MEMOIRS, REPORTS, REVIEWS AND ABSTRACTS, IN FOREIGN LANGUAGES.

Examples of Cyclones and Depressions of Pure Thermal and Pure Dynamical Origin.

By Sakuhei FUJIWHARA.

There are various kinds of cyclones and depressions such as tropical and extra-tropical, permanent, semipermanent and travelling, warm-centred and cold centred, primary and secondary etc. There are also many theories and hypotheses intending to explain the phenomenon, among which Ferrel's convection or condensation theorie, Hann's mechanical theory, Clayton-Bigelow's counter current theory, Shaw's theory of normal cyclone and the theory of eviction as well as Bjerknes theory of polar front are worth mentioning. Though not complete these theories contains some or other truth? It seems to me that in nature there exist various mechanisms giving rise to cyclonic vortices or depressions and they cannot be fully explained by one or two simple theories. Formerly the present author had believed that the revolving motion and the depression of barometer are two inevitable facts of a cyclonic depression. But he finds now a kind of depression which has no rotational motion and a cyclone which shows hardly a depression of barometer. Fig. 1⁽¹⁾ is the reproduction of the weather chart for 6 o'clock, March 11, 1924 prepared at the Central Meteorological Observatory, Tokyo, in which we can see a depression covering the area of warmer air over the sea to the northeast of Korean straits, in contrast to the cooler air due to the nocturnal cooling of the surrounding land. The area was originally belonging to a high pressure. At 18h of the previous night there was neither trace of depression nor warmer air over the sea. At the noon of the 11th, the depression was still existing, but the air temperature was gradually equalized and at the 18h of that day the depression vanished. The remarkable fact is that no cyclonic wind was observed all through the interval during which the depression was existing, while on the morning land breeze was remarkable at Kōryo. Similar cases were frequently observed, but the phenomema were not so pure as in the case above mentioned, for in those cases lines of discontinuity were shifting near by and hence it is hardly distinguishable whether the depressions were due to those lines or to local high (or low) temperature.

There is another class of cyclonic phenomena due to pure kinematical action.

(1) Vol. II, No 8, p. 232.

On August 25, 1922 Tokyo has experienced a heavy down pour of rain and very strong southerlies. On the previous day an intense typhoon passed over and a high area occupied the vicinity of the Bonin Islands. A moderate depression was formed on the 25th over the sea near Ryukiu. Between these high and low, the barometric gradient was very steep and a southerly current was strongly accelerated, which reached the Japanese coast by Tokyo Bay on the velocity of about 20 m/s. As Tokyo Bay lies extending from north to south, the southerly current dashed into the Bay and swept over the Kwantō Plane. There is the mountain mass of Asio and Nikko in the east of which lies the valley of Kinu River. In the south of the mountain mass there is the plane of Saitama-Gumma Prefecture surrounded by mountain ranges on north to west and southwest sides. The southerly air current from Tokyo Bay encountered on its west margin with the mountain mass and that part of the current deflected to the west, while the main part of the current proceeded straight to the Valley Kinu. The deflected part of the current then turned to southwest, south and southeast, guided by the mountain range at last completed the circulation being absorbed in the southerly current at the north of Tokyo Bay. The cyclonic motion thus introduced produced a depression of barometer about 1 mm of mercury, which existed all the day and vanished on the night. The Southerlies were prevailed also on that night and following day, but wind velocity was not enough to maintain the depression.

Nearly the same phenomenon was experienced on the 1st of September, 1924, when the great earthquake broke out. On that occasion a line of discontinuity was sweeping from the west and hence, the secondary cyclone then occurred could not simply be attributed to the southerlies only. The line stretched from SW to NE and passed away towards the east leaving the depression at its original position, which died when the mother southerly current subsided.

On working on the daily weather chart of the Far East we have abundant examples of the evolution of depressions on the line of discontinuity. This phenomenon takes place preferably over a special area of the earth where topographic condition is favourable to it. The two places above described are also very remarkable on this connection.

Numerical Consideration.

Suppose that by nocturnal cooling the temperature of the surface land area falls to 0°C or 273°A , and that over sea to 3°C or 276°A . As the result the air strata over the land contracts more than that over the sea and hence the isobaric surfaces over the land become lower and consequently the air over the sea bulges

out toward the land⁽¹⁾. Thus the atmospheric pressure at the sea level over the land increases and that over the sea decreases and respectively becomes $P_e=769$ mm and $P_s=768$ mm of mercury. The maximum bulge takes place at a certain height above the sea level because of the surface friction of the earth. At a higher altitude there exists a level where this effect of nocturnal cooling scarcely sensible. Let this height be denoted by H and suppose that the temperature T_H and pressure P_H at this height remain uniform and unchanged. Let the lapse rate of air temperature over the land and sea be denoted respectively by α and β then,

$$T_H = T_e - \alpha H = T_s - \beta H,$$

$$\frac{P_H}{P_e} = \left(\frac{T_e - \alpha H}{T_e} \right)^{\frac{g}{R\alpha}}, \quad \frac{P_H}{P_s} = \left(\frac{T_s - \beta H}{T_s} \right)^{\frac{g}{R\beta}},$$

$$\frac{P_s}{P_e} = \left(\frac{T_e - \alpha H}{T_e} \right)^{\frac{-g}{R\alpha}} \left(\frac{T_s - \beta H}{T_s} \right)^{\frac{g}{R\beta}}.$$

Neglecting small quantities we have

$$\left(1 - \frac{1}{769} \right) = \left(1 - \frac{g}{R} \frac{H}{273} + \frac{gH}{R 276} \right),$$

Since $g=980$ cm/s/s; $R=2.87 \times 10^6$ c.g.s, we have

$$H=957 \text{ m.}$$

This height is rational, and if we assume that $\alpha=0$ owing to the inverting tendency of temperature, then $T_H=T_e=273$, $\beta=3/957=0.3^\circ\text{C}/100 \text{ m.}$

This is also admissible, for the lapse rate on a winter morning. Hence It seems that the above mentioned depression was produced by the superior nocturnal cooling over the land than over the sea.

