FREQUENCIES OF AIR MASSES IN THE NORTHERN PART OF JAPAN FROM THE BAI-U SEASON TO SUMMER

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Abstract On the bases of cluster analysis air masses in the northern part of Japan from the Bai-u season to summer were classified. Also, seasonal and annual variations in air mass frequencies were examined. The polar air mass did not dominate in midsummer and the tropical air mass had an effect on the summer temperature fluctuation.

Key words: northern part of Japan, summer, polar air mass, low temperature, cluster analysis

1. Introduction

The summer temperature in the northern part of Japan, especially in the Tohoku District, tends to fluctuate in that it sometimes becomes extremely low. Ninomiya and Mizuno (1985) stated that such low summer temperatures were caused by the maritime polar air mass mingling with the *'Yamase'* wind (cold northeasterly wind). This polar air mass was also called the Okhotsk air mass (Kudo, 1984). On the other hand, Kanno *et al.* (1989) suggested, on the bases of the local-climate observations, that the low temperatures in the northern part of Japan from the Bai-u season (rainy season from May to July in Japan) to summer were caused by several air masses. They also noted that the polar air mass in the Bai-u season did not appear in midsummer.

The most appropriate means of investigating the conditions of air mass appearance in warm seasons is by the use of climatological data. Consequently, in this paper, seasonal and annual appearance of air masses in the northern part of Japan were examined by applying the cluster analysis. An attempt was also made to find out the causes of the low summer temperatures. Since the cluster analysis was thought to be effective to discriminate various kinds of meteorological elements (*e.g.* Tagami, 1982), it was used in this study for classifying the distribution of equivalent potential temperatures.

The data used for this study were equivalent potential temperatures calculated from the temperature, dew-point temperature and surface pressure at 09:00 JST from May to August at 34 meteorological stations shown in Fig. 1. The data was obtained, from 1976 to 1985, a period of ten years.

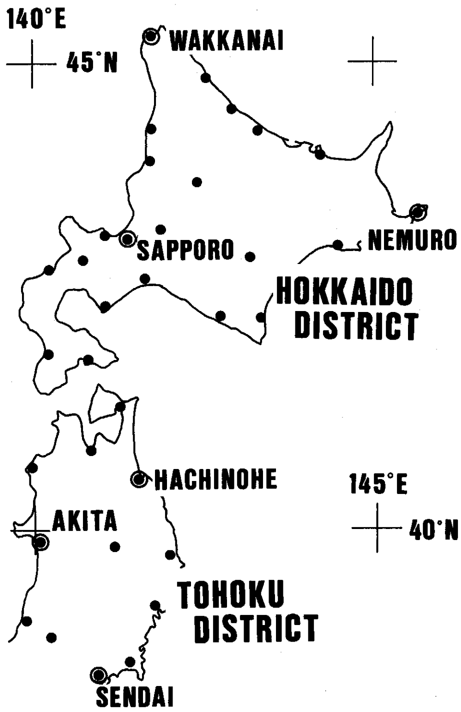

Fig. 1 Locations of the meteorological stations

2. Distinction of Air Mass from the Bai-u Season to Summer

The daily frequency of equivalent potential temperatures at six representative meteorological stations (Wakkanai, Nemuro, Sapporo, Hachinohe, Akita and Sendai) were investigated in order to recognize the air mass in the northern part of Japan from the Bai-u season to summer. In all stations some peaks in the frequency of equivalent potential temperatures were exhibited (Fig. 2). According to the partial collective method every peak corresponded to an air mass (Corcoran, 1987).

The first peak was observed near 300K at Wakkanai on the coast of the Sea of Okhotsk ; at Nemuro, Hachinohe, and at Sendai on the Pacific coast. This value agreed with the polar air mass research of Kanno (1988); therefore, this 300K air mass was designated as the polar air mass. The other peaks, whose values were more than 339K, existed at Akita and Sendai.

