A Hypothesis on Complex of Tropical and Extratropical Cyclones for Typhoon in the Middle Latitudes

II. Synoptic Structure of Typhoons Louise, Kezia and Jane Passing over the Japan Sea

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§1. Synoptic structure of Typhoon Louise

1. Typhoon Louise (1955) who passed over the Japan Sea, maintaining her central pressure of ca. 980 mb and showing no apparent redevelopment (see Fig. 1), is selected to confirm our hypothesis on complex of tropical and extratropical cyclones, derived from the synoptic analysis of redeveloped Typhoon Marie. The examination was carried out in

the same idea mentioned in the first paper [3].

2. Separating her Secondary Typhoon from 3-hourly surface weather charts during her traverse through Kyushu, we obtained the characteristic aspects of her Main Typhoon; radius of inner region (b') of 200 km and lowering of the central pressure from the surroundings (π') of 30 mb. The paths of the Main and Secondary Typhoons during this period are shown in Fig. 2.

3. The characteristic aspects of the Main Typhoon, analyzed in 2, are same as those of Marie. It can be allowed to use the following supposition for the Main Typhoon during its passage over the Japan Sea, as in case of Marie; (i) radius of inner region (b') is unchanged, and (ii) damping rate (K) is 0.02. Thus, we can calculate the 3-hourly values of π' taking π'_0 of 30 mb at 0900 JST, Sept. 30. These values are listed in Table 1. Now we can prepare the tracing paper on which the 3-hourly pressure field of the Main Typhoon is copied, as an available tool for the following analysis.

4. The separation of the accompanying extratropical cyclone for the case of Marie, had been carried out by the assumption that the Main Typhoon travelled along the straight path with a uniform speed. But this simplified assumption can not be applied to the present case, for it is supposed that the Louise's Main Typhoon must have travelled along the curved path by the following evidences. The analyzed path (from 2100 JST, Sept. 29 to 0900 JST, Sept. 30, see Fig. 2) of the Main Typhoon does not show the

Fig. 1. Path and Central Pressure of Typhoon Louise. 03/30—Position at 0300 JST, Sept. 30.

Fig. 2. Paths of Main Typhoon, Secondary Typhoon and Extratropical Cyclone:

-----x-----x----- Path of Main Typhoon, from 2100 JST, Sept. 29 to 0900 JST, Oct. 1 (x-----x analyzed by the method in § 1, 2; -----x----- Obtained by the trial method).
 x-----x Path of Secondary Typhoon, from 2100, Sept. 29 to 0600, Sept. 30.
 —●—●— Path of Extratropical Cyclone, from 0300, Sept. 30 to 0900, Oct. 1.

straight line, and its position at 0900 JST, Oct. 1 may be roughly identified with one of the double center on the surface weather chart (see Fig. 5). The appearance of this double center may be understood as a result of a chance that the decaying Main Typhoon and the developing extratropical cyclone have nearly equal intensities. We connect, for the path of the Main Typhoon over the Japan Sea, the two known points, initial point (at 0900 JST, Sept. 30) and one of the double center with a smooth curve, as the first approximation.

5. Thus, we can determine the central position of the Main Typhoon, considering the following restrictions:

(i) The Main Typhoon locates its central position near the curve presented in Section 4.

(ii) The pressure field of the accompanying extratropical cyclone, obtained by elimination of the field of the Main Typhoon using the tracing paper already prepared, must satisfy the following characters.

(a) The center of the extratropical cyclone has its position near the intersection point of warm and cold fronts estimated by the extrapolation of them, a part of which appears on the surface weather chart.

(b) The isobars within the warm sector of that extratropical cyclone are nearly straight lines.

(iii) The successive 3-hourly central positions of the Main Typhoon lie on a smooth curve.

After some trials, we can find out the path of the Main Typhoon and of the accompanying extratropical cyclone, as shown in Fig. 2. It is seen from this analysis, that the northern one of the double center refers to the Main Typhoon and the other to the accompanying extratropical cyclone.

6. The composite charts of these two

Table 1.

Date	0900 JST Sept. 30	1200	1500	1800	2100	0000 Oct. 1	0300	0600	0900
π' (mb)	30	28	27	25	24	22	21	20	19

cyclonic systems analyzed in this way are shown in the bottom of Figs. 3-5, and the estimated values of the central pressure of the separated extratropical cyclone (p_e) are listed in Table 2. Application of Petterssen's Method [2] to the separated extratropical cyclone, as in the case of Marie, presents a comparably good result as shown in Table 3.

