phi_{24})_{pred.}$; predicted north latitude of typhoon center 12 hours after chart time and 24 hours after chart time.

$p_{12})_{pred.}$, $p_{24})_{pred.}$; predicted central surface pressure 12 hours after chart time and 24 hours after chart time.

The set of regression equations computed by the IBM 704 was obtained as follows. "P.R." stands for the percentage reduction of variance.

$$\begin{aligned}\lambda_{12})_{pred.} = &+16.1 + 1.6463\lambda_0 - 0.6574\lambda_{-12} - 0.0045_3 h_{37} - 0.0132_0 h_3 \\ &+0.0130_6 h_{91} - 0.0036_2 h_{59} + 0.0085_7 h_{10} + 0.0063_1 h_{27} \\ &-0.0055_1 h_{38} - 0.0057_3 h_{84}, \qquad \text{P.R.} = 99.5\%\end{aligned}$$

$$\Phi_{12})_{pred.}=-20.5+1.7539\Phi_0-0.7386\Phi_{-12}-0.0033_8h_{60}+0.0057_6h_{90}$$
$$+0.0039_3h_{24}-0.0037_0h_4+0.0059_0h_{26}-0.0090_0h_{53}$$
$$+0.0018_9h_{43}+0.0051_6h_{34}, \qquad P.R.=99.3\%$$

$$p_{12})_{pred.}=+1157.6+0.1144_1H_0-0.2079p_{-24}-0.0444_2h_{50}-0.0241_8h_{89}$$
$$+0.1048_5h_{40}-0.0672_3h_{62}-0.0870_4h_{45}+0.0879_4h_{51}$$
$$-0.0304_9h_{58}-0.0387_8h_{83}, \qquad P.R.=85.8\%$$

$$\lambda_{24})_{pred.}=+23.0+2.2253\lambda_0-1.2510\lambda_{-12}+0.0076_5h_{44}-0.0273_7h_3$$
$$+0.0202_9h_{27}-0.0242_0h_{52}+0.0105_8h_{90}+0.0114_7h_{18}$$
$$-0.0163_1h_{37}+0.0116_2h_{10}, \qquad P.R.=97.9\%$$

$$\Phi_{24})_{pred.}=-51.2+2.2119\Phi_0-1.1799\Phi_{-12}-0.0083_4h_{60}+0.0135_3h_{26}$$
$$+0.0142_0h_{90}+0.0054_0h_{29}-0.0176_7h_{53}+0.0096_0h_{87}$$
$$-0.0104_0h_{59}+0.0101_5h_{32}, \qquad P.R.=97.5\%$$

$$p_{24})_{pred.}=+1057.7+0.1093_3H_0-0.1430p_{-24}-0.2472p_{-12}+0.1982\Phi_0$$
$$-1.2546\lambda_{-24}+0.0445_6h_{29}+0.0911_6h_{40}-0.1353_6h_{62}$$
$$+0.0890_0h_{39}, \qquad P.R.=61.7\%$$

An operational independent test is now under progress by the staff members of U.S. Navy Commanding Fleet Weather Central/Joint Typhoon Warning Center, Guam (Captain Rotsch, Commander).

It should be marked that the reduction of variance for the last regression equation in each case is very large. To check this somewhat misleading result, regression equations for the deepening or filling of central surface pressure of typhoons were derived, with predictands chosen as follows:

$\Delta p_{12})_{pred.} = p_{12} - p_0)_{pred.}$: filling of central pressure 12 hours after chart time.

$\Delta p_{24})_{pred.} = p_{24} - p_0)_{pred.}$: filling of central pressure 24 hours after chart time.

The following set of regression equations based on the <u>same data sample</u> was obtained:

$$\Delta P_{12})_{pred.}=460.0-0.1216\cdot P_{-24}-0.2339\cdot P_{-12}+0.1322\cdot\Phi_0+0.0186\cdot H_0-0.0855\cdot h_{45}$$
$$+0.0945\cdot h_{40}-0.0621\cdot h_{62}+0.0460\cdot h_{44}-0.0313\cdot h_{83}-0.0158\cdot h_{50},$$
$$P.R.=43.7\%$$

$$\Delta P_{24})_{pred.}=318.8-0.1248\cdot P_{-24}-0.3182\cdot P_{-12}+0.2981\cdot\Phi_0-1.3611\cdot\lambda_{-24}+1.2191\cdot\lambda_0$$
$$-0.0398\cdot h_{29}+0.0836\cdot h_{40}-0.1396\cdot h_{62}+0.0926\cdot h_{39}+0.0428\cdot h_{73},$$
$$P.R.=45.6\%$$

It should be noted that the variance reductions for these regression equations decreased sharply as compared with the reductions for the regression equations predicting central pressure rather than the change of pressure.

	Percentage reduction	
$p_{12})_{pred.}$	85.8	(first ten terms)
$p_{24})_{pred.}$	61.7	(first nine terms)
$\Delta p_{12})_{pred.}$	43.7	(first ten terms)
$\Delta p_{24})_{pred.}$	45.6	(first ten terms)

The set of regression equations for deepening or filling was computed to see whether the screening procedure applied can pick up such physically significant quantities as vorticity. The result of this test was clearly negative. The computation experiment, the author believes, shows that the 91 700-mb. height values used as possible predictors were far from mutually independent, so that the regression equations for $\Delta p_{12})_{pred.}$ and $\Delta p_{24})_{pred.}$ do not contain physically significant quantities like vorticity.