Concerning the air mass analysis on the 850 mb surface, the tropical air mass was thought to be the equivalent potential temperatures which exceeded 330K. The modified equatorial air mass was thought to correspond to temperatures which exceeded 340K (Saito, 1966). Ogawa (1987) indicated that the value of the tropical air mass was more than 336K. For this reason, the tropical air mass, in this study, was defined as the equivalent potential temperatures exceeding 339K.

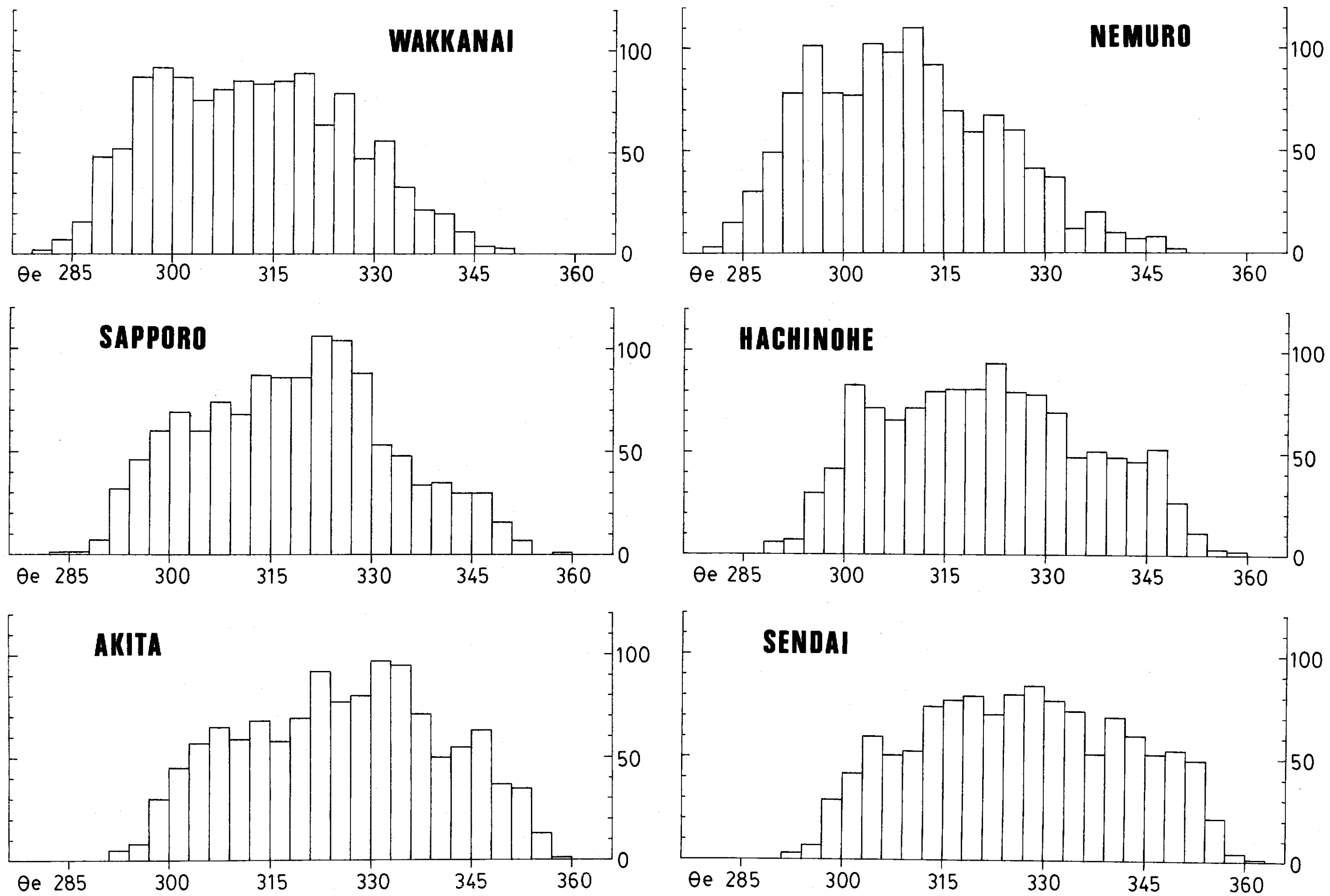

Fig. 2 Frequencies of equivalent potential temperature

On the other hand, a definite peak was seen near 309K at Nemuro and a peak at 321-327K existed at Sapporo.