7. The wind records at Tomakomai, Sap-

poro and Rumoi, which show a passage of the weak wind zone, are to be noticed (see Fig. 6). These stations are located in the intermediate region of the two paths. While the records at Haboro and Aomori, out of this region, have not such a passage of the remarkable weak wind zone (see Fig. 6). This weak wind zone did not occur on the passage of the central portion of typhoon. Therefore, it was not the TYPHOON EYE. Such a remarkable phenomenon can be understood by the superposition of the Main Typhoon and accompanying extratropical cyclone, as already mentioned in the first paper. The above mentioned matters are shown more illustratively in Fig. 7, which represents the detailed resultant pressure field

Fig. 3 (a)

Fig. 3 (b)

Figs. 3, 4 and 5; (a) Surface Weather Chart, (b) Composite Chart of Main Typhoon and Extratropical Cyclone (Dotted and dashed lines represent the pressure field of Main Typhoon and numerals on them indicate the pressure lowering from surroundings).

Fig. 4 (a)

Fig. 4 (b)

Fig. 5 (a)

Fig. 5 (b)

obtained by superposition of these two cyclonic systems. This matter of fact is considered as the principal evidence which supports indirectly our hypothesis.

§2 Synoptic structure of Typhoon Kezia

1. Typhoon Kezia (1950) which decayed slowly over the Japan Sea (see Fig. 8) is selected to examine whether the slowly decaying typhoon is also accompanied by extratropical cyclone.

2. The characteristic aspects of the Main Typhoon during its traverse through Kyushu, are obtained as follows; radius of inner region $b' = 180$ km and lowering of the central pressure from surroundings $\pi' = 20$ mb. The damping rate of the Main Typhoon, 0.023 is evaluated by Matano's formula [1]. The 6-hourly values of π' , taking π'_0 of 20 mb at 0300 JST, Sept. 14, are listed in Table 4.

Table 2.

Date	0000 JST Sept. 30	0300	0600	0900	1200	1500
p_e (mb)	1007	1003	1000	998	998	997
Date	1800	2100	0000	0300	0600	0900
	Oct. 1					
p_e (mb)	996	994	993	992	990	989

Table 3.

Reference Time	Equation for Pressure Deepening	Expected value of the Central Pressure (mb)					
		1800 JST Sept. 30	2100	0000 Oct. 1	0300	0600	0900
1500 JST Sept. 30	$\Delta p = -3.5t + 0.27t^2$	994	992	990	989	989	988
1800	$\Delta p = -4.0t + 0.35t^2$		993	989	987	986	985
2100	$\Delta p = -3.0t + 0.59t^2$			992	990	990	990
0000 Oct. 1	$\Delta p = -5.0t + 0.26t^2$				980	984	980
0300	$\Delta p = -4.5t + 0.39t^2$					988	985
0300	$\Delta p = -4.0t + 0.12t^2$						986
p_e (mb)		996	994	993	992	990	989

Fig. 6. Wind Records at Tomakomai Sapporo, Rumoi, Haboro and Aomori.

Fig. 7. Resultant Pressure Field of Main Typhoon and Extratropical Cyclone, at 0700 JST, Oct. 1,

Fig. 8. Path and Central Pressure of Typhoon Kezia. 03/14 --- Position at 0300 JST, Sept. 14.

Table 4.

Date	0300 JST Sept. 14	0900	1500	2100	0300 Sept. 15	0900
π' (mb)	20	17	15	13	11	10

3. The double center which suggests the central position of the Main Typhoon, appears on the surface weather chart at 0900 JST, Sept. 15, and analyzed path of the Main Typhoon before 0300 JST, Sept. 14 is not straight (see Fig. 9). Thus, the path of the Main Typhoon over the Japan Sea can not be supposed as straight, and the analysis is performed by the same way as in the case of Louise. The paths of the Main Typhoon and the extratropical cyclone are shown in Fig. 9.

4. The composite charts, thus obtained, are shown in Figs. 10 and 11. The estimated central pressures of the accompanying extratropical cyclone (p_e) are listed in Table 5. Also in the present case, the wind observation at Rumoi in the intermediate region of

two paths shows the passage of the weak wind zone, while that at Esashi out of this region does not show such one (see Table 6).