3. REGRESSION EQUATIONS FOR THE MOVEMENT AND THE CENTRAL SURFACE PRESSURE OF TYPHOONS IN THE SOUTHERN CHINA SEA

Equations were developed for predicting the movement and central pressure of typhoons located in the Southern China Sea from surface data. To obtain the pressure pattern relative to the typhoon center, the author took the grid points provided by the intersection of 5° meridians and parallels. Twenty-five grid point pressures were read off the surface weather map to give the pressure pattern relative to the typhoon center, as shown in figure 2.

Using daily weather maps covering the 5-year period 1956-1960, the author got 35 fully developed typhoon days. The number of possible predictors was 30, as follows:

X_1, X_2 ----- X_{25}; surface pressure values at chart time ($X_{13} = p_0$).

λ_0, λ_{-12}; east longitude of typhoon center at chart time and 12 hours prior to chart time.

ϕ_0, ϕ_{-12}; north latitude of typhoon center at chart time and 12 hours prior to chart time.

p_{-12}; central surface pressure 12 hours prior to chart time.

The predictands were:

$\lambda_{12})_{pred.}$, $\lambda_{24})_{pred.}$: predicted east longitude of typhoon center 12 hours after chart time and 24 hours after chart time.

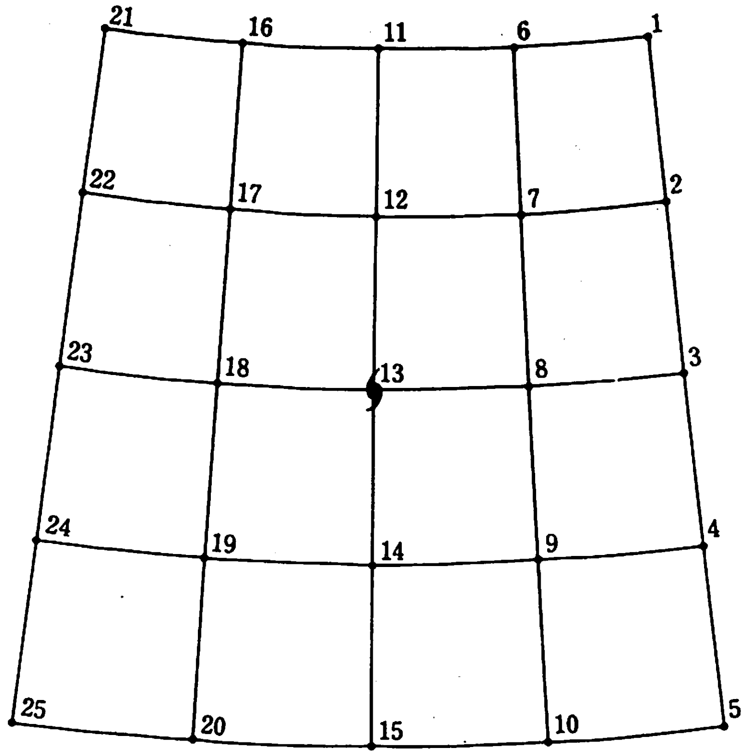

Figure 2. - Grid for reading surface pressure relative to typhoon center.

$\phi_{12})_{pred.}$, $\phi_{24})_{pred.}$: predicted north latitude of typhoon center 12 hours after chart time and 24 hours after chart time.

$P_{12})_{pred.}$, $P_{24})_{pred.}$: predicted central surface pressure 12 hours after chart time and 24 hours after chart time.

The following set of regression equations was computed by the IBM-704, where "P.R." stands for the percentage reduction of variance.

SOUTHERN CHINA SEA

$$\lambda_{12})_{pred.} = 97.9 + 1.0122 \cdot \lambda_0 - 0.1562 \cdot X_4 + 0.1717 \cdot X_{17} - 0.1151 \cdot X_6, \quad P.R. = 95.3\%$$

$$\Phi_{12})_{pred.} = -23.5 + 1.3085 \cdot \Phi_0 - 0.2469 \cdot \Phi_{-12} - 0.0864 \cdot X_{23} + 0.1839 \cdot X_{20} - 0.0746 \cdot X_1, \quad P.R. = 97.6\%$$

$$p_{12})_{pred.} = -745.8 + 0.9142 \cdot p_0 - 0.3190 \cdot \lambda_{-12} + 0.8608 \cdot X_3, \quad P.R. = 74.1\%$$

$$\lambda_{24})_{pred.} = 31.7 + 0.9901 \cdot \lambda_0 - 0.1383 \cdot X_2 + 0.3068 \cdot X_{17} - 0.2010 \cdot X_6, \quad P.R. = 86.1\%$$

$$\Phi_{24})_{pred.} = 246.3 + 1.6031 \cdot \Phi_0 - 0.5607 \cdot \Phi_{-12} - 0.1078 \cdot X_{23} - 0.1359 \cdot X_1, \quad P.R. = 94.5\%$$

$$p_{24})_{pred.} = -767.6 + 0.7901 \cdot p_0 - 0.2744 \cdot p_{-12} - 0.8948 \cdot \lambda_{-12} + 1.3412 \cdot X_3, \quad P.R. = 66.0\%$$

An operational independent test would be most welcome, especially by meteorologists along the coasts of the Southern China Sea; e. g., at Hong Kong and Manila.