3. The Cluster Analysis for the Equivalent Potential Temperature Distribution

An attempt was made to classify the distribution of equivalent potential temperatures in the northern part of Japan. Due to the time span and amount of data, it was difficult to apply the cluster analysis *i.e.* 123 samples and 34 variables in a single year. Therefore, first, the cluster analysis was applied for five years (1981 to 1985) and then the discriminant analysis was executed for the remaining five years (1976 to 1980).

The cluster analysis dendrogram is shown in Fig. 3. The clusters were divided at the distance index of less than 6×10^5 because it was at this point that the number of clusters increased. As a result, seven equivalent potential temperature distribution patterns were

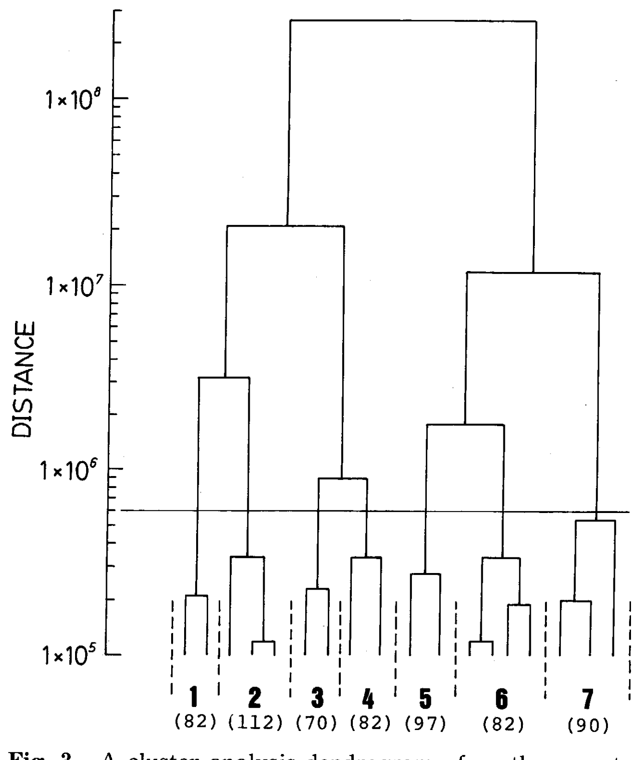

Fig. 3 A cluster analysis dendrogram of northern part of Japan's equivalent potential temperature distribution
The bold numbers indicate the equivalent potential temperature distribution patterns. The numbers in the parentheses indicate data numbers.

