Relationship between Directions of Wind aloft in Kanto District, Cental Japan, and Pressure Fields aloft over East Asia

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INTRODUCTION

An attempt to relate weather conditions in a region or at a point to the regional airflow is one of the synoptic climatological analyses. Jacobs (1947) indicated that regional airflow can be specified by direction and speed of the gradient wind, isobaric curvature and vertical air mass structure. He classified regional airflow in Hokkaido, Japan, based on eight directions of gradient wind estimated from the surface chart, together with four pressure patterns – ridge or high, trough, low center and col. From lack of data aloft, early investigators, including Jacobs, had to use directions of gradient wind estimated from the surface chart as criteria of classifications, as Maejima (1954) stated. And when data aloft became available, directions of wind aloft were used as criteria.

However, whether at the surface or aloft, gradient wind directions can not satisfactorily specify regional airflow. So in many investigations, gradient wind directions in combination with other indecies were used as criteria. For example, Lamb (1950, 1964) classified eight directional types, the direction referring to the general airflow over the British Isles and to the overall movement of synoptic systems from each cardinal point (each subdivided into anticyclonic, cyclonic, hybrid and unspecified categories) and three non-directional types, and Schüepp (1959) made a Witterungslagen system, which was based on the principles set out by Lauscher (1954, 1958), with respect to the low-level airflow direction and the related upper-level circulation pattern. Schüepp modified Lauscher's scheme principally with respect to the curvature of the airflow and by the inclusion of explicit reference to the vertical motion.

Regional airflow can be specified to further extent by gradient wind directions together with pressure patterns in and around the region. However, here arises a problem on identification of pressure patterns. Namely most of all identification of pressure patterns were in nature subjective (Maejima, 1954). This subjectivity may be more excessive in identifying daily pressure patterns at the surface, which may come mainly from many depressions and anticyclones moving with various speed and intensity. Therefore, daily pressure patterns in the middle troposphere which cause few depressions and anticyclones could be identified easier than those at the surface. However, most of all identification of daily pressure patterns in the middle troposphere was so far also subjective.

It is known that throughout winter season daily pressure patterns in the middle troposphere over Japan and East Asia are characterized by the remarkable trough (Kurashima, 1972).

So, the author made it clear that daily pressure aloft fields within each direction of wind aloft could be objectively classified, by investigating statistically both daily forms of the trough over Japan and East Asia in winter season, from which outlines of pressure aloft fields over this area should be given, and daily directions of wind aloft at Tateno station, which could represent those in Kanto District.

DATA AND METHOD

Daily directions of wind aloft and weather charts used in this investigation were as follows; daily directions of wind aloft: 700-mb pressure level wind directions observed at 12GMT at Tateno station (36 03N, 140 08E), daily weather charts: daily 700-mb pressure level weather charts at 12GMT which cover fully middle latitudes from 100E to 170E.

The data processing was conducted for three winters, from December to Febuary of 1961–1962, 1962–1963, and 1963–1964 (271 days).

Table 1 Daily occurrence frequency of 700-mb height contour lines at Tateno station

Contour (gpm)	Days
3120	4
3060	27
3000	80
2940	68
2880	54
2820	30
2760	8
Total	271

In this investigation simple procedures were adopted. On daily 700-mb weather charts, contour lines (60m interval) are almost parallel each other in middle latitudes, and specific contour lines appear over this area throughout winter season. So the form of the trough can be approximately represented by that of one or several contour lines. Table. 1 shows daily occurrence frequency of 700-mb height contour lines of the three winters at Tateno station. From this table, the contour line of 3000 gpm was adopted as a specified one.

The forms of the trough, which appeared insistently on daily 700-mb weather charts, were evaluated by the following three procedures, determining (1) longitude of southernmost location of the specified contour line between 100E and 170E, (2) latitude of the specified contour line at a specified meridian, and (3) latitudinal difference between two longitudes of the specified contour line. By the first procedure the longitudinal location of the trough on the specified contour line is roughly indicated. The second is referred to the meridional shift of the specified contour line along a specified longitude and as it can be expected that height anomaly at 700-mb pressure level is generally associated with anomaly of the surface temperature (Asakura, 1955), this also indicates the features of surface temperature along a specified longitude. The last roughly indicates the inclination of the specified contour line, which represents the degree of deepness of the trough.