REFERENCE

K. Veigas, R. G. Miller, and G. M. Howe, "Probabilistic Prediction of Hurricane Movement by Synoptic Climatology," Occasional Papers in Meteorology, No. 2, Travelers Weather Research Center, 1959, 54 pp.

AN OBJECTIVE TECHNIQUE FOR PREDICTING 12-HOUR AND 24-HOUR TYPHOON MOVEMENT

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This study is concerned with the statistical prediction of the motion of typhoons in the western North Pacific, utilizing the concept of a steering current. The study is limited to the region from 10°N. to 34°N. and from the coasts of China to 180°E. excluding the Southern China Sea. Regression equations were derived on the basis of the observed typhoon motion in the 5-year period 1956-1960. The data were divided into five groups according to latitude. The number of cases is shown in table 1. The total number is 297.

Table 1. - Typhoon cases grouped according to latitude.

Latitude group	Number of observations
10.0°-14.9°N.	65
15.0°-19.9°N.	77
20.0°-24.9°N.	77
25.0°-29.9°N.	57
30.0°-34.0°N.	21

Height values for sixteen grid-points were read from the 700-mb. weather map. Height gradients in the zonal and meridional direction were obtained as a measure of the steering current. The grid is illustrated in figure 1. The grid points were separated by 5° of longitude and 5° of latitude relative to each typhoon center.

An elaborate scheme for making use of the steering principle has been developed by Riehl et al.[1]. Recognizing difficulties in obtaining mean wind data through a deep layer around the hurricane, they chose the 500-mb. chart as an approximate representation of the mean-wind flow from the surface to approximately 300 mb.

The objective technique of the Riehl-Haggard system frequently provides a good estimate of hurricane movements in the Atlantic. The author of this paper has extended this system to typhoon movement in the North Pacific with some modifications.

Steering winds were computed from the contour gradients at 700 mb. instead of 500 mb. The experience of forecasters suggests that data from 700-mb. charts predict typhoon movement in the lower latitudes of the Pacific with a higher reliability than do 500-mb. data. Miller et al. [3] reported rather similar experiences.

The zonal (east-west) and meridional (north-south) displacements are computed separately. For the movement of the Pacific typhoons, which is frequently larger in magnitude than for Atlantic hurricanes, a grid covering 20° longitude and 20° latitude centered on the position of the typhoons is used.

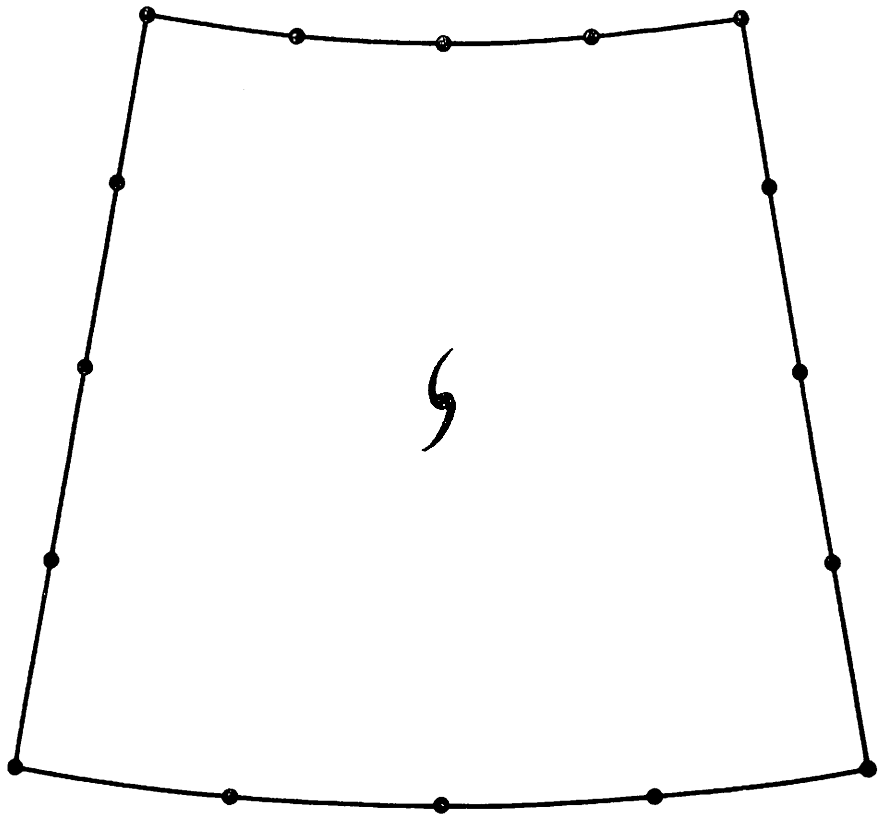

Figure 1. - Grid for reading 700-mb. height values.

The zonal component was determined first. The mean 700-mb. height differences between the two parallels located 10° north and south of the storm position were computed. This was then correlated with a 12 or 24 hour east-west movement in degrees of longitude. Stratifying the 297 typhoon cases by zones (i.e., 10.0°-14.9°N., 15.0°-19.9°N., 20.0°-24.9°N., 25.0°-29.9°N., 30.0°-34.0°N.), the regression equations for the zonal component of a 12 or 24-hour east-west movement in degrees of longitude were obtained as shown in tables 2 and 3, where r stands for the correlation coefficient.

