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TROPICAL CYCLONE SPINUP AND INTENSITY CHANGE

by

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ABSTRACT

It has been established that changes in the intensity of tropical cyclones are related to those in the angular momentum at the upper levels (e.g. Holland, 1983; Holland and Merrill, 1984). In this paper, an application of this concept is presented. Using operationally available data, time changes of the angular momentum at the 200 hPa level at 6 degrees latitude radius from the centre of a tropical cyclone were computed. An increase in angular momentum (spinup) was found to be related to the intensification of the cyclone. On the other hand, spindown (a decrease in angular momentum) over a prolonged period correlated well with the dissipation of the cyclone. In addition, the peak intensity of the cyclone was usually reached 48-72 hours after the occurrence of maximum spinup.

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1. INTRODUCTION

Empirical evidence suggests that the proximity of an upper-level trough is conducive to the intensification of a tropical cyclone. For example, Sadler (1976, 1978) showed cases of tropical cyclone genesis and intensification in which the Tropical Upper Tropospheric Trough (TUTT) was in the vicinity. Weakening of tropical cyclones, on the other hand, is usually attributed to landfall, dry or cold air intrusion and lower sea surface temperatures.

Analyses of data around intensifying tropical cyclones also reveal that the upper-level flow appears to be the most important factor (Gray, 1979; McBride and Zehr, 1981; Holland, 1983; Askue and Gray, 1984; Merrill, 1985). For example, in their calculation of angular momentum budgets for developing and non-developing cloud clusters, McBride and Zehr (1981) showed that the flux of angular momentum was the greatest near the 100-200 hPa outflow layer. The magnitude also increases with the intensity of the tropical cyclone. Modelling studies such as those of Challa and Pfeffer (1980) and Holland and Merrill (1984) also found that angular momentum increases at the upper levels represent the major contributing factor in the intensification of the model tropical cyclone.

Based on some of these observational and numerical findings, the Northern Territory Regional Office of the Australian Bureau of Meteorology developed a program to compute the angular momentum budget around a tropical cyclone (Australian Bureau of Meteorology, 1985). This paper describes a study using a modified version of the program to determine changes in the angular momentum around a tropical cyclone and their relationship to those in central pressure.

2. DATA AND METHODOLOGY

(a) Tropical cyclone data

Tropical cyclones in the western North Pacific within the area bounded by 10-30^{o}N and 105-125^{o}E during 1985-86 for which shipping warnings had been issued by the Royal Observatory were chosen in this study. The 31 tropical cyclones in this data set are listed in the Appendix. All 0000 and 1200 UTC positions were included regardless of the intensity of the cyclone. The minimum sea-level pressure (MSLP) near the centre of a tropical cyclone as obtained from post-analysis was chosen to represent its intensity.

(b) Wind data

Operationally available wind data at 200 hPa were used in this study. These include regular rawinsonde data as well as aircraft reports and satellite observations. For each time period, the data were interpolated to a 5x5 degrees latitude grid using the Cressman scheme (Cressman, 1959).

(c) Spinup and angular momentum computation

In this paper, the term spinup refers to the time rate of change of relative angular momentum at 200 hPa at 6 degrees latitude radius from the centre of a tropical cyclone. It is the sum of three terms :

(i) total horizontal flux of angular momentum by the mean and eddy circulations,

(ii) the Coriolis torque, and

(iii) the beta torque.

The last two terms were defined by Holland (1983). They represent the contribution of the earth's rotation due to the movement of the cyclone. A positive value of the spinup indicates an increase in angular momentum. To compute the spinup, the interpolated wind data at the 8-point compass bearings around the cyclone were used.

3. RESULTS

(a) General

For every cyclone, the value of spinup at each time period was compared with that of central pressure. In general, an increase in intensity (decrease in MSLP) follows an increase in the magnitude of spinup. On the other hand, a "spindown" (negative values of spinup) is associated with the weakening and dissipation of a cyclone. Tropical Storm Val (8517) represents a good example of spindown (Fig. 1). Throughout its lifetime, the values of spinup were negative. This is apparently the major contributing factor for its demise over the sea as tropical cyclones very seldom dissipate over water in September when intense surges of the winter monsoon are absent.