In winter season pressure system generally moves from west to east over Japan and East Asia. So the western or windward portion of the region are especially important. Therefore, 100E and 140E were adopted as two specified meridians in this investigation.

The forms of the trough over this area are generally U-shaped (Fig. 1). Therefore, the location of the trough can not be determined distinctly, especially in the vicinity of 140E.

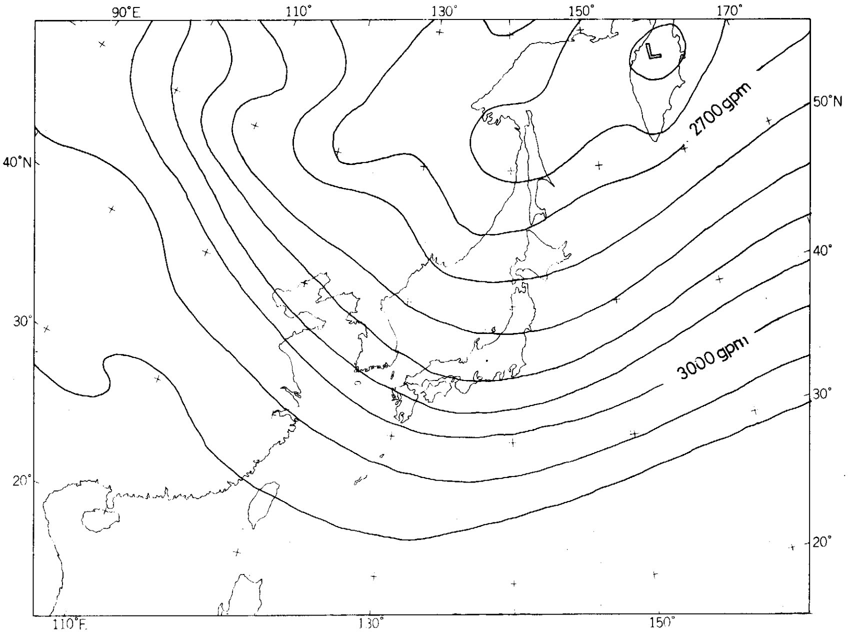


Fig. 1 700-mb synoptic weather chart (1962, Feb. 19)

So regarding the longitudinal location of the trough, three groups were somewhat arbitrarily set, namely (1) troughs west of 130E, (2) troughs between 130E and 150E, and (3) troughs east of 150E, and these three groups are called in this paper the first group, the second group, and the third group, respectively.

RESULTS

Daily occurrence frequency of the directions of wind aloft at Tateno station

Daily occurrence frequency of the directions of the wind aloft observed at Tateno station is arranged in Tab. 2. This table shows that west wind is the most frequent in each winter and reaches the frequency of 33 per cent on average, and three westerly winds, namely WSW, W, and WNW winds occur about 75 per cent on average. When NW wind is included, the occurrence frequency of these four westerly winds amounts to about 85 per cent on average. In this paper these four westerly winds were investigated.

Latitudinal locations at 100E and 140E of 3000 gmp contour line

Latitudinal locations at 100E and 140E of 3000 gpm contour line, which were evaluated on daily 700-mb weather charts, are plotted on co-ordinate plane and examined their distributions along each axis of co-ordinates (ordinate, latitudes at 100E; abscissa, at 140E)

There are few remarkable differences among its latitudinal locations in the four wind directions. On the other hand, in the three groups with disregard to the four wind directions the situations are somewhat different. That is, its locations at 100E in the third group are lower and those at 140E in the second group are on the whole lower as compared with those in the other two groups. In the three groups in each wind direction, there are also some

Table 2 Daily occurrence frequency (%) of 700-mb wind directions observed at Tateno station

Wind Dir.	1961–62	1962–63	1963–64	Mean
NNE		2		0.7
N		2		0.7
NNW	6	4	3	4
NW	12	9	10	10
WNW	20	27	19	22
W	41	28	30	33
WSW	16	19	25	20
SW	.2	6	9	6
SSW		3	2	2
S	1			0.3
SSE	1		2	1
No Wind	1			0.3

remarkable differences in latitude. Both latitudes at 100E and 140E are shown in Figs. 2, 3, 4, and 5. Oblique lines in these figures are isarithms, which indicate the same inclination of the contour line.

