CHARACTERISTIC FEATURES OF CLOUDS IN ANTARCTICA AS OBSERVED AT SYOWA STATION

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***Abstract*:** The relationship between atmospheric conditions and cloud types in Antarctica was investigated on the basis of aerological data at Syowa Station in 1979 and 1980. When a low pressure passed near Syowa Station, type I clouds in which the vertical profile of temperature was nearly moist adiabatic were most popular. These clouds were formed in both January and July. Type II clouds which were found in an isothermal layer were frequently observed in July, but they hardly appeared in January. Clouds of this type are characteristic and interesting clouds in the polar regions. One of the reasons why the number of cloudy days in July was more than that in January would be due to the appearance of type II clouds in July.

1. Introduction

In the polar regions where the atmosphere is remarkably cold near the earth surface and it contains only a small amount of water vapor, clouds would have features which are different from clouds at middle latitudes and low latitudes. Some authors studied the formation and structure of clouds in the polar regions. HERMAN and GOODY (1976) presented a numerical model of Arctic summer stratus. GOTAAS and BENSON (1965) observed ice fog at Fairbanks and studied the effect of suspended ice crystals on radiative cooling. In the Arctic Canada the observation of snow crystals was made in 1977 (KIKUCHI and KAJIKAWA, 1979; KIKUCHI and UYEDA, 1979: KAJIKAWA *et al.*, 1980; MAGONO and KIKUCHI, 1980). Following the experiment the observation (TAKEDA *et al.*, 1982; KIKUCHI *et al.*, 1982; FUJIYOSHI *et al.*, 1982) of wintertime clouds and precipitation in the Arctic Canada was also made from November 1979 to January 1980. On the basis of the analysis of upper-air sounding data, the observation by means of two radars and the measurement of snow crystals, they described that three types of clouds were observed frequently. Though type II clouds in their papers, in which air temperature hardly changed with height, were not identified clearly by eye observation, most of these clouds were detected by 8.6 mm-radar. Precipitation originated from them contributed to about 20% of total precipitation amount during the observation period.

At Syowa Station in Antarctica KIKUCHI *et al.* (1976) observed the height of clouds using two fish-eye lens cameras and compared it with the result of radiosonde observation. Some observations related to snow crystals and cloud droplets were also made at Syowa Station (KIKUCHI, 1970, 1972). During clear-sky precipitation events at South Pole Station, SMILEY *et al.* (1980) observed ice-crystal layers by means of a lidar and determined the average altitudes of precipitation layer tops.

In comparison with clouds in the Arctic the features of clouds in Antarctica have not been clarified sufficiently yet. At Syowa Station in Antarctica surface observations of cloud type and cloud amount have been carried out since 1957 and upper air sounding has been made since 1959. In this paper the characteristic features of clouds in Antarctica are studied using aerological data and surface observation data at Syowa Station and weather charts in January and July of 1979 and in July of 1980. January and July were chosen as they represent typical season summer and winter, respectively.

2. Classification of Atmospheric Conditions

Atmospheric conditions in January and July were classified into four types on the basis of the vertical profile of air temperature (actually temperatures at 500 and 900 mb levels). In the case of July the upper atmosphere is defined as warm (cold) when a temperature at 500 mb level is higher (lower) than −40°C and it is called moderate when the temperature is nearly −40°C. The lower atmosphere is defined as warm (cold) when a temperature at 900 mb level is higher (lower) than −20°C. Considering the temperatures at 500 and 900 mb levels, atmospheric conditions are classified into WW, MW, WC and CC conditions. WW means warm conditions

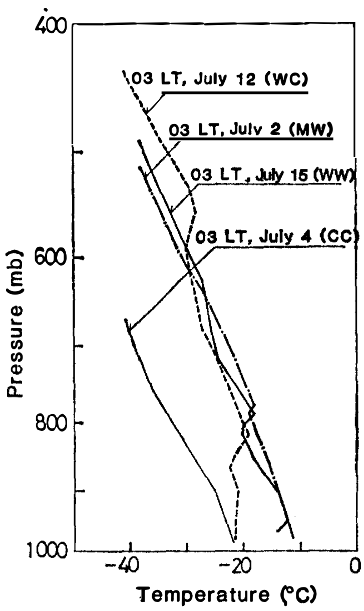

Fig. 1. Four typical vertical profiles of temperature in July 1979 at Syowa Station.