Another result is that consistently small values of spinup of $< 10\ m^{-1}s^{-1}day^{-1}$ suggest that the cyclone is not likely to intensify. An example of this is Tropical Storm Mac (Fig. 2). The maximum spinup value during its entire life span was only $6.6\ m^{-1}s^{-1}day^{-1}$.

(b) Time lag between maximum spinup and maximum intensity

For each cyclone, the time T_s when the maximum spinup was reached and the time when the cyclone attained its maximum intensity, T_c, were determined. The values of this time lag, $T(=T_s-T_c)$, are listed in Table 1. In this table, the cases with $T < 0$ or maximum spinup < 0 or no occurrence of intensification were excluded. For 15 out of the remaining 23 cases, T was between 48 and 72 h (see also Fig. 3). The mean value of T is about 50 h while 72 h is the modal value. An example of this lag relationship between maximum spinup and minimum MSLP is Typhoon Faye (Fig. 4).

Of all the cases in which the time lag is < 36 h, the values of the maximum spinup were all $< 15\ m^{-1}s^{-1}day^{-1}$. These results therefore suggest that if the maximum spinup is greater than this value, it is quite likely that the cyclone will deepen to its maximum intensity within the next 48-72 h.

(c) Maximum spinup versus pressure fall

It would be useful if an empirical relation could be established between the maximum spinup values and the largest fall in the MSLP from the time of occurrence of maximum spinup. A scatter diagram of these two parameters is shown in Fig. 5. Only cases with $T > 0$ and the value of maximum spinup > 0 are plotted. However, a linear regression analysis does not give a statistically significant correlation between the two variables. This could be due to a small sample size, underestimation of the value of spinup because of the interpolation procedure or other factors which affect the intensification of tropical cyclones.

4. DISCUSSION

Using operationally available data, changes in the angular momentum at 200 hPa were found to be related to those in the intensity of tropical cyclones. The main result is that a lag exists between the time when the angular momentum at 200 hPa reached the maximum and that when the cyclone attained its maximum intensity. In most cases, this time lag is between 48-72 h. Although no significant correlation can be found between the values of the maximum spinup and and maximum intensity, persistent small values of spinup (< 10 $m^{-1}s^{-1}day^{-1}$) suggest the unlikelihood of tropical cyclone development. In addition, spindown (negative spinup) over prolonged periods indicates possible dissipation of the cyclone.

From a forecasting point of view, these results can be applied to provide guidance in predicting the intensity change of a tropical cyclone. Independent testing of the results will be performed using the data for the 1987 cyclones. Promising results can lead to the development of forecast rules.

The existence of a lag between the time of maximum spinup and that of maximum intensity also has some implications in the adjustment processes in tropical cyclone intensification. An increase in angular momentum causes an imbalance between the mass and the wind fields at the upper levels. An adjustment in the mass field then occurs which is eventually reflected at the surface as a pressure drop. Questions of how this process takes place and why it takes two to three days will need to be resolved from future observational and/or numerical studies.

5. ACKNOWLEDGEMENT

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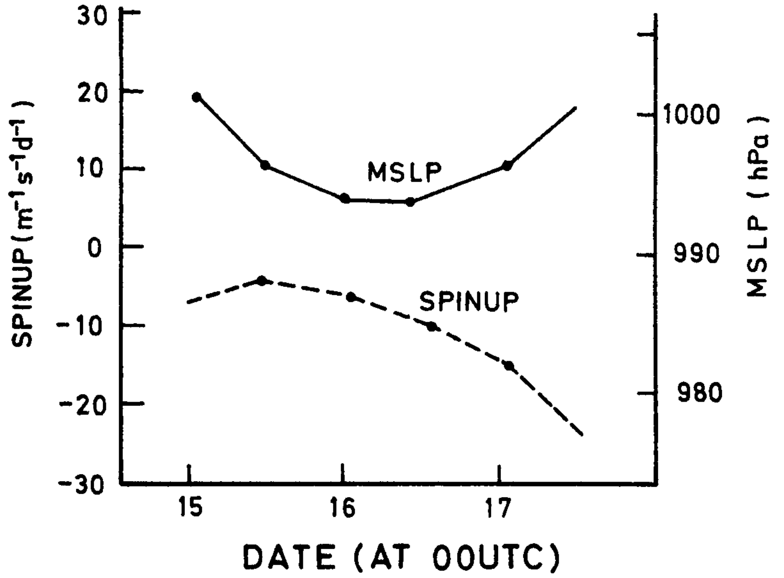