In WSW wind, the latitudes at 100E in the first group are higher and those at 140E in the second group are lower as compared with those in the other two groups (Fig. 2). In W wind, the latitudes at 100E in the third group and those at 140E in the second group are somewhat lower as compared with those in the other two groups (Fig. 3). In WNW wind, the latitudes at 140E in the third group are on the whole higher as compared with those in the other two groups (Fig. 4). In NW wind, the latitudes at 100E are lower and those at 140E were higher in the third group than in the second group. The first group was here eliminated because of few samples (Fig. 5).

Inclination of the contour line between 100E and 140E

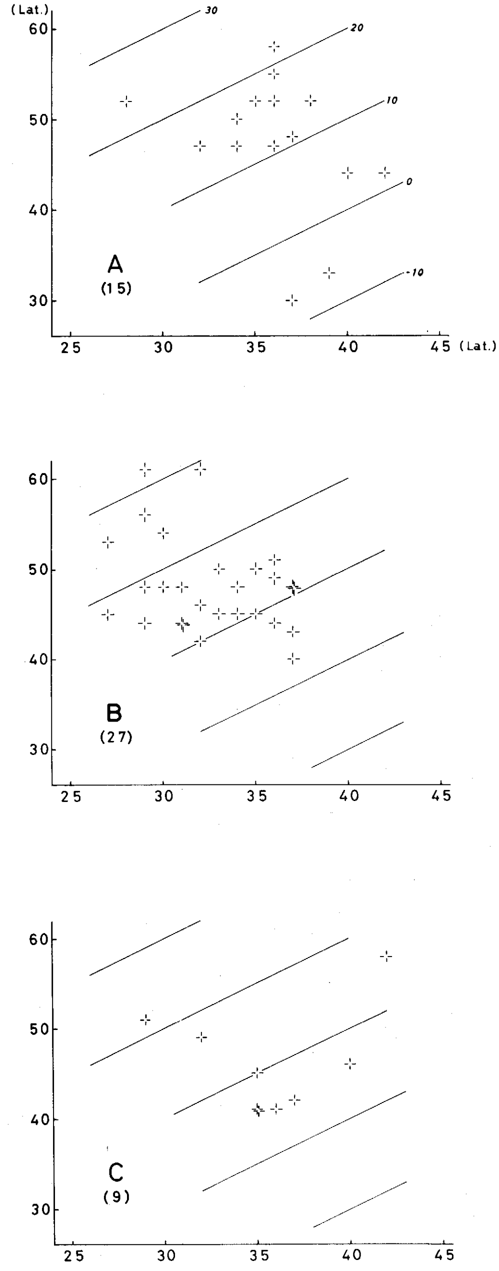
In this section, inclination in the three groups in each wind direction is discussed.

Inclination of the contour line between 100E and 140E are also shown in Figs. 2, 3, 4, and 5. Distributions of dots in the figures were examined.

In WSW wind, the inclination in the first and the second groups is steeper than in the third group (Fig. 2). In W wind, there is a marked contrast in inclination between the second and the third groups (Fig. 3). The inclination in the second group is on the whole steeper than in the third group. In WNW wind, the inclination in the first and the second groups is steeper than in the third group (Fig. 4). In NW wind, the inclination in the second group is steeper than in the third group (Fig. 5).

From these facts, the three groups defined in this investigation were found to be useful for the pressure pattern classification.

However, these analyses as to the latitude and the inclination of the contour line were subjective. So objective analyses were carried out with regard to the latitude and the inclination according to the groups, the directional winds, and the groups in the directional winds, respectively.