Next we shall consider the case of the cyclonic whirl produced kinematically on 25th Aug. 1922, in Kwanto plane. Assume a circular atmospheric whirl with the diameter of 75 km and the height of 1 km, in which air circulate about the center with the average velocity of 5 m/s.

Then the total kinetic energy is

$$\begin{aligned} E_t &= \frac{1}{2} \times 0.00129 \times 250000 \times \pi \times (3750000)^2 \times 100000 \\ &= 6.5 \times 10^{20} \text{ ergs} \end{aligned}$$

Suppose the southerly current with the front of more than 100 km and the thickness of 1 km and mean velocity of 15 m/s.

1) In a state of stable equilibrium under the earth's gravity the vertical displacement is not easy and hence a horizontal motion will take initiative, when a supply of air is wanted somewhere in the stable atmosphere, if there is no hinderance to it existing near by. This is the principle of superiority of horizontal motion to vertical one in the fluid layer under the earth's gravity.

Suppose that 10 km of the front at the western edge of the current encounters the mountain ridge and turn to the left then guided by mountain walls, goes round to SW and S and forms a whirl. The rate of kinetic energy thus gained by the whirl is

$$\delta E/\delta t = \frac{1}{2} \times 0.00129 \times 2250000 \times 100000 \times 1000000 \times 1500 \text{ erg/sec}$$

and hence $E = 2.4 \times 10^{21}$ ergs

for the total kinetic energy gained during 3 hours. If we suppose that about 3/4 of the total kinetic energy is destroyed by eddies and friction then even the inflow of 4 hours is sufficient to produce the above calculated whirl. Since the figures assumed in the above calculation nearly correspond to the actual ones on August 25, 1922, hence it is probable that the secondary cyclone formed at Saitama plain is produced by the pure kinematical process. Next we shall examine if the amount of barometric depression of the secondary may be explained as the kinematical production. Assume that the barometric gradient is balanced by the centrifugal force, then,

$$p \frac{v^2}{r} = G,$$

where v is the velocity of circular motion with the radius r and G is the gradient of pressure. The amount of depression is

$$p = \int_0^R G dr = \int_0^R \frac{pv^2}{r} dr = \int_0^R p\omega^2 r dr,$$

where ω is the angular velocity, the motion being supposed to be a concentric rotation like a solid disk for the sake of brevity.

Then
$$p = \frac{p\omega^2 R^2}{2} = \frac{pV^2}{2}$$

Where V represents the maximum velocity occurring at the outermost boundary of the whirl. The value of V may lie between 5 m/s and 15 m/s

Hence if we put $V = 10$ m/s, then

$$p = 647 \text{ dyne per cm.} \doteq 0.6 \text{ mm of mercury}$$

If we put $V = 15$ m/s, then $p \doteq 1.3$ mm of mercury.

These figures are sufficiently near the value of actual depression in the scope of the accuracy that we want. Hence the cyclonic whirled took place on Aug. 25, 1922 in Kwanto plane is most probably produced by a pure kinematical process.

From the fact and inference given above we can see that under suitable conditions there exist purely kinematical cyclonic whirled and purely thermal barometric depressions in the earth's atmosphere, though they occur rather seldom and not marked in their intensities. The kinematical one is marked with its circulating motion accompanying rather slight barometric depression. The thermal one is caused

by local cooling and its circular motion develops rather slightly, while the amount of depression is comparatively great. Many years ago Professor Okada⁽¹⁾ showed that there is a definite type of secondary depression formed in Kohu district in Central Japan, owing to the intense insolation in summer months, which frequently accompanies a thunder storm and travels toward ESE and visits Tokyo. The depression of this type is caused as well known by local heating and the whirl motion develops more intensely in this case than in the case of cooling.

That by the simplest mechanisms mentioned above cyclonic depressions, though small, can be formed is an interesting fact for us to formulate the idea on the evolution and growth of ordinary cyclones and typhoons; because such depressions, though of minor power by themselves, may contribute their energy to and help the growth of a major cyclone when there are many of them, or may form a seed for greater one when a surface of discontinuity of great energy passes near by or when an unstable thick layer of atmosphere richly laden with moisture occupies the vicinity.

Some Investigations on Duration and Intensity of Rainfall at Nagano.

(Abstract of the original Japanese article pp. 6—12)

By K. TUTUMI.

The present author gives results of statistics on the duration of rainfall observed at the Nagano Meteorological Station. Results are shown in 4 tables. (p.) The first table contains frequencies of rainfall which set in A.M. (and which set) in P.M. The second table contains the result of summation of rains beginning between 0^h—6^h, between 6^h—12^h, between 12^h—18^h and between 18^h—24^h.

In these tables, monthly values for April to October are shown. These data are taken from the records of a selfregistering raingauge. In winter pluviograph is not generally in good working order, so that results for November to March are not given here. In these tables the small figures in bracket are numbers of thunderstorms in corresponding months. Small figures at right foot are numbers of rainfall, amount of which is less than 0.1 mm.

The third table gives the frequency of the period of breaking of rainfall. The author observed the time between the beginning of a rain and its next breaking epoch, or between two epochs of breaking, and numbers of events corresponding to 0—5 min., 5—10 min., are given. To get rid of the ambiguity of determination of such breaking epoch, the author compares these results with the smoothed values

(1) Bulletin of the Central Meteorological Observatory Vol. 1 No 2.