Next, the meridional component was determined. The mean 700-mb. height differences between the two meridians located 10° east and west of the storm position were computed to the nearest meter at 5° intervals. This was then correlated with a 12 or 24 hour north-south movement in degrees of latitude.

Stratifying the 297 typhoon cases into five zones, the regression equations for the meridional component of a 12 or 24-hour north-south movement in degrees of latitude were obtained as shown in tables 2 and 3.

Thus the zonal and meridional displacements were computed, and these were then combined to obtain the final forecast position.

The regression equations expressed in tables 2 and 3 are fully empirical ones. Success or failure of the system depends, to a large extent, upon the accuracy of the 700-mb. analyses, to which the computations are extremely

Table 2. - Regression equations and correlation coefficients (r) for typhoon movement, grouped by latitude.

Twelve Hours Displacement		
	Eastward component	Northward component
10.0°~14.9°N	$\Delta\lambda=-1.2+0.024\cdot\Delta h$, r=0.54	$\Delta\phi=0.6+0.013\cdot\Delta h'$, r=0.30
15.0°~19.9°N	$\Delta\lambda=-0.9+0.021\cdot\Delta h$, r=0.58	$\Delta\phi=0.8+0.019\cdot\Delta h'$, r=0.46
20.0°~24.9°N	$\Delta\lambda=-0.3+0.034\cdot\Delta h$, r=0.80	$\Delta\phi=0.4+0.044\cdot\Delta h'$, r=0.36
25.0°~29.9°N	$\Delta\lambda=\ 0.2+0.034\cdot\Delta h$, r=0.68	$\Delta\phi=0.6+0.031\cdot\Delta h'$, r=0.58
30.0°~34.0°N	$\Delta\lambda=\ 1.7+0.015\cdot\Delta h$, r=0.34	$\Delta\phi=\quad +0.050\cdot\Delta h'$, r=0.78

Table 3. - Regression equations and correlation coefficients (r) for typhoon movement, grouped by latitude.

Twenty-four Hours Displacement		
	Eastward component	Northward component
10.0°~14.9°N	$\Delta\lambda=-2.2+0.034\cdot\Delta h$, r=0.32	$\Delta\phi=1.3+0.030\cdot\Delta h'$, r=0.36
15.0°~19.9°N	$\Delta\lambda=-1.3+0.047\cdot\Delta h$, r=0.61	$\Delta\phi=1.5+0.046\cdot\Delta h'$, r=0.53
20.0°~24.9°N	$\Delta\lambda=-0.2+0.073\cdot\Delta h$, r=0.80	$\Delta\phi=1.3+0.069\cdot\Delta h'$, r=0.61
25.0°~29.9°N	$\Delta\lambda=\ 1.0+0.066\cdot\Delta h$, r=0.63	$\Delta\phi=1.4+0.057\cdot\Delta h'$, r=0.55
30.0°~34.0°N	$\Delta\lambda=\ 4.7+0.037\cdot\Delta h$, r=0.37	$\Delta\phi=0.2+0.097\cdot\Delta h'$, r=0.82

sensitive. For example, a set from the dependent data is shown in figures 2 and 3.

Operational testing was carried out during the 1962 season and the results are given in table 4. Further independent rigorous testing is needed before this system can be adopted for routine use.

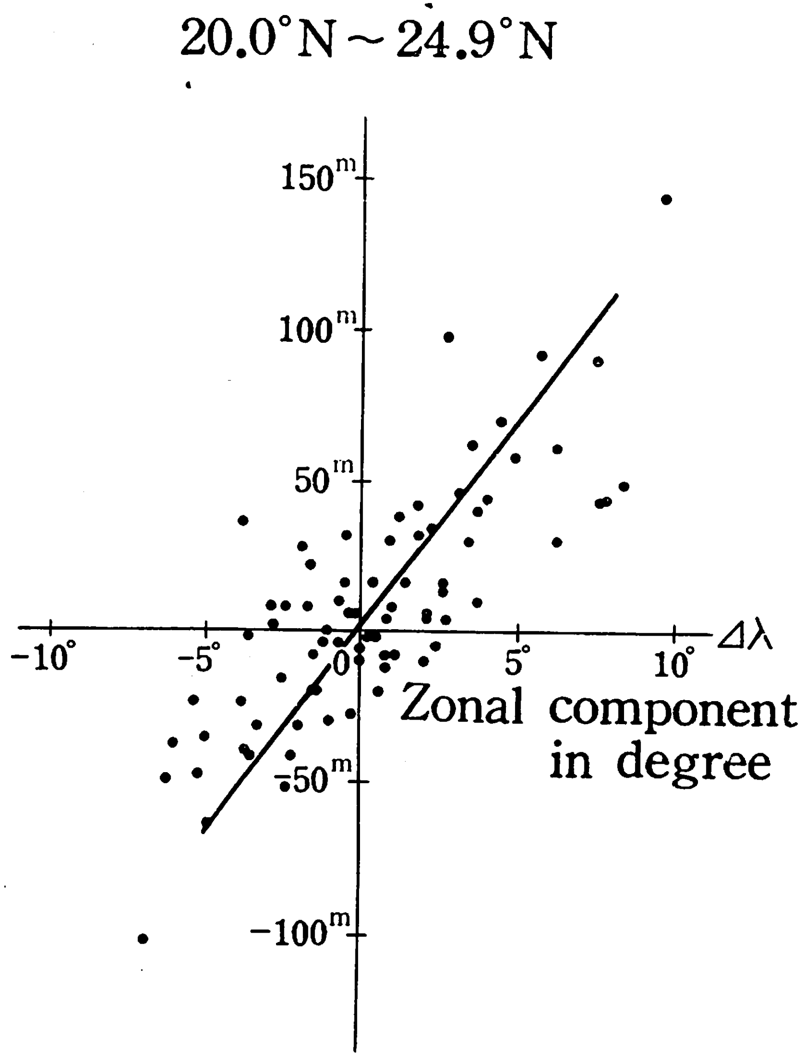

Figure 2. - Zonal component of 24-hour typhoon movement (20.0°-24.9°N.) as a function of mean longitudinal height difference at 700 mb.