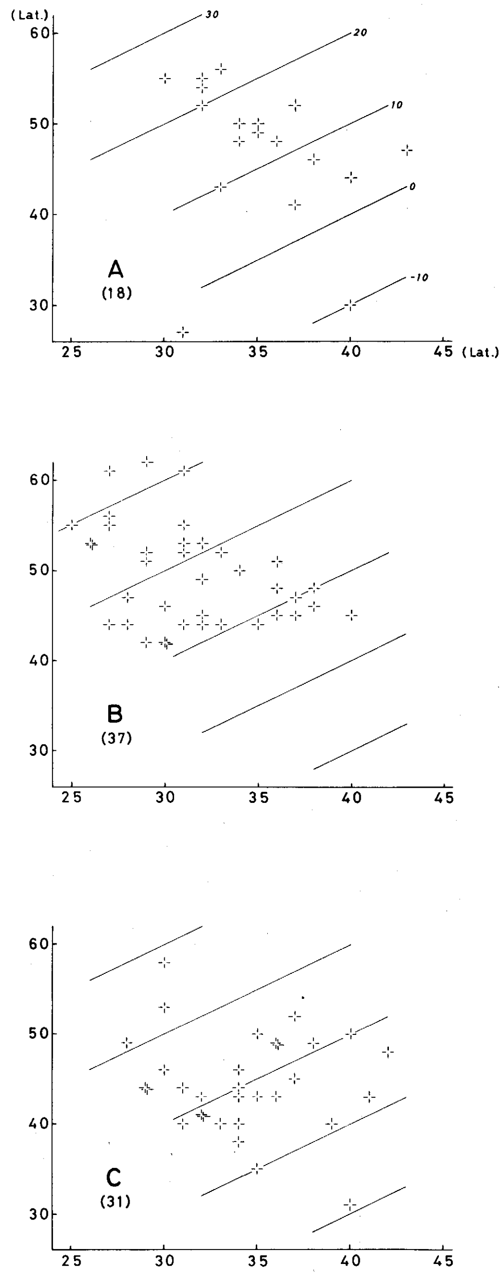


Fig. 2 Latitudes at 100E and 140E of the contour lines in WSW winds.

Fig. 3 Same as Fig. 2, except in W winds.

A: the first group, B: the second gr., C: the third gr.
Ordinate: latitude along 100E, abscissa: latitude along 140E.
Numbers in brackets are those of samples.

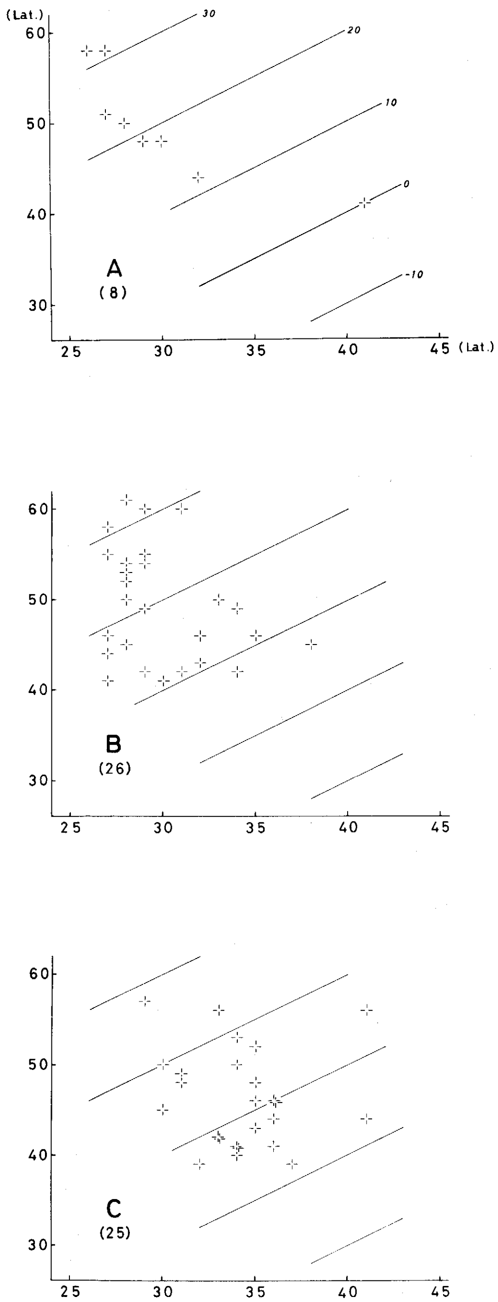


Fig. 4 Same as Fig. 2, except in WNW winds.

