Classification of Atmospheric Circulation
by Zonal Indices

Takayoshi AOYAMA

INTRODUCTION

The classification of natural seasons is an important problem in the field of modern climatology although the study regarding natural seasons have not yet been fully developed.

The classification of natural seasons has been done by using weather patterns at sea level or aloft, or by variations of climatic elements. Using singularities at a single place, Takahashi (1942) and Sakata (1950) proposed natural seasons in Japan. Lamb (1950) and Yoshino (1967) set up natural seasons by weather patterns for the British Isles and Japan respectively. Yazawa (1949) investigated the regional differences in the beginning and ending of six natural seasons. In his classification of the natural seasons, Maejima (1967) clarified the weather climatological features and regional differences. Moreover, the relationship between natural seasons and weather singularities were examined.

Maejima (1968) pointed out the importance of the study regarding natural seasons, especially in a broad region. An investigation of the natural seasons in a broad region should, in the author's opinion, be based upon through knowledge of the features of the seasonal march of atmospheric circulation.

In this article, the author investigated the seasonal march of the pressure pattern using the zonal index for the high latitudes of the northern hemisphere.

ZONAL INDEX FOR THE NORTHERN HEMISPHERE

Using the average 5-day values presented by the Japan Meteorological Agency (1967), the author obtained the zonal index between 60°N and 80°N, for the reason that the higher latitudes exhibit more marked seasonal differences.

As the first step, the author calculated the 5-day mean zonal index around the Northern Hemisphere. The seasonal variation of the zonal index shows four maxima and minima. The primary maximum appears at the 52nd pentade (September, 13-17). The secondary maximum occurs at the 31st (May, 31 - June, 4) and the 16th pentade (March, 17-21). The smallest peak appears at the 2nd pentade (January, 6-10). The minima appear at the 39th (July, 10-14), the 8th (February, 10-14), the 70th (December, 12-16) and the 23rd pentades (April, 21-25).

Considering that the seasonal march from winter to summer is more conspicuous than the reverse change, the annual variation of the zonal index is interesting.

A year can thus be divided into eight periods in terms of the zonal index. The zonal index tends to increase in four periods, that is, the 8th - the 16th, the 23rd - the 31st, the 39th - the 52nd pentades, and the 71st - the 2nd pentades. The remaining four
periods (the 2nd - the 8th, the 16th - the 23rd, the 31st - the 39th and the 52nd - the 70th pentades) are the periods when the zonal index decreases. These two types of circulation may differ from each other.

REGIONAL DIVISION BY ZONAL INDEX

The isopleth diagrams were made which shows the seasonal variation of the altitude difference for 500-mb surface between 60°N and 80°N and between 30°N and 50°N at every 10 degrees of longitude.

The Eastern Hemisphere exhibits a marked seasonal variation of the zonal index whereas the Western Hemisphere shows only vague seasonal variations. It is clear that the trough on the east coast of Asia migrates over a wide range of longitude from 130°E to 170°W, while the trough on the east coast of North America is rather confined to the longitudes between 80°W and 50°W at 70°N. According to Kato (1968), the trough at 50°N migrates between 120°E and 180°E longitude on the east coast of Asia and between 40°W and 60°W in North America-Atlantic. Thus, the seasonal variation of pressure field is larger in the Eastern Hemisphere than in the Western Hemisphere.

Using the pattern of this isopleth diagram, the author divided the latitude circles from 60°N to 80°N and from 30°N to 50°N into five sectors, i.e. 30°E - 120°E, 130°E - 160°W, 150°W - 100°W, 90°W - 30°W and 20°W - 20°E (Fig. 1). In the sector from

Fig. 1 The latitudinal zone for the calculation of zonal index and the sectors for the partial indices.
Fig. 2  The annual marches of the partial zonal indices and the classification of atmospheric circulation. Shaded areas represent transitional periods.
150°W to 100°W there is a maximum axis of zonal index in the higher latitudes and minimum axis in the lower latitudes. Other preferred sector for the maximum axis in the higher latitudes and the minimum axis in the lower latitudes is found from 20°W to 20°E. Both the east coasts of Asia and of North America (i.e. 130°E - 160°W and 90°W - 30°W) are characterised by a minimum axis of zonal index in the higher latitudes and maximum axis in the lower latitudes. The sector from 30°E to 120°E shows the particular seasonal variation of the pattern of the zonal index. In the higher latitudes the maximum axis in this sector are interrupted in the latter half of April and mid-July. The higher latitudes show the maximum axis from January to the first half of April and the minimum axis from the latter half of July to the first half of August.