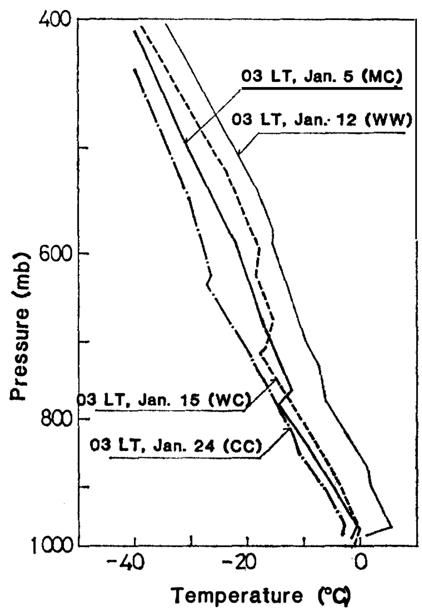

Fig. 2. Four typical vertical profiles of temperature in January 1979 at Syowa Station.

both at upper and lower levels, and MW means a moderate condition at upper levels and a warm condition at lower levels. The temperature is higher in January than in July throughout the layer between the earth surface and 500 mb level and the variation of temperature within a month is larger in July than in January. In the case of January −30 and 0°C were used as critical values at 500 and 900 mb levels respectively, and atmospheric conditions are determined as WW, WC, MC and CC. Typical examples of the vertical profile of air temperature in four types of atmospheric condition are shown in Figs. 1 and 2.

Figure 3a is a weather chart corresponding to WW type (July 15, 1979) and Fig.