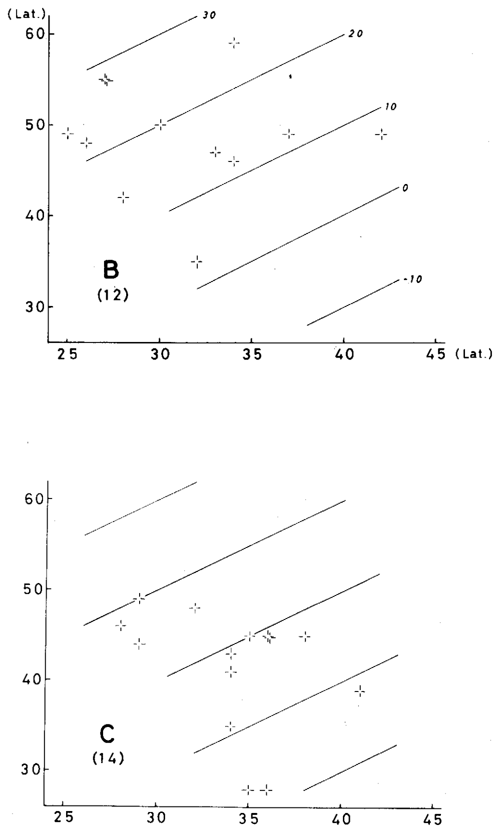


Fig. 5 Same as Fig. 2, except in NW winds.

Table 3 Means of the latitudinal locations at 100E and 140E of the contour, the inclination, and the thickness at Tateno station

	LATITUDE (deg) 100E	140E	INCLINATION (deg)	THICKNESS (gpm)
WSW	47.5	34.1	13.4	2840
W	47.1	33.2	13.9	2825
WNW	48.1	31.7	16.4	2804
NW	44.8	32.8	12.0	2810
1st gr.	47.6	34.4	13.2	2846
2nd gr.	48.9	31.3	17.6	2811
3rd gr.	44.7	34.4	10.3	2808
WSW 1	47.4	36.0	11.4	2869
WSW 2	48.1	32.6	15.6	2829
WSW 3	46.0	35.7	10.3	2836
W 1	46.9	35.1	11.9	2849
W 2	49.4	31.4	17.9	2810
W 3	44.5	34.3	10.2	2829
WNW 1	49.8	30.0	19.8	2815
WNW 2	49.3	29.9	19.4	2795
WNW 3	46.3	34.2	12.1	2810
NW 2	48.7	31.3	17.4	2813
NW 3	41.5	34.1	7.4	2812

Statistical tests of the means of the latitudes at 100E and 140E

Means of the latitudes at 100E and 140E of the contour line are arranged in Tab. 3.

Significant differences of the means were statistically investigated by "student-t" test. In the four directional winds with disregard to the groups defined in this investigation, there are some significant differences in latitude (Tab. 4). The latitudinal locations at 100E are significantly different between in WNW and NW winds. That is, the latitude at 100E in WNW is significantly higher than in NW wind. As for the latitude at 140E, there are two significantly different pairs, that is, in WSW and WNW winds, and in W and WNW winds. The latitude in WNW wind is significantly lower than in the other two directional winds.

In the three groups with disregard to the four directional winds, there were also some significant differences in latitude (Tab. 5). At 100E the latitude in the third group is significantly different form in the others. In this case, the latitude in the third group is significantly the lowest among in the three groups. At 140E the latitude in the second group is very significantly different from in the others, That is, the latitude in the second group is significantly the lowest among those in the three groups.

In the three groups in each directional wind, there are also some significant differences in latitude (Tab. 6). In WSW wind, the latitude at 140E in the second group is significantly the lowest among in the three groups. In W wind, the latitude at 100E in the third group is significantly lower than in the second group. In WNW wind, the latitude at 140E in the third group is significantly the highest among in the three groups. In NW wind, the latitude at 100E in the second group is significantly higher than in the third group. In Tab. 6, results of "student-t' test as to the latitudes in the same groups in the different directional winds are also arranged.