Fig. 1 Time variations of spinup and MSLP of Tropical Storm Val (1985)

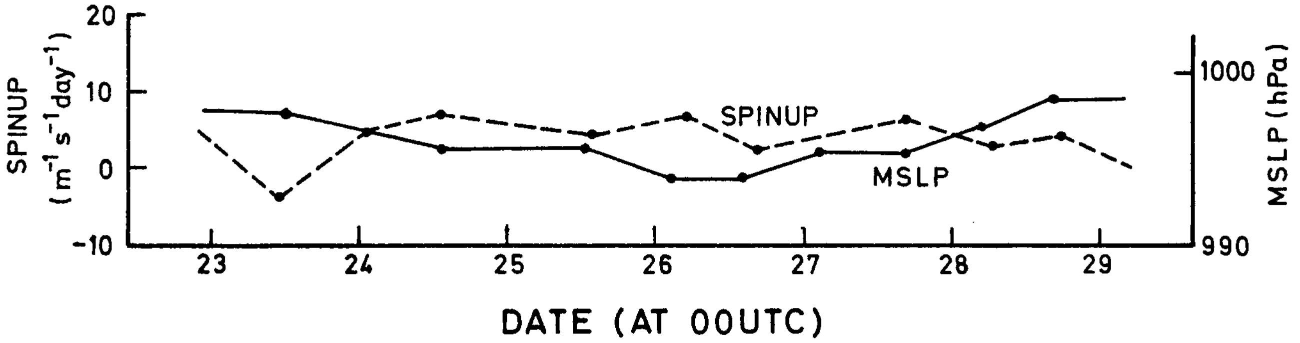

Fig. 2 Time variations of spinup and MSLP of Tropical Storm Mac (1986)