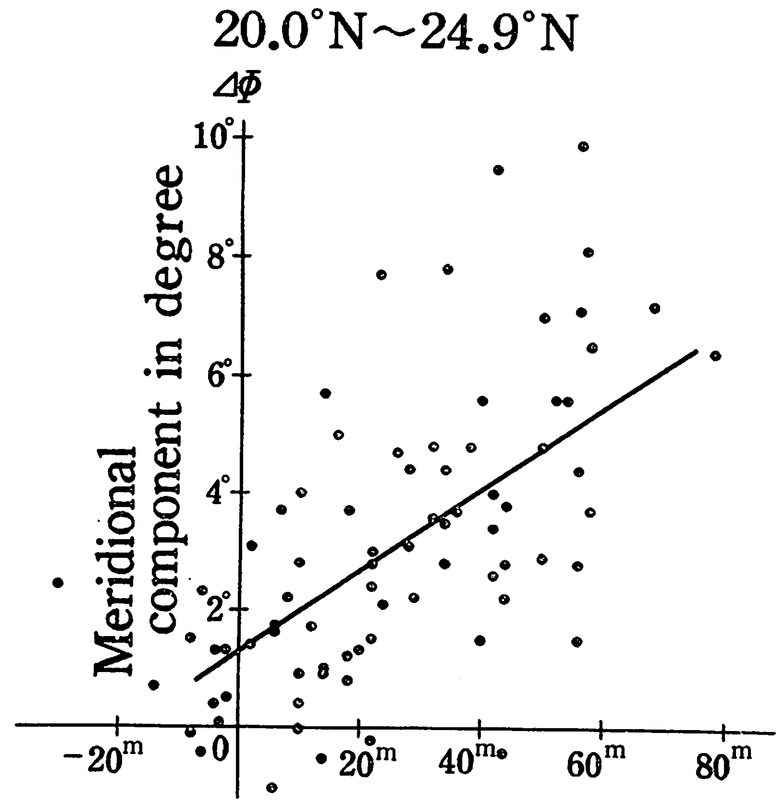

Figure 3. - Meridional component of 24-hour typhoon movement (20.0°-24.9°N.) as a function of mean latitudinal height difference at 700 mb.

Table 4. - Test on independent data for typhoons in 1962.

($\Delta\lambda$, $\Delta\phi$ ----- Predicted; $\Delta\lambda'$, $\Delta\phi'$----- Observed)

Name of Typhoons	Date & Hour (JMT)	Position		12 hours						24 hours					
				Predicted position		$\Delta\lambda$	$\Delta\lambda'$	$\Delta\phi$	$\Delta\phi'$	Predicted position		$\Delta\lambda$	$\Delta\lambda'$	$\Delta\phi$	$\Delta\phi'$
		°E	°N	°E	°N					°E	°N				
Joan	July 7. 21	129.4	21.7	130.2	23.5	0.8	0.0	1.8	0.7	131.5	23.1	2.1	-1.3	3.4	1.4
	8. 09	129.4	22.4	129.2	24.2	-0.2	-1.3	1.8	0.7	129.3	25.9	-0.1	-2.1	3.5	2.6
	8. 21	128.1	23.1	128.3	24.7	0.2	-0.7	1.6	1.9	128.9	26.3	0.8	-2.8	3.2	4.5
	9. 09	127.3	25.0	128.2	27.8	0.9	-2.0	2.8	2.6	129.6	30.5	2.3	-2.8	5.5	6.3
	9. 21	125.3	27.6	127.0	31.0	1.7	-0.8	3.4	3.7	129.3	32.7	4.0	-0.2	5.1	8.9
	10. 09	124.5	31.3	127.3	36.4	2.8	-0.6	5.1	5.2	132.3	41.2	7.8		9.9	
	10. 21	125.1	36.5												
Kate	July 20. 09	120.1	19.7	119.8	21.2	-0.3	-0.7	1.5	-0.2	120.2	22.9	0.1	-1.5	3.2	-0.3
	20. 21	119.4	19.5	118.9	20.6	-0.5	-0.8	1.1	-0.1	119.0	21.7	-0.4	-0.8	2.2	0.2
	21. 09	118.6	19.4	117.9	20.5	-0.7	0.0	1.1	0.3	118.1	21.7	-0.5	1.8	2.3	1.4
	21. 21	118.6	19.7	118.4	22.0	-0.2	1.8	1.3	1.1	118.9	22.4	0.3	2.7	2.7	2.9
	22. 09	120.4	20.8	120.8	23.0	0.4	0.9	2.2	1.8	122.1	26.9	1.3	0.3	6.1	4.2
	22. 21	121.3	22.6	121.3	25.7	0.0	0.3	3.1	2.4	121.3	28.1	0.4	-1.0	5.5	4.7
	23. 09	120.7	25.0	120.3	27.5	-0.4	-0.4	2.5	2.3	120.6	29.9	-0.1	-3.4	4.9	5.0
	23. 21	120.3	27.3	120.1	30.1	-0.2	-3.0	2.8	2.7	120.4	32.8	0.1	-3.3	5.5	4.5
	24. 09	117.3	30.0	118.9	33.0	1.6	-0.3	3.0	1.8	121.8	36.0	1.5		6.0	
	24. 21	117.0	31.8												
Louise	July 21. 09	155.9	22.1	155.0	23.6	-0.9	0.0	1.5	0.9	154.6	25.4	-1.3	0.6	3.3	3.8
	21. 21	155.9	23.0	155.0	25.4	-0.9	0.6	2.4	2.9	154.4	27.5	-1.5	-1.5	4.5	4.0
	22. 09	156.5	25.9	156.2	28.1	-0.3	-2.1	2.2	1.1	156.8	30.2	0.3	-4.9	4.3	1.5
	22. 21	154.4	27.0	154.0	28.3	-0.7	-2.8	1.3	0.4	154.0	29.8	-0.7	-5.1	2.8	0.6
	23. 09	151.6	27.4	150.1	27.8	-1.5	-2.3	0.4	0.2	149.1	28.4	-2.6	-5.6	1.0	0.6
	23. 21	149.3	27.6	148.2	27.8	-1.1	-3.3	0.2	0.4	147.8	28.5	-1.5	-6.3	0.7	0.2