Table 4 Results of "student-t" test of the latitudes at 100E and 140E of 3000 gpm contour lines in the four directional winds (%)

	WSW	W	WNW	NW	
WSW	*	20	1	20	140E
W	–	*	5	–	
WNW	–	30	*	50	
NW	10	10	5	*	
	100E				

Table 5 Same as Tab. 3, except in the three groups (%)

	1	2	3	
1	*	0.1	–	140E
2	40	*	0.1	
3	5	0.1	*	
	100E			

Table 6 Same as Tab. 3, except in the groups of the four directional winds (%).

	WSW 1	WSW 2	WSW 3	W 1	W 2	W 3	WNW 1	WNW 2	WNW 3	NW 2	NW 3	
WSW 1	*	1	–	50			1					140E
WSW 2	–	*	5		30			1		50		
WSW 3	–	40	*			40			40		40	
W 1	–			*	1	50	5					
W 2		40		30	*	1		10		–		
W 3			–	40	0.1	*			–		–	
WNW 1	0.1			40			*	–	5			
WNW 2		50			–		–	*	0.1	30		
WNW 3			–			30	20	10	*		–	
NW 2		–			–			–		*	20	
NW 3			20			20			5	1	*	
	100E											

Table 7 Results of "student-t" test of the inclinations in the four directional winds (%)

	WSW	W	WNW	NW
WSW	*	–	5	50
W		*	10	30
WNW			*	5
NW				*

Table 8 Same as Tab. 7, except in the three groups (%)

	1	2	3
1	*	2	20
2		*	0.1
3			*

Table 9 Same as Tab. 7, except in the groups of the four directional winds (%)

	WSW 1	WSW 2	WSW 3	W 1	W 2	W 3	WNW 1	WNW 2	WNW 3	NW 2	NW 3
WSW 1	*	20	–	–			1				
WSW 2		*	10		30			10		–	
WSW 3			*			–			50		40
W 1				*	5	–	1				
W 2					*	0.1		50		–	
W 3						*			40		30
WNW 1							*	40	1		
WNW 2								*	0.1	50	
WNW 3									*		10
NW 2										*	1
NW 3											*

Statistical tests of the means of the inclination

Means of the inclination of the contour line between 100E and 140E are also arranged in Tab. 3.

Significant differences of the means were also statistically investigated by "student-t" test. In the four directional winds, there are two significantly different pairs in inclination, that is, in WSW and WNW winds, and in WNW and NW winds (Tab. 7). In this case, the inclination in WNW wind was significantly steeper than in WSW and NW winds.

In the three groups with disregard to the four directional winds, the second group is significantly different from the other two groups in inclination (Tab. 8). That is, the inclination in the second group was significantly the steepest among the three groups.

In the three groups in each directional wind, there are also some significantly different pairs in inclination (Tab. 9). In W wind, the inclination in the second group is significantly the steepest among in the three groups. In WNW wind, the inclination in the third group is significantly the gentlest among the three groups. In NW wind, the inclination in the second group is significantly steeper than in the third group. In Tab. 9, results of "student-t" test as to the inclination in the same groups in the different directional winds are also arranged.

From these statistical analyses, the three groups were found to be useful for the pressure pattern classification. So in the next section, it would be discussed whether there are significantly different thermal conditions in low-level air layers according to the groups, the directional winds, and the groups in the directional winds, respectively.

Thickness (1000-mbs~700-mbs) at Tateno station

When there is a significant difference between thicknesses of two groups it can be expected that average temperatures of air columns are also significantly different between the two groups. In this investigation, thickness between 700-mbs and 1000-mbs at Tateno station was adopted. Means of the thickness between 700-mbs and 1000-mbs are also arranged in Tab. 3. Significant differences of the means were also statistically investigated by "student-t' test.

In the four directional winds, there are some significant differences in thickness (Tab.