CLASSIFICATION OF ATMOSPHERIC CIRCULATION BY PARTIAL ZONAL INDICES

The author calculated partial zonal index in each sector of Fig. 1. Fig. 2 shows the result.

The partial zonal indices in the four sectors show the four maxima and minima, like the zonal index for the whole hemisphere. It is noted that the annual march of the partial zonal indices in the sectors of 20°W - 20°E and 90°W - 30°W differ from the seasonal variation of the zonal index in the Northern Hemisphere. The sector from 90°W to 30°W lacks the maximum in January and has a broad peak from April to July. The seasonal variation of the zonal index in the sector from 20°W to 20°E shows a minimum in summer and an autumnal maximum at the 60th pentade (October 23-27).

The pattern of the pressure field at the 500-mb level in the Northern Hemisphere can be given by a combination of partial zonal indices in the five sectors. The difference among the five partial zonal indices becomes greatest in winter, because the zonal indices in the sectors from 90°W to 30°W and from 130°E to 160°W decrease from October to March. On the contrary, the partial zonal indices show little regional differences in summer. These features of partial zonal indices are largely responsible for the pattern of the pressure field.

In this paper the maximum and minimum points of the partial zonal indices are used for the classification of atmospheric circulation. The author classified the circulation into three great types: The first is the circulation that the partial zonal indices increase steadily in all sectors. The second is that all the partial zonal indices decrease. The third is the transitional circulation types and the trends of partial zonal indices differing from each other. Judging from Fig. 2, fourteen periods of circulation can be determined. The periods from the 11th to the 14th, from the 25th to the 28th, and from the 40th to the 49th pentades are of the first case, that all the zonal indices increase.

### Table 1

The order of occurrence of the maxima or minima for partial indices during the transitional periods.

<table>
<thead>
<tr>
<th>sector</th>
<th>6-10</th>
<th>14-16</th>
<th>22-25</th>
<th>28-33</th>
<th>38-40</th>
<th>49-59</th>
<th>70-74</th>
</tr>
</thead>
<tbody>
<tr>
<td>20°W - 20°E</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>30°E-120°E</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>130°E-160°W</td>
<td>1</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>2</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>150°W-100°W</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>90°W - 30°W</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>4</td>
<td>5*</td>
</tr>
</tbody>
</table>

* The minimum does not occur in this period.
The opposite case is true from the 4th to the 6th, from the 16th to the 22nd, from the 33rd to the 38th and from 60th to the 69th pentades. Other periods belong to the third case which has a transitional character. The shortest transitions appear in mid-March and July, and the longest transition appear from September to mid-October.

Table 1 shows the order of occurrence of the maxima or minima for partial indices during the transitional periods. From a hemispheric point of view, there are two ways in which the occurrence of maximum or minimum propagates. In the first case, the maxima or minima occurring in a given sector appear in the sectors which are situated symmetrically to the former one (e.g. the 14th - the 16th, the 21st - the 25th, the 68th - the 71st pentade). The other case is that the maxima or minima of zonal indices spread gradually from one sector to a neighbouring sector.

CONCLUSION

In this paper, the mean values of zonal index for each pentade are calculated. The author divided the zone between 60°N to 80°N and between 30°N to 50°N into five sectors by the pattern of seasonal variation of zonal index. By using the combination of partial zonal indices for five sectors, a year is classified into fourteen periods. These new results may contribute to the classification of the atmospheric circulation and natural seasons.

The author wishes to treat the seasonal variation of pressure patterns at sea level from the stand point of dynamic climatology.

ACKNOWLEDGEMENTS

The author wishes to express his appreciation to Prof. T. Yazawa, Dr. Maejima and Dr. Nakamura of the Tokyo Metropolitan University for the advice and suggestions.

REFERENCES CITED