	24. 09	146.0°E	28.0°N	145.0°E	28.1°N	-1.0	-3.0	0.1	0.2	144.6°E	28.4°N	-1.4	-5.0	0.4	0.9
	24. 21	143.0	27.8	142.3	28.2	-0.7	-2.0	0.4	1.1	142.2	28.9	-0.8	-4.4	1.1	2.0
	25. 09	141.0	28.9	140.0	28.8	-1.0	-2.4	-0.1	0.9	141.5	29.1	-0.5	-5.5	0.2	2.7
	25. 21	138.6	29.8	137.2	30.5	-1.4		0.7	1.9	136.4	32.9	-2.2		3.1	
	26. 09	135.5	31.7	136.9	33.6	1.4		1.9		139.2	35.6	3.7		3.9	
Nora	July 29. 21	132.0	19.4	130.2	21.1	-1.8	-0.4	1.7	1.4	128.6	23.1	-3.4	-2.6	3.7	2.6
	30. 09	131.6	20.8	130.1	23.0	-1.5	-2.2	2.2	1.2	128.6	28.9	-3.0	-4.3	8.1	2.8
	30. 21	129.4	22.0	128.0	25.1	-1.4	-2.1	3.1	1.6	126.8	27.5	-2.6	-2.1	5.5	3.5
	31. 09	127.3	23.6	124.2	27.1	-3.1	-0.3	3.5	1.9	121.1	29.8	-6.2	-2.0	6.2	4.1
	31. 21	127.0	25.5	125.2	28.2	-1.8	-1.7	2.7	2.2	124.2	30.7	-2.8	-3.0	5.2	4.2
	Aug. 1. 09	125.3	27.7	122.3	30.3	-3.0	-1.3	2.6	2.0	121.9	32.7	-3.4	-1.1	5.0	5.3
	1. 21	124.0	29.7	123.1	32.4	-0.9	0.2	2.7	3.3	125.2	35.0	1.2		5.3	
	2. 09	124.2	33.0	126.1	37.4	1.9		4.4		129.4	41.6	5.2		8.6	
Opal	Aug. 3. 09	134.3	15.3	132.2	17.3	-2.1	-2.7	2.0	2.0	130.3	19.7	-4.0	-5.4	4.4	3.7
	3. 21	131.6	17.3	129.6	19.2	-2.0	-2.7	1.9	1.7	127.9	21.4	-3.7	-3.2	4.1	2.7
	4. 09	128.9	19.0	126.1	20.5	-2.8	-2.7	1.5	1.1	123.4	22.2	-5.3	-4.9	3.2	2.3
	4. 21	126.2	20.1	124.7	22.7	-1.5	-2.2	2.6	1.2	122.1	24.7	-4.1	-3.9	4.6	3.4
	5. 09	124.0	21.3	122.5	24.4	-1.5	-1.7	3.1	2.2	121.2	26.8	-2.8	-3.8	5.5	4.5
	5. 21	122.3	23.5	120.6	26.9	-1.7	-2.1	3.4	2.3	119.0	29.5	-3.3	-3.8	6.0	5.0
	6. 09	120.2	25.8	119.6	28.5	-0.6	-1.7	2.7	2.7	118.7	31.2	-1.5	-2.3	5.4	7.2
	6. 21	118.5	28.5	118.0	30.7	-0.5	-0.6	2.2	4.5	118.2	32.9	-0.3		4.4	
	7. 09	117.9	33.0	120.2		2.3				124.1		6.2	7.5		5.7
	7. 21														
	8. 09	125.4	38.7												
Patsy	Aug. 9. 21	114.6	15.5	113.0	17.1	-1.6	-2.3	1.6	1.8	111.7	19.9	-2.9	-4.2	3.4	4.0
	10. 09	112.3	17.3	110.8	18.7	-1.5	-1.9	1.4	2.2	109.7	20.3	-2.6	-3.8	2.6	4.3
	10. 21	110.4	19.5	109.1	21.5	-1.3	-1.9	2.0	2.1	108.3	23.8	-2.1	-4.1	4.3	2.8
	11. 09	108.5	21.6	107.9	23.8	-0.6	-2.2	2.2	0.8	107.6	25.6	-0.9		4.0	
	11. 21	106.3	22.4	106.5	25.8	0.2		3.4		107.1	31.8	0.8		6.0	