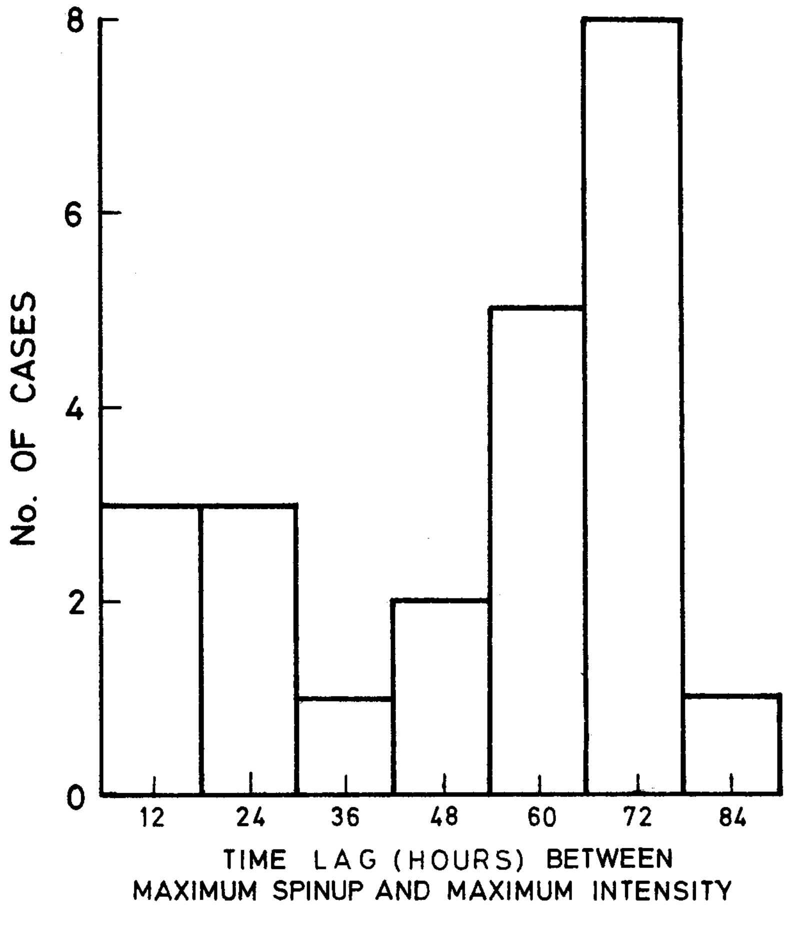

Fig. 3 Time lag (hours) between the occurrence of maximum spinup and that of maximum intensity