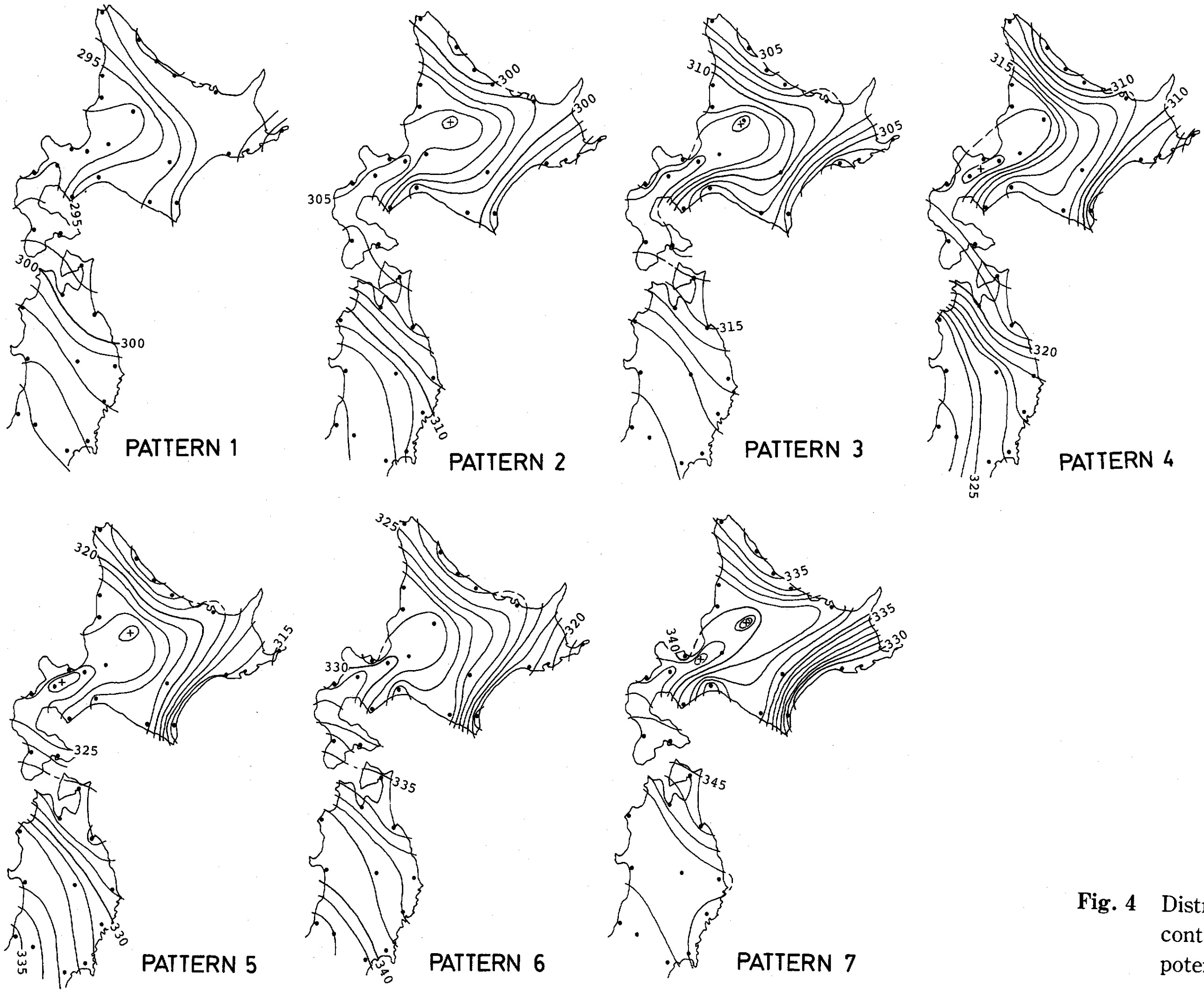

Fig. 4 Distribution patterns containing equivalent potential temperatures

derived.

The mean equivalent potential temperature in each distribution pattern based on five years of data (1981 to 1985) is shown in Fig. 4. Large gradient zones of equivalent potential temperatures could be seen in the northeastern part of the Tohoku District, the mountain ranges and the coastal areas of the Pacific and the Sea of Okhotsk in Hokkaido. The air mass property was different on the both sides of these areas.