Table 10 Results of "student-t" test of the thicknesses in the four directional winds (%)

	WSW	W	WNW	NW
WSW	*	10	0.1	1
W		*	1	10
WNW			*	50
NW				*

Table 11 Same as Tab. 10, except in the three groups (%)

	1	2	3
1	*	0.1	0.1
2		*	–
3			*

Table 12 Same as Tab. 10, except in the groups in the four directional winds (%)

		WSW			W			WNW			NW	
		1	2	3	1	2	3	1	2	3	2	3
WSW	1	*	2	10	30			5				
	2		*	–		20			1		30	
	3			*			–			10		20
W	1				*	1	20	20				
	2					*	10		20		5	
	3						*			5		20
WNW	1							*	30	–		
	2								*	10	10	
	3									*		–
NW	2										*	–
	3											*

10). The thickness in WNW wind is significantly thinner than in WSW and W winds, that is, average temperature of air columns in WNW wind is lower than in WSW and W winds. And the thickness in WSW wind is significantly thicker than in NW wind, that is, average temperature in WSW wind is higher than in NW wind.

In the three groups with disregard to the four directional winds, there are some significant differences in thickness (Tab. 11). The thickness in the first group is very significantly the thickest among in the three groups. That is, average temperature of air columns in the first group is the highest among in the three groups.

In the three groups in each directional wind, there are also significant differences in thickness (Tab. 12). In both WSW and W winds, the thicknesses in the first groups are significantly thinner than in the second groups, respectively. That is, average temperatures in the first groups are higher than in the second groups, respectively. In Tab. 12, results of "student-t" test as to the thicknesses in the same groups of the different directional winds are also arranged.

DISCUSSION AND CONCLUSION

By eye-investigation, it seems that contour lines in middle latitudes over Japan and East Asia are almost parallel. So the form of 3000 gpm contour line was analysed under the assumption that the form of the contour line could represent that of the trough. However, there remained apprehensions, whether the form of the trough could be represented by the form of a signle specified contour line. Tab. 1 shows that 2940 gpm contour line appears the secondary most frequent at Tateno station. So the latitudinal locations at 100E and 140E of 2940 gpm were also analysed and furthermore correlation of latitudinal differences at 100E and 140E between 3000 gpm and 2940 gpm contour lines were investigated regarding the three groups of W wind. It came from these investigations that the form of the through can be represented by the form of a specified contour line of 3000 gpm in this case.

Strictly speaking, the inclination defined in this paper is not a real one at least with respect to the following two points. First, this index does not express intricate situations of the contour line between 100E and 140E. Because the index was derived from the latitudinal difference of the contour line at only two meridians, 100E and 140E. However, there were only several cases in which intricate situations of the contour line appeared on daily 700-mb weather charts. Secondly, this index is apparently unreal, when the trough is west of 140E. As illustrated in Fig. 6, the farther the trough is west of 140E, the more the index contains unreality. However, as mentioned before, the form of the trough is generally U-shaped, so latitudinal differences of the contour line between the trough axes and 140E are not so large, and sometimes negligible, when the troughs are west of 140E. Most of all trough axes in the first group are between 120E and 130E. So the locations of the trough axes in the first group could be approximately estimated. Therefore, the inclination defined in this paper may indicate the degree of deepness of the trough, when it is considered, to which group the trough belongs.

When there is a significant difference of thicknesses, there is a significant difference of average temperatures. However, it must be noticed that average temperature of air column does not represent its thermal structure. Therefore, it can not be concluded that there is no significant difference in theremal structure of air column, even when there is no significant difference in thickness.

In WNW wind, the inclination is the largest and the latitude at 140E of the contour line is the lowest and furthermore the thickness is the thinnest among the four directional winds.

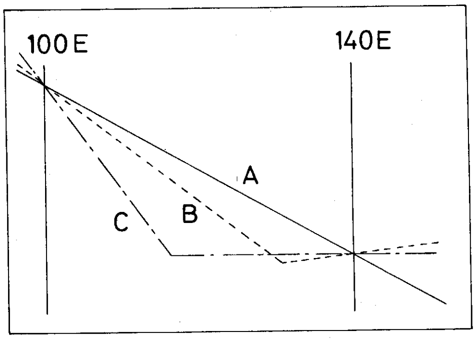


Fig. 6 Schematic figure which shows unreality of the calculated inclination.

Though the calculated inclinations are same in cases of A, B, and C, it is clear from the figure that inclinations between 100E and trough axes are notably different. The farther the trough is west of 140E, the more the calculated inclination contains unreality.