		°E	°N	°E	°N					°E	°N				
Ruth	Aug. 14. 21	146.0	16.0	144.6	16.6	-1.4	-0.1	0.6	1.3	113.6	16.9	-2.4	-0.3	0.9	3.6
	15. 09	145.9	17.3	144.5	18.0	-1.4	-0.2	0.7	2.3	143.5	18.4	-2.4	-0.4	1.1	4.1
	15. 21	145.7	19.6	144.1	20.5	-1.6	-0.2	0.7	1.8	141.1	20.8	-4.6	-0.9	1.2	3.7
	16. 09	145.5	21.4	111.3	22.4	-1.2	-0.7	1.0	1.9	143.4	23.7	-2.1	-1.5	2.3	4.4
	16. 21	144.8	23.7	143.4	25.2	-1.4	-0.8	1.9	2.5	142.3	27.0	-2.5	-2.2	3.7	5.0
	17. 09	144.0	25.8	143.2	28.0	-0.8	-1.4	2.2	2.5	142.8	30.3	-1.2	-2.6	4.4	4.9
	17. 21	142.6	28.3	142.5	31.1	-0.1	-1.2	2.6	2.4	143.1	34.1	0.5	-1.9	5.8	2.6
	18. 09	141.4	30.7	143.3	33.5	1.9	-0.7	2.8	0.6	148.6	36.3	5.3	-0.7	5.6	1.6
	18. 21	140.7	31.3	142.3	32.7	1.6	0.0	1.4	1.0	145.2	34.1	4.5	0.0	2.8	1.3
	19. 09	140.7	32.3	142.9	33.7	2.2	0.0	1.4	0.3	146.5	35.2	5.8	0.4	2.9	1.2
	19. 21	140.7	32.6	143.2	34.8	2.5	0.4	2.2	0.9	147.3	36.9	6.6		4.3	
	20. 09	141.1	33.5	143.9	35.1	2.8		1.6		146.5	36.7	5.4		3.2	
Sarah	Aug. 16. 09	125.8	23.8	124.6	24.7	-1.2	-0.7	0.9	0.1	123.7	25.9	-2.1	-1.0	2.1	-0.4
	16. 21	125.1	23.9	124.7	24.6	-0.4	-0.3	0.7	-0.5	124.8	25.6	-0.3	-0.3	1.7	-0.6
	17. 09	124.8	23.4	124.0	24.8	-0.8	0.0	1.4	-0.1	123.6	26.3	-1.2	-0.1	2.9	-0.6
	17. 21	124.8	23.3	124.4	24.7	-0.8	-0.1	1.4	-0.5	124.4	26.1	-0.4	1.0	2.8	-0.1
	18. 09	124.7	22.8	124.6	23.7	-0.1	1.0	0.9	0.4	124.9	24.8	0.2	0.8	2.0	2.8
	18. 21	125.7	23.2	125.6	23.9	-0.1	0.8	0.7	2.4	125.9	24.9	0.2	-0.7	1.7	4.9
	19. 09	126.5	25.6	127.6	26.7	1.1	-0.7	1.1	2.4	129.2	27.9	2.7	0.3	2.3	3.3
	19. 21	125.8	28.0	126.1	29.2	1.6	0.3	1.2	0.9	129.6	30.3	3.8	0.9	2.3	2.4
	20. 09	126.1	28.9	128.1	30.1	2.0	0.6	1.2	1.5	130.7	31.3	4.6	2.4	2.4	1.6
	20. 21	126.7	30.4	128.9	30.7	2.2	1.8	0.3	0.1	132.7	31.2	6.0		0.8	
	21. 09	128.5	30.5	131.0	31.1	2.5		0.6		135.1	31.8	6.6		1.3	
Thelma	Aug. 21. 09	146.9	18.2	145.4	19.4	-1.5	-1.2	1.2	1.4	144.6	20.7	-2.3	-3.1	2.5	3.1
	21. 21	145.7	19.6	144.5	20.9	-1.5	-1.9	1.3	1.7	143.0	22.4	-2.7	-4.0	2.8	3.1
	22. 09	143.9	21.3	143.4	23.4	-0.4	-2.1	2.1	1.4	143.4	25.2	-0.4	-3.6	3.9	3.1
	22. 21	111.7	22.7	140.8	24.0	-0.9	-1.5	1.3	1.7	140.1	25.7	-1.6	-2.8	2.7	3.2
	23. 09	140.2	24.4	139.6	36.6	-0.6	-1.3	2.2	1.5	139.4	28.4	-0.8	-2.5	4.0	2.6
	23. 21	138.9	25.9	139.4	27.8	0.5	-1.6	1.9	1.1	140.5	29.6	1.6	-1.5	3.7	2.4
	24. 09	137.3	27.0	138.6	29.1	1.3	0.1	2.1	1.3	140.5	31.3	3.2	-0.6	4.3	3.0
	24. 21	137.1	28.3	138.7	31.0	1.3	-0.7	2.7	1.7	140.4	33.5	3.0	-0.8	5.2	4.2
	25. 09	136.7	30.0	138.8	34.1	2.1	-0.1	4.1	2.5	142.3	38.3	5.6	-0.3	8.3	5.9
	25. 21	136.6	32.5	138.8	37.4	2.2	-0.2	4.9	3.4	142.4	41.9	5.8		9.4	
	26. 09	136.4	35.9												