The equivalent potential temperature distribution pattern 1 indicated ca. 300K with small gradient, so this distribution pattern was recognized as the case of the dominance of polar air mass on the entire area. Distribution patterns 2, 4 and 5 had large gradient of equivalent potential temperatures in the northeastern part of the Tohoku District. These distribution patterns were similar to that of temperature distribution patterns appearing when the *'Yamase'* Wind blows. Because of the fact that the equivalent potential temperature for distribution pattern 2 was *ca.* 300K in Hokkaido, it was

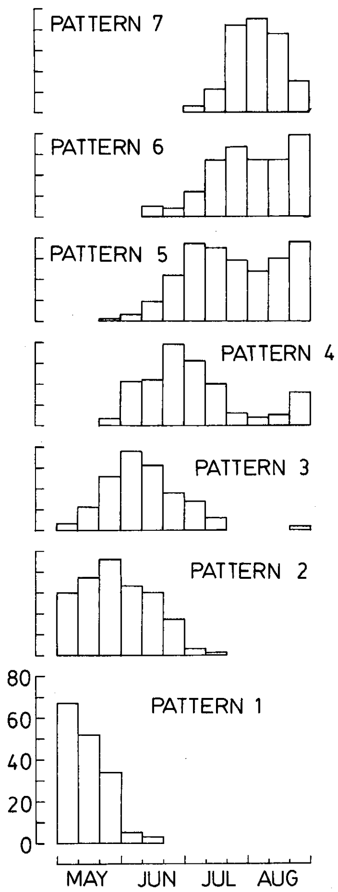

Fig. 5 Frequencies of ten day equivalent potential temperature distribution patterns

assumed that the polar air mass reached Hokkaido in this distribution pattern.

From the location of the isolines of *ca.* 340K, the tropical air mass prevailed in the Tohoku District in the equivalent potential temperature distribution pattern 6 and extended to the Japan Sea side in Hokkaido in distribution pattern 7. From these facts, distribution patterns 1 and 2 were examples of the dominate polar air mass; and distribution patterns 6 and 7 were those of the intrusion of the tropical air mass.

Figure 5 shows the frequency of every equivalent potential temperature distribution pattern for ten days from May to August during the years 1976-1985. The peaks of frequency of each distribution pattern shifted in accordance with the seasonal advancement. Distribution pattern 1, which had its frequency peak at the first ten days of May, was identified as the late spring type. Distribution pattern 2, which possessed its peak at the last ten days of May, was regarded as the before-and-early Bai-u type. Because distribution patterns 1 and 2 did not appear in the midsummer, it was realized that the polar air mass did not exist in this season. Distribution pattern 3 with its peak at the first ten days and the middle ten days of June was considered to be the early Bai-u type, and distribution pattern 4 with its peak in the last ten days of June and the first ten days of July was regarded as the late Bai-u type. Distribution pattern 5 frequently appeared in the last ten days of June, July and August. This period of appearance was the longest of all the distribution patterns. This distribution pattern was identified as the late Bai-u to midsummer type. Distribution patterns 6 and 7 were of the midsummer types. Distribution pattern 7 was most frequent from the last ten days of July to the middle ten days of August when the annual temperature was highest.

4. The Frequencies of Equivalent Potential Temperature Distribution Patterns in Each Year

The annual frequencies of equivalent potential temperature distribution patterns were investigated and the conditions of dominant air masses in warm and cold summers were considered.

Figure 6 shows the deviation of frequency in each distribution pattern from 10-year means. In the decade from 1976 to 1985, the years 1976 and 1980 had very cool summers, the years 1978, 1984 and 1985 had very hot summers. In cool summers, distribution pattern 5 very frequently appeared, while distribution pattern 7 hardly existed. On the other hand, in hot summers, the frequency of distribution pattern 7 was high and that of distribution pattern 5 was low.

The frequency of each ten day distribution pattern in a very cool summer year (1980) and in a very hot summer year (1978) can be seen in Fig. 7. During a cool summer year, distribution patterns 4 and 5 appeared in the last ten days of July and August, and appearing most was distribution pattern 5. On the other hand, during a hot summer year, distribution pattern 5 frequently existed in the last ten days of June and the last ten days of August ; however distribution patterns 6 and 7 occurred from July to the last ten days of August. Distribution patterns 1 and 2, which indicated the dominance of the polar air mass, appeared before the first ten days of June and did not exist in midsummer.