In the second group, the latitude at 140E of the contour line is the lowest and the inclination is the largest and furthermore the thickness is nearly the thinnest among the three groups. These features are also seen in Figs. 2, 3, 4, and 5. From these facts it is expected that there are frequent bursts of cold air from Siberia to Japan in WNW wind or the second group. This surmise seems to be supported on the whole by the latitudes at 100E and 140E, the inclinations, and the thicknesses of the three groups or the four directional winds. As the latitude at 100E in the first group is almost the same as in the second group, there may be also bursts of cold air in the first group. As mentioned before, the inclination in the first group does not mean inclination between 100E and the trough axis. The latter inclination is at least one and a third times as large as the former inclination. So in the first group, cold air form Siberia may flow southwards to the west of 130E and then flow eastwards. During this zonal flow stage, cold air may change into warmer air. Difference of the thicknesses in the first and the second groups may suggest this change of cold air. Kurashima (1956) made composite maps paying special attention to the movement of upper cold air tongue over East Asia and defined three types, the meridional, the transitional, and the zonal types. Assuming that these three types are applied to the three groups, the meridional type may correspond to the second group, the transitional type to the first group, and the zonal type to the third group. Comparing the thicknesses in the first and the third groups, those in the first group are always thicker than those in the third group in each directional wind. This fact suggests that average air column temperature may be higher in the first group than in the third group. This suggestion may be reasonable, because in the first group the trough is west of Japan and warmer air, which may be derived from both warmed cold air and warm air from the southward, may flow in Japan.

It was found from this investigation that daily pressure aloft fields could be objectively classified even when directions of wind aloft were the same in the region, by investigating the forms of the trough over Japan and East Asia, and that longitudinal location of the trough was one of the important and useful criteria in classifying the pressure aloft fields over this area. And it was also found that air column thicknesses were statistically different among the groups defined in this paper. However, it is not yet confirmed whether there may be statistical differences in regional climatic conditions, such as precipitation amounts and surface temperatures or their distributions in a region, for example, Kanto District in this paper, among the groups of the same wind direction. According to Asakura (1955), anomaly of 5-day mean 700-mb height associated not so well with that of 5-day mean surface temperature at Tokyo, about 60 km southwest of Tateno. So it is interesting to investigate daily surface temperatures in each group defined in this paper.

ACKNOWLEDGMENT

The author wishes to express his gratitude to Prof. Dr. T. Yazawa, Ass. Prof. Dr. I. Maejima, and Mr. T. Aoyama, Department of Geography, Tokyo Metropolitan University for their kindful advice.

REFERENCE CITED

Asakura, T. (1955): The relationship of anomaly charts of 5-day mean 700-mb height to anomaly of 5-day mean surface temperature. *Jour. Met. Res.*, 7, 696–704. (in Japanese with English abstract)

Jacobs, W. C. (1947): Bases for a synoptic climatology or synchronous climatology. *Met. Monogr.*, 1, 38–43.
Kurashima, A. (1956): Investigation on the broad-scale weather types (1). *Jour. Met. Res.*, 8, 438–42. (in Japanese)
—— (1972): *Monsoon.* Kawadeshobo-shinsha, Tokyo, 251p. (in Japanese)
Lamb, H. H. (1950): Types and spells of weather around the year in the British Isles: annual trends, seasonal structure of the year, singularities. *Quart. Jour. Royal Met. Soc.*, 76, 393–429.
—— (1964): *The English Climate.* 2nd ed. English Universities Press, London, 212p.
Lauscher, F. (1954): Dynamische Klimaskizze von Österreich. In Flohn, H. (ed.) Witterung und Klima in Mitteleuropa, *Forsch. dt. Landeskunde* 88, Stuttgart, 145–58.
—— (1958): Studien zur Wetterlagenklimatologie der Ostalpenländer. *Wetter u. Leben,* 10, 79–83.
Maejima, I. (1954): Synoptic aspects of winter climate over Japan. *Bull. Geogr.* Inst. Tokyo Univ., 3, 127–148. (in Japanese with English abstract)
Schüepp, M. (1959): Die Klassifikation der Witterungslagen. *Geof. pura e appl.* 44, 242–8.

DATA SOURCES

Daily Climatological Data of Japan, Japan Met. Agency, Tokyo (JMA).
Aerological Data of Japan, JMA.
Daily Weather Maps, JMA.