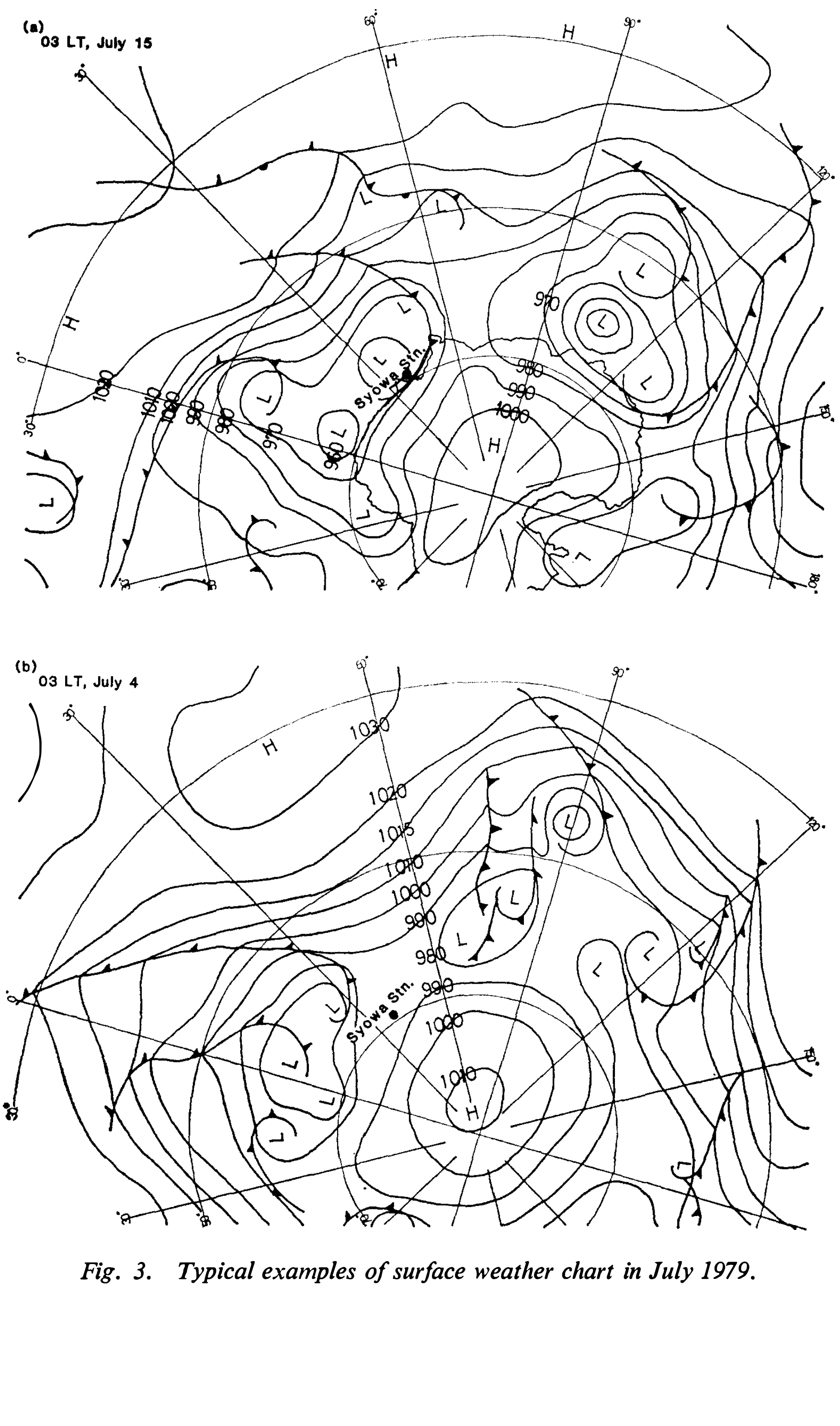

Fig. 3. Typical examples of surface weather chart in July 1979.

3b is a weather chart of CC type (July 4, 1979). On July 15 the center of a low pressure was near Syowa Station and the warm air mass of sea origin spread over the station at low levels. In July a similar synoptic pattern is seen for almost all cases of WW type and it is often seen for cases of MW type. On July 4 Syowa Station was in the region of an Antarctic high and winds were weak at the station. This synoptic pattern is a typical one for cases of CC type in July. In WC type the upper atmosphere is warm and the lower atmosphere is cold. Consequently, the layer through which temperature hardly changes with height is often formed. However, we could not find any synoptic pattern which is common for this type. Most of weather charts of CC condition in January show the synoptic pattern in which the center of low pressure of front was near Syowa Station. But in January it would be difficult to find the relation between weather charts and the other atmospheric conditions.

3. Types of Clouds

Clouds in January and July can be classified into typical four types which refer to the cloud types in the Arctic Canada by TAKEDA *et al.* (1982) on the basis of vertical profile of temperature in the cloud layer. A layer in which the relative humidity with respect to water exceeds 75% is defined to be a cloud layer in this paper, based on the comparison between the surface observation of cloud amount and the above-mentioned cloud definition (WADA, 1982).

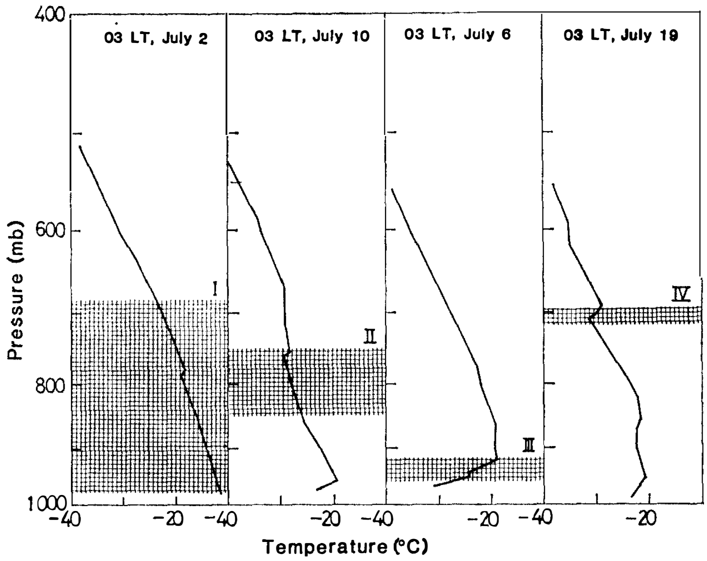

Fig. 4. Four types of clouds at Syowa Station. Hatched area shows cloud layers and solid lines indicate the vertical profile of temperature.

Typical four types of clouds are shown in Fig. 4. In the type I cloud the vertical profile of temperature is nearly moist adiabatic. In the type II cloud the temperature is nearly constant (actually less than 0.4°C/100 m) and in the type III cloud a strong inversion exists at low levels. The type IV cloud is found at middle levels between 500 and 900 mb levels and an inversion or a stable lapse rate is seen in the cloud layer. Appearance frequencies of these types in January and July of 1979 and

Table 1. Appearance frequency of each cloud type in January and July in 1979 and in July in 1980.