§3. Synoptic structure of Typhoon Jane

1. It is found, in Fig. 12, that Typhoon Jane (1950) also decayed slowly over the Japan Sea.

2. The characteristic aspects of the Main Typhoon during its passage through Shikoku and Kinki, are analyzed as follows; $b'=180$ km

Fig. 9. Paths of Main Typhoon (from 1500 JST, Sept. 13 to 0900 JST, Sept. 15), Secondary Typhoon (from 1500 to 2100, Sept. 13) and Extratropical Cyclone (from 1500, Sept. 13 to 0900, Sept. 15). (see legend under Fig. 2)

Fig. 10 (a)

Fig. 11 (a)

Fig. 10 (b)

Fig. 11 (b)

Figs. 10 and 11 (see legend under Figs. 3,4 and 5).

Table 5.

Date	1500 JST Sept. 13	2100	0300 Sept. 14	0900	1500	2100	0300 Sept. 15	0900
p_e (mb)	1004	1002	1002	1000	998	996	995	995

Table 6.
(Wind Velocity)

Date	0400 JST Sept. 15	0500	0600	0700	0800	0900
Esashi	17.1 m/s	15.8	27.0	21.9	16.3	18.0
Rumoi	8.5 m/s	5.2	4.0	4.6	4.8	3.2

Fig. 12. Path and Central Pressure of Typhoon Jane. 03/3 --- Position at 0300 JST, Sept. 3.

Table 7.

Date	1500 JST Sept. 3	2100	0300 Sept. 4	0900
π' (mb)	20	17	15	13

and $\pi' = 20$ mb. The values of π' over the Japan Sea, using $K = 0.023$, are listed in Table 7, where π'_0 is 20 mb at 1500 JST, Sept. 3.

3. The path of this typhoon is directed approximately north-eastward before her landing on Japan (see Fig. 12), as in the case of Marie. We can extrapolate straightly the path of the Main Typhoon, which is obtained by the analysis during its passage over land, to obtain its successive positions over the Japan Sea as shown in Fig. 13.

4. The composite charts of these two cyclonic systems are shown in bottom of Figs. 14 and 15, and the estimated central pressures of the accompanying extratropical cyclone (p_e) are listed in Table 8. The passage of the weak wind zone is found at Hakodate in the intermediate region of these two paths, while Urakawa out of this region is being covered by relatively strong wind during that period (see Table 9).

Fig. 13. Paths of Main Typhoon, Secondary Typhoon and Extratropical Cyclone:

-----x-----x----- Path of Main Typhoon, from 0300 JST, Sept. 3 to 0900 JST, Sept. 4 (x-----x analytically obtained; -----x----- extrapolated).

x-----x Path of Secondary Typhoon, from 0900 to 1300, Sept. 3.

-----●----- Path of Extratropical Cyclone, from 0300, Sept. 3 to 0900, Sept. 4.

Fig. 14 (a)

Fig. 14 (b)

Figs. 14 and 15 (see legend under Figs. 3, 4 and 5).

Table 8

Date	0300 JST Sept. 3	0900	1500	2100	0300 Sept. 4	0900 Sept. 4
p_e (mb)	1009	1008	1001	996	993	992

Fig. 15 (a)

Fig. 15 (b)

Table 9.
(Wind Velocity)

Date	0300 JST Sept. 4	0400	0500	0600	0700	0800
Urakawa	18.8 m/s	22.6	17.3	15.7	16.1	9.3
Hakodate	13.9 m/s	6.9	3.6	1.1	7.8	9.1

§ 4. Summary

The synoptic study for Typhoon Marie which redeveloped over the Japan Sea, presented the result that this typhoon is a complex system of the Main Typhoon and the

extratropical cyclone, and that the apparent redevelopment of this typhoon is not caused by the Main Typhoon, but due to the development of accompanying extratropical cyclone [3]. The similar result is obtained in the present paper, after the synoptic analyses for Typhoons Louise, Kezia and Jane which ma-

intain or weaken their central pressure over the Japan Sea. Consequently, we may suppose that almost all the typhoon which entered into the Japan Sea have the same structure given by our hypothesis.

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