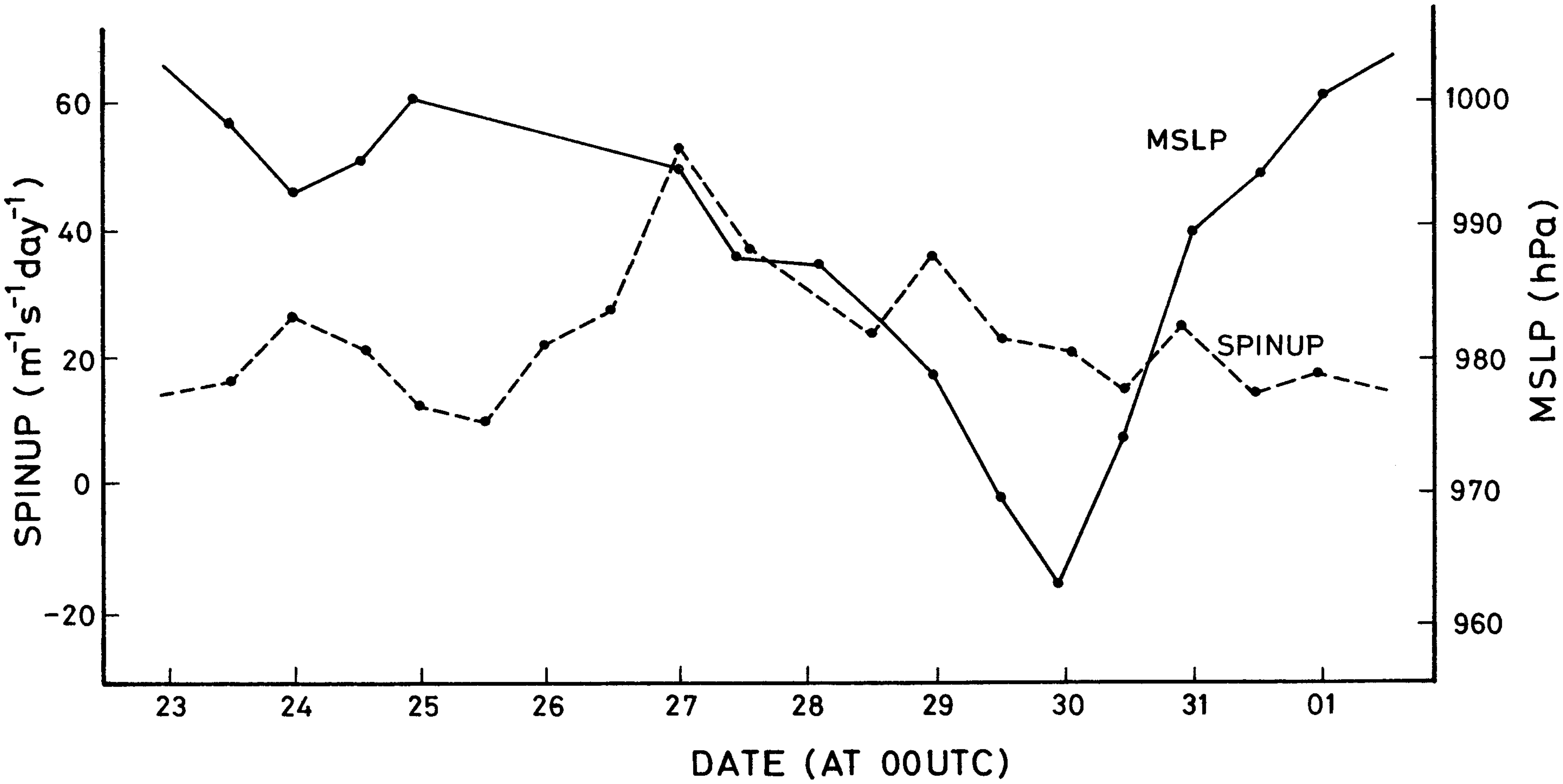

Fig. 4 Time variations of spinup and MSLP of Typhoon Faye (1985)

