Orographic Influence on Atmospheric Pressures and Currents. (V)

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— Abstract —

A secondary anticyclone appears invariably over a lofty mountainous district when a large continental or oceanic high stretches out towards that district, while a typhoon splits into 2 parts, when it crosses over a mountain range. In this paper, these facts are illustrated by referring to isobaric distortions in various weather maps and they are possibly explained by three theories, *i. e.* 1. static theory, 2. dynamic theory, 3. frictional theory.

However, the dynamic action is too feeble to exert any noteworthy influence upon the typhoon. And the friction is also incompetent to account for the anticyclonic emergence over high mountains, though it may explain the decline of typhoon on land.

§ 1. Introduction

In the earlier papers,⁽³⁾⁽⁶⁾ the writer expounded two theories which anticipated the appearance of an anticyclone on the elevated land. One of them, called "static theory", ascribed the birth of the anticyclone to the increase of barometric pressure caused by the lifting of the air mass. The other, called "dynamic theory", attributed it to the clockwise rotation of the air mass (in the northern hemisphere) which became apparent by its decreasing angular velocity on the elevated land. The same reasoning will lead to a consequence that the depressed land is the nursery of low pressure, while the elevated land is the birth place of high pressure.

Several weather maps shown in the former papers gave good evidences for the fact that an ovaliform high pressure zone appears in the mountainous district and that a cyclone falls off there in splitting into two, each on either side of the mountain range.

§ 2. Friction

There are some who believe friction plays, in this respect, the more important part than any other factors. This point may be examined in the following. Under the assumption that the wind is opposed to frictional force proportional to its velocity, Guldberg and Mohn obtained the following wellknown equations:⁽⁷⁾

$$\tan \alpha = 1/k, \quad (1)$$

$$v = \frac{1}{\rho} \frac{G}{\sqrt{k^2 + l^2}}, \quad (2)$$

when α = angle of deviation, k = coefficient of friction,
 G = pressure gradient, ρ = air density, $l = 2\omega \sin \varphi$.

From (1) and (2) the inflow of the air through unit area per unit time towards the low pressure zone is easily calculated as

$$\rho v \cos \alpha = \frac{Gk}{k^2 + l^2}. \quad (3)$$

This inflow, if expressed in the angle of deviation (1), is

$$\frac{g}{2l} \sin 2\alpha. \quad (4)$$

So, the inflow is maximum at the angle of 45° . Therefore, the wind tends to fill up the cyclone, if the angle of deviation is larger than 45° , but it deepens the cyclone, if it is less than 45° . This consequence holds true, only on the condition that the air aloft does not so excessively flow out by friction as the air below.

As the angle of deviation is, in most cases, not less than 46° ,⁽⁸⁾ the frictional force usually fritter the cyclonic energy away. It must, however, be noted that the same force can likewise be proved to dissipate the anticyclonic energy in the mountainous district. This is contrary to the fact that anticyclone always develops on the tableland.

The frictional force slackens the wind velocity, which in turn induces the pressure to rise. However, the pressure rises in so small an amount that even the total destruction of the wind velocity of 40 m/sec diminishes the pressure only by 6.5 mb. Thus, the frictional theory is hardly tenable to serious objections.

§ 3. Static theory compared with the other two theories

As is mentioned before, according to the dynamic theory the enhanced anticyclonic movement of the air on an elevated land augments high pressure, but the effect must be much reduced in rugged or densely forested mountains.

Therefore, compared with these two theories, the static orographic effect seems to play the more prominent part in producing the outstanding influence on atmospheric pressure. The following illustrations from the weather maps justify the conclusions reached by the static and dynamic theories, though it cannot be decided which of them is better.

§ 4. High pressures at high levels

It is not rare in the daily weather maps that a small ovaliform high pressure area becomes visible and remains long in the backbone mountain range of Japan proper when the grand anticyclone area over South Siberia extends eastward to the North Pacific. These facts have already been pointed out in the former papers. At present, the writer intends to go still further and show the intimate connection between the contours and

Fig. 1. Weather map,
2100 L. T. (full lines),
0900 L. T. (broken lines), Dec. 28, 1950.

Fig. 3. Weather map,
0600 L. T., Dec. 29, 1950.

A detached secondary high pressure area appeared already early in the morning on Dec. 28, and at 1300 local time (denoted by a broken line in Fig. 1.) it bulged in two directions, one towards northeast embracing the coast lines of Chugoku District with its sack-shaped isobars, and the other towards south-east enclosing Kyushu District with similar isobars. And twelve hours later this solitary high pressure area was seen sitting over the mainland of Japan, conforming its margin to the shape of the coast. Since then this secondary high lingered for a while at the same place, shrinking or bulging more or less from

isobaric curving.

Figs. 1, 2, 3, 4 and 5 are the examples where a series of weather maps shows the deforming isobars for every three hours from Dec. 28 to 29, 1950.

Fig. 2. Weather map,
0000 L. T.,
Dec. 29, 1950.

Fig. 4. Weather map,
1200 L. T., Dec. 29, 1950.

Fig. 5. Weather map,
2100 L. T., Dec. 29, 1950.

time to time. Its inner core bounded by a 1036-mb isobar just fitted the contours of the most lofty mountainous region in the heart of Japan proper.

This fact may be much better understood by referring to Fig. 6 which was drawn from the barographic records collected by the writer as much as possible.

This secondary anticyclone usually appears over the mainland of Japan if the grand high stretches out to the Japanese Islands not only from the Asiatic continent, but also from the Sea of Okhotsk or from the South Seas.