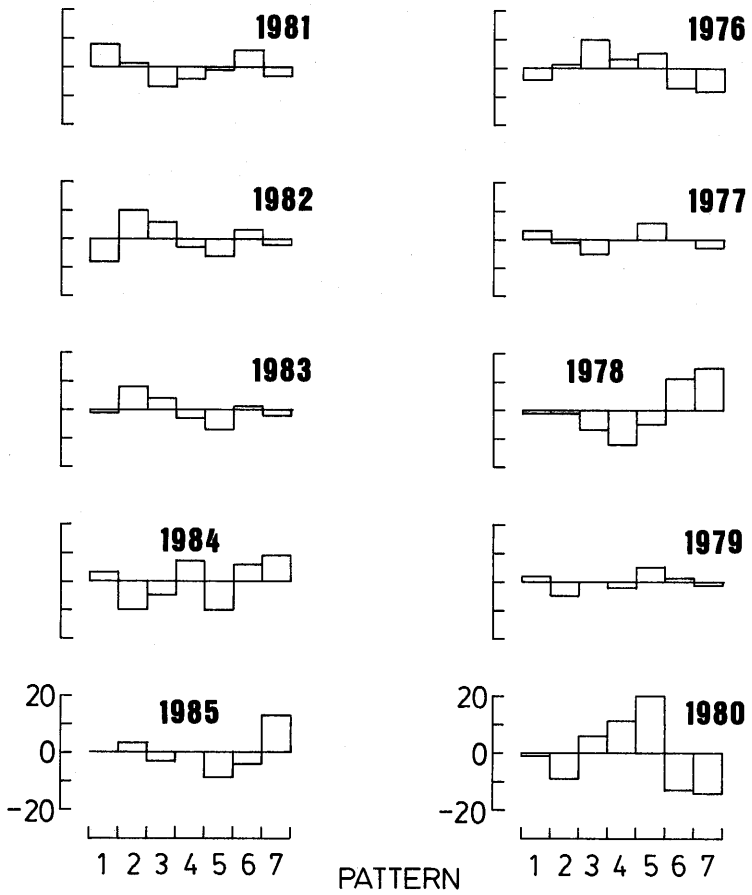

Fig. 6 Equivalent potential temperature distribution patterns containing mean frequency deviations

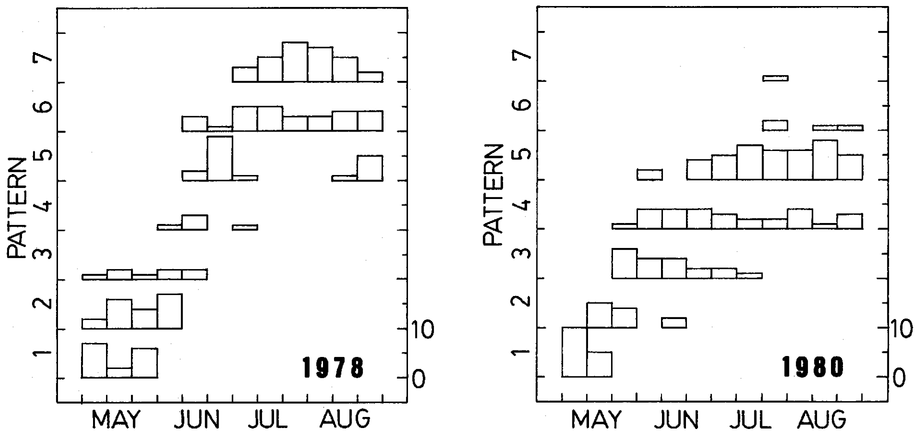

Fig. 7 Frequencies of ten day equivalent potential temperature distribution patterns in 1978 and 1980

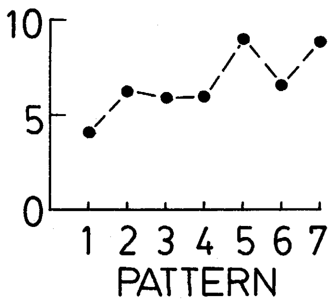

Fig. 8 Standard deviation of frequencies of equivalent potential temperature distribution patterns

Finally, the standard deviation of the annual frequency of each equivalent potential temperature distribution pattern can be seen in Fig. 8. The year-to-year variation in frequency for distribution pattern 1 was small and those of distribution patterns 5 and 7 were large. Thus, the year- to-year variations in appearance of the polar air mass was small and that of the tropical air mass was large.