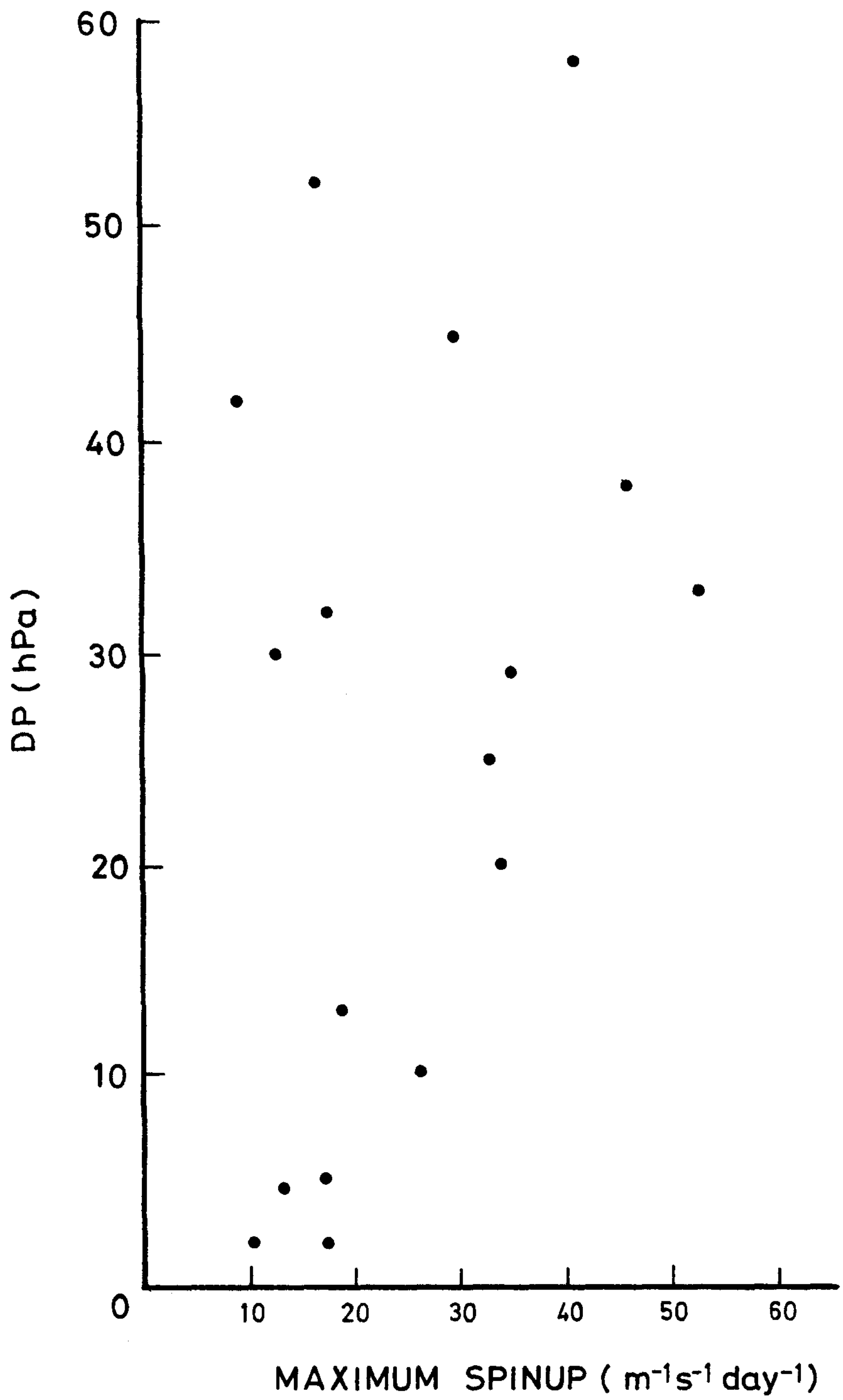

Fig. 5 Scatter diagram of the magnitude of maximum spinup and the change in MSLP (DP) between the time of maximum spinup and that of maximum intensity

Table 1. MAXIMUM SPINUP, CHANGE IN MSLP AND TIME DIFFERENCE BETWEEN TIME OF MAXIMUM SPINUP AND THAT OF MAXIMUM INTENSITY

Tropical cyclone	maximum spinup $m^{-1}s^{-1}day^{-1}$	pressure change (hPa)	time lag (h)
1985			
TD June	10.2	2	12
Typhoon Hal	46.1	38	66
TD July	32.1	3	66
Typhoon Jeff	35.0	29	66
STS Mamie	18.7	13	18
Typhoon Nelson	12.8	30	84
Typhoon Tess	33.8	20	66
TS Winona	15.2	10	24
Typhoon Andy	20.0	28	48
Typhoon Brenda	17.7	32	60
Typhoon Cecil	28.9	40	66
Typhoon Faye	52.8	33	72
TD Gordon	13.9	2	12
1986			
Typhoon Nancy	9.2	42	60
Typhoon Vera	16.5	52	60
TD August	13.1	4	42
Typhoon Abby	29.7	45	54
TS Dom	43.8	10	72
Typhoon Ellen	26.2	10	24
TS Herbert	17.2	2	6
STS Ida	16.9	5	72
Typhoon Joe	41.2	58	60
Typhoon Marge	32.9	25	36

APPENDIX

List of tropical cyclones used in the study :

Year	Name	Time (UTC)	Month
1985	Tropical Depression	170600-200600	June
	Typhoon Hal (8505)	190000-250000	June
	Tropical Depression	040000-081200	July
	Typhoon Jeff (8507)	220000-020600	July-August
	STS Mamie (8510)	151800-191800	August
	Typhoon Nelson (8511)	171800-240600	August
	Typhoon Tess (8516)	010000-061800	September
	TS Val (8517)	150000-171800	September
	TS Winona (8518)	190000-221200	September
	Typhoon Andy (8519)	271200-020000	Sep-October
	Typhoon Brenda (8520)	300600-050000	Sep-October
	Typhoon Cecil (8521)	120000-161200	October
	Typhoon Dot (8522)	130000-220000	October
	Typhoon Faye (8524)	230000-011200	Oct-November
	TD Gordon (8525)	230000-251200	November
1986	TS Mac (8604)	230000-290600	May
	Typhoon Nancy (8605)	210000-250000	June
	Typhoon Peggy (8607)	030000-121200	July
	STS Sarah (8610)	300600-041200	July-August
	Tropical Depression	091200-120000	August
	Typhoon Vera (8613)	150600-281800	August
	Typhoon Wayne (8614)	180000-060600	Aug-September
	Typhoon Abby (8616)	130600-200600	September
	TS Dom (8619)	051800-111800	October
	Typhoon Ellen (8620)	110000-191200	October
	TS Georgia (8622)	180000-221800	October
	TS Herbert (8623)	080600-120000	November
	STS Ida (8624)	110000-161800	November
	Typhoon Joe (8625)	180600-241800	November
	Typhoon Marge (8628)	140600-250000	December
	Typhoon Norris (8629)	211800-011800	December-Jan