		°E	°N	°E	°N					°E	°N				
Vera	Aug. 25. 21	133.3	22.5	134.2	24.9	0.9	0.5	2.4	0.7	135.9	26.9	2.4	-0.2	4.5	2.8
	26. 09	133.8	23.2	133.5	26.0	-0.3	-0.6	2.8	2.1	133.7	28.2	-0.1	-2.1	5.0	4.1
	26. 21	133.2	25.3	133.8	27.1	0.6	-1.5	1.8	2.0	135.1	29.0	1.9	-2.3	3.7	4.3
	27. 09	131.7	27.3	133.1	29.5	1.4	-0.8	2.2	2.3	134.9	31.6	3.2		4.3	
	27. 21	130.9	29.6	132.6	30.9	1.9		1.4		135.3	33.7	4.4		3.8	
Wanda	Aug. 28. 21	130.5	17.4	128.9	18.6	-1.6	-1.1	1.2	0.0	127.7	19.9	-2.8	-3.8	2.5	2.4
	29. 09	129.4	17.4	127.8	18.5	-1.6	-2.7	1.1	2.4	126.6	19.6	-2.8	-6.4	2.2	1.9
	29. 21	126.7	19.8	125.1	21.0	-1.6	-3.7	1.2	0.5	123.9	22.4	-2.6	-5.6	2.6	0.2
	30. 09	123.0	19.3	121.2	20.6	-1.8	-1.9	1.3	0.7	119.6	21.9	-3.4	-4.0	2.6	1.7
	30. 21	121.1	20.0	119.1	21.4	-2.0	-2.1	1.4	1.0	117.2	21.9	-3.9	-4.6	2.9	0.9
	31. 09	119.0	21.0	116.6	22.5	-2.4	-2.5	1.5	-0.1	111.8	24.0	-4.7	-4.5	3.0	1.0
	31. 21	116.5	20.9	114.5	22.4	-2.0	-2.0	1.5	1.1	112.6	22.6	-3.9	-3.5	1.7	1.9
	Sept. 1. 09	114.5	22.0	112.7	23.6	-1.8	-1.5	1.6	0.8	111.1	25.2	-3.4		3.2	
	1. 21	113.0	22.8	111.2	24.3	-1.8		1.5			24.5	-3.4		1.7	
Tropical Storm	Aug. 30. 21	144.9	17.0	142.9	18.4	-2.0	-2.8	1.4	3.1	141.1	20.0	-3.8	-7.1	3.0	2.7
	31. 09	142.1	20.1	139.7	20.9	-2.4	-4.3	0.8	-0.4	137.4	22.0	-4.7	-7.2	1.9	-0.2
	31. 21	137.8	19.7	135.7	20.8	-2.1	-2.9	1.1	0.2	133.9	21.9	-3.9	-5.4	2.2	-0.3
	Sept. 1. 09	134.9	19.9	132.8	20.6	-2.1	-2.5	0.7	-0.5	130.8	21.8	-4.1	-4.8	1.2	-1.1
	1. 21	132.4	19.4	130.3	20.4	-2.1	-2.3	1.0	-0.6	128.4	21.3	-4.0	-3.7	1.9	-0.4
	2. 09	130.1	18.8	128.1	20.1	-2.0	-1.4	1.3	0.2	126.1	21.5	-4.0	-1.9	2.7	0.1
	2. 21	128.7	19.0	127.1	20.4	-1.6	-0.5	1.4	-0.1	125.9	21.9	-2.8	-1.6	2.9	0.6
	3. 09	128.2	18.9	127.0	20.2	-1.2	-1.1	1.3	0.7	126.2	21.7	-2.0	-3.2	2.8	2.1
	3. 21	127.1	19.6	126.0	21.2	-1.1	-2.1	1.6	1.4	125.4	22.0	-1.7	-3.3	2.4	2.2
	4. 09	125.0	21.0	124.0	20.8	-1.3	-1.2	-0.2	0.8	122.6	21.4	-2.4	-2.6	0.4	2.7
	4. 21	123.8	21.8	121.7	21.9	-2.1	-1.4	0.1	1.9	119.9	22.7	-3.9	-3.6	0.9	3.4
	5. 09	122.4	23.7	120.7	26.5	-1.7	-2.2	2.8	1.5	119.1	28.7	-3.3	-3.5	5.0	3.3
	5. 21	120.2	25.2	118.1	27.7	-2.1	-1.3	2.5	1.8	116.7	30.0	-3.5	0.2	4.8	4.2
	6. 09	118.9	27.0	118.9	28.3	-2.0	1.5	1.3	2.4	115.5	29.7	-3.4	1.8	2.7	5.7
	6. 21	120.4	29.4	119.6	31.6	-0.8	0.3	2.2	3.3	119.6	33.7	-0.8		4.3	
	7. 09	[illegible]	32.7	122.7	34.5	2.0		1.8		126.2	36.3	5.5		3.6	

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