From these results, the polar air mass did not dominate in midsummer and the fluctuation of summer temperature was probably controlled by the appearance of the tropical air mass in the northern part of Japan. The maritime polar air mass which was investigated by Ninomiya and Mizuno (1985) was thought to be the warmer air mass than the polar air mass appearing before summer.

5. Conclusion

By examining the frequency of equivalent potential temperatures from May to August for the years 1976-1985, several peaks could be recognized, and both polar and tropical air masses were identified. As the result of the cluster analysis for the distribution of equivalent potential temperature, seven distribution patterns were obtained. Distribution patterns 1 and 2 showed the dominance of the polar air mass, while distribution patterns 6 and 7 explained the intrusion of tropical air mass. Distribution patterns 4 and 5 frequently appeared during the cool summer, and distribution patterns 6 and 7 frequently existed during the hot summer. Both in cool and hot summer years, neither of distribution patterns 1 and 2 appeared after the middle ten days of June. The standard deviations of frequency for distribution patterns 5 and 7 indicated that the year-to- year variations in the tropical air mass were large.

From these results the following information can be concluded. The polar air mass did not dominate in midsummer and the summer temperature fluctuations were effected by the tropical air mass in the northern part of Japan.

Acknowledgment

The author wishes to express his sincere thanks to Professor Ikuo Maejima, Assistant Professor Takehiko Mikami and Mr. Shuichi Oka, Department of Geography, Tokyo

Metropolitan University, for their hearty guidance throughout this study and for reading the manuscript. He is also grateful for the helpful suggestions from the staff members, the research workers and the graduate students, and the seminar members of climatology, Tokyo Metropolitan University. The outline of this study was reported at an annual meeting of the Meteorological Society of Japan in the spring of 1988.

References Cited

Corcoran, W. T. (1987): Airmass climatology. *The Encyclopedia of Climatotogy.* Van Nostrand Reinhold Company, 986p.

Kanno, H. (1988): Polar air mass in the Bai-u season over East Asia. *Geographical Review of Japan,* **61**, 615-631.**

Kanno, H., Oka, S. and Maejima, I. (1989): Low air temperature distributions in summer in North Honshu : Cases by observations of local climate at the Shimokita hills. *Annals of the Tohoku Geographical Association,* **41**, 15-24.**

Kudo, T. (1984): Characteristics of Okhotsk airmass during the typical Yamase period. *Tenki,* **31**, 411-419.*

Ninomiya, K. and Mizuno, H. (1985): Anomalous cold spell in summer over northeastern Japan caused by northeasterly wind from polar maritime airmass. Part 2. Structure of the northeasterly flow from polar maritime airmass. *Journal of the Meteorological Society of Japan,* **63**, 859-871.

Ogawa, H. (1987): *Tasaina nihon no kikou (The variegated climate of Japan).* in Matsui, K. and Ogawa, H. (eds.) *"Nihon no fudo (Japan and its nature)",* Heibon-sha, 7-20.*

Saito, N. (1966): A preliminary study of the summer monsoon of southern and eastern Asia. *Journal of the Meteorological Society of Japan.* **44**, 44-59.

Tagami, Y. (1982): Macro-scale airflow patterns and distributions of climatic elements in the Japanese Islands. *Geographical Review of Japan,* **55**, 799-813.**

(*: in Japanese, **: in Japanese with English abstract)