The mathematical analysis⁽⁶⁾ has shown that the dynamical effect augments with the height, as well as with the breadth of the mountain range and sine of latitude. So the Siberian tableland so extensive in length and breadth and so high in altitude and latitude ought to bring forth an outstandingly high pressure area over the continent.

Fig. 7 tells not only the correctness of this conclusion, but also the close connection between the isobars and the contours; as an example, the 775-mm Hg isobar coincides with the 1500-m contour and the 770-mm Hg isobar with the 500-m contour.

On the other hand, it may partly be due to the low latitude that any conspicuous anticyclonic area is not found on the Himalayas, though crowned with the highest peaks in the world.

Of course, this orographic effect is the secondary cause as a generating power of the anticyclonic movement, and its principal impetus comes naturally from the general circulation of the atmosphere.

Fig. 8 is another example of a secondary anticyclone usually found over the widest part of the region of great plateaus between the Rocky Mountains and the Sierra Nevada.

Fig. 6. Weather map, 0600 L. T. (full lines), 0900 L. T. (broken lines), Dec. 29, 1950.

Fig. 7. The map showing the intimate relation between isobars and contours in winter.

in North America. It always occurs when the subtropical belt of high pressure becomes strongly active, and it is well known as the so-called Great Basin high and persists to remain there for a long time.

§ 5. The orographic effect upon a typhoon

Just when the center of the typhoon Muroto was located about 37 km north of Cape Muroto on Sept. 21, 1934 at 5 h L. T. a secondary depression was detected 9 km north of that cape. This depression was said to have become apparent so suddenly that it was properly interpreted as having been born under the orographic influence on the southern side of a mountain range about 1000 m high when the primary one had been marching along the valley on the northern side.⁽⁹⁾ These twins of cyclones went along side by side while on land, but once one of them was out on the sea, the other seemed to have disappeared entirely from the weather map. After crossing Japan proper at its western part from south to north, the same typhoon was seen on the Sea of Japan, whence it cut across the mainland again from west to east at its northeastern extremity.

This traverse from the Sea of Japan to the Pacific Ocean over the mountain chains in Tohoku District caused the typhoon to split into 2 parts. However, when on the sea again, they got united, forming a large depression. Gradual shifting of isobaric configurations during this period can be clearly seen in Figs. 9, 10, 11, 12, 13, 14 and 15, and the validity of the theoretical conclusions obtained so far is pointed out.

Another example may be cited from weather maps when a typhoon landed at Makurazaki at the southern end of Kyushu Island on Sept. 17, 1945. As there were very few

Fig. 8. Synoptic weather map, Northern Hemisphere, 500 mb chart, 0300 G. M. T. Nov. 6, 1949.

Fig. 9. Weather map, 1400 L. T., Sept. 21, 1934.

Fig. 10. Weather map, 1500 L. T., Sept. 21, 1934.

Fig. 11. Weather map,
1600 L. T., Sept. 21, 1934.

Fig. 12. Weather map,
1700 L. T., Sept. 21, 1934.

Fig. 13. Weather map,
1800 L. T., Sept. 21, 1934.

Fig. 14. Weather map,
1900 L. T., Sept. 21, 1934.

Fig. 15. Weather map,
2000 L. T., Sept. 21, 1934.

Figs. 9~15 are reproduced from the
Memoirs of the Central Meteorological
Observatory 9, 42 (1935).

meteorological materials to know the detailed structure of the typhoon at sea, we were not certain, whether the typhoon had already been upon the sea with two centers or not. However, a weather map (Fig. 16) at the time when the typhoon landed ashore showed one hardly visible isobaric bulge on the southeast margin of the typhoon. Ultimately the bulge swelled out to a large cyclone as the typhoon proceeded along the backbone mountain chain of the island, accompanying the primary cyclone on the west side. When they reached the north end of the island, one of the cyclones was found disappeared from the weather maps (see Figs. 16, 17, 18, 19 and 20).

Figs. 21 and 22 are respectively the 850-mb and 700-mb charts on that day at 18h. They show the separation of the typhoon through the mountain range much more

Fig. 16. Weather map, 1600 L. T., Sept. 17, 1945.

Fig. 17. Weather map, 1615 L. T., Sept. 17, 1945.

Fig. 18. Weather map, 1700 L. T., Sept. 17, 1945.

Fig. 19. Weather map, 1800 L. T., Sept. 17, 1945.

Fig. 20. Weather map, 1900 L. T., Sept. 17, 1945.

Fig. 21. Weather map, 850-mb chart, 1800 L. T., Sept. 17, 1945.

Fig. 22. Weather map, 700-mb chart, 1800 L. T., Sept. 17, 1945.

Figs. 16~22 are reproduced from the Memoirs of the Central Meteorological Observatory 33, (1949).

distinctly than ordinary weather maps.*

§ 6. Course of a typhoon

The topographic influence may have something to do with forecasting the path of a typhoon, provided that the atmosphere then prevailing is known previously as to its stability. For instance, the typhoon is likely to choose a path round the mountain range if the atmosphere is stable, but to cross over it if unstable. Of course it is true that the typhoon usually keeps away from mountains and shifts towards straits or valleys, as a necessary result of the present theories. However, even though the orographic influence is outstandingly predominant and bends the landwards steering typhoon towards the straits, either the center of the cyclone would shift not beyond the shorelines of the straits, or a secondary cyclone would newly appear on land and go parallel with the primary cyclone which is maintaining the original course through the straits.

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* Some Meteorologists infer from a W-shaped barographic record taken at a station on an island that the typhoon has been double-centered on the sea. However, others take it for a proof that it has taken a zigzag course instead of a straight one.