	Temperature profile in cloud layer			
	I	II	III	IV
July 1979	16	11	3	10
July 1980	25	13	1	7
Jan. 1979	15	0	3	11

in July of 1980 were derived from the upper air sounding data which had been made every 12 hours but three or four observations in a month at Syowa Station. They are shown in Table 1. Type I clouds were often observed in both January and July. Type II clouds were found in July, but they were not observed in January. The appearance frequency of type III clouds is small in both January and July. Type IV clouds appeared in both January and July.

4. Relation Between the Atmospheric Conditions and the Appearance of Type II Clouds

Appearance frequency of atmospheric conditions is shown in Table 2 together with that of cloud types. Columns T and C represent the observation numbers of each atmospheric condition and clouds in each atmospheric condition, respectively. Columns I, II, III and IV show the observation numbers of each cloud type, respectively. If the two or more layers were observed in a profile, the numbers are counted to be two or more. But in columns T and C the number is shown to be one. In July type I clouds are most popular in WW and MW conditions, and a large part of type II clouds are observed in connection with WC condition. The relation of the appearance of type III and IV clouds to the atmospheric conditions is not clear. Table 2 also shows that in July clouds appeared in most of WW and MW conditions, as seen from the ratios of column C to column T. In January type I and IV clouds were found predominantly. Most of type I clouds are observed in CC condition

Table 2. Observation number of each type cloud for atmospheric conditions.

		T	C	I	II	III	IV	(II)
July 1979	WW	9	9	6	3	0	2	3
	MW	10	7	8	2	1	2	2
	WC	32	10	1	6	2	5	23
	CC	7	2	1	0	0	1	1
July 1980	WW	20	13	12	3	1	4	7
	MW	10	7	6	2	0	1	2
	WC	26	12	6	7	0	1	20
	CC	2	2	1	1	0	1	1
Jan. 1979	WW	8	1	0	0	0	1	3
	WC	10	2	2	0	0	1	5
	MC	23	9	3	0	2	7	0
	CC	19	10	10	0	1	2	0

T: Total observation number, C: Clouds' observation number.

and type IV colud is mostly observed in MC condition.

Type II clouds, which are hardly observed at middle and low latitudes, were sometimes found in July, but they were not found in January. The observation number of an isothermal layer in each atmospheric condition is shown in the last column (II) of Table 2. Isothermal layers are observed in about three fourths of WC conditions in July (23/32 in 1979 and 20/26 in 1980), though they are observed in less than half of the other conditions. Namely, the isothermal layers were formed in the atmosphere which was warm at upper levels and cold at lower levels. Type II clouds appered in three different conditions of WC, WW and MW. In WC condition type II clouds were found only in less than a third of the observation number of the isothermal layer (6/23 in 1979 and 7/20 in 1980). But in WW and MW conditions they were observed in more than half of the observation number (5/5 in 1979 and 5/9 in 1980) in spite of their small appearance number.

Table 3. Observation number of the isothermal layer and type II clouds at middle levels and low levels.

		Isothermal	Type II
July 1979	middle	13	8
	low	16	3
July 1980	middle	11	11
	low	19	2

The heights of type II-cloud layers are shown in Table 3. In this table "middle levels" means that the isothermal layer or the type II-cloud layer is found above 900 mb level and "low levels" means that the layer stretches down to the level below 900 mb level. Table 3 shows that isothermal layers frequently stretch down to low levels, but most of type II clouds exist at middle levels.

The prevailing winds observed in association with the appearance of the isothermal layer are shown in Table 4. At Syowa Station northeasterly winds are predominant throughout the year (SEINO and SUZUKI, 1964). Wind directions are grouped into the directions of N to E (0 to 90°) and the other directions. The first column and the second column indicate the observation numbers of the winds with

Table 4. Appearance number of the direction and speed of prevailing winds in the isothermal layer for each atmospheric condition.

		N to E	Other directions	(nNE / NE)	(NE / nNE)	S	W	(S / W)	(W / S)
July 1979	WW	1	1	1	0	2	1	0	0
	MW	2	0	0	0	2	0	0	0
	WC	5	7	10	1	4	18	1	0
	CC	0	1	0	0	0	1	0	0
July 1980	WW	5	0	0	1	5	2	0	0
	MW	1	1	0	0	1	1	0	0
	WC	6	9	5	0	2	14	3	1
	CC	1	0	0	0	0	1	0	0

direction of N to E and the other winds throughout the isothermal layer, respectively. The third column $\binom{\text{nNE}}{\text{NE}}$ means the number of cases showing the winds other than N to E winds in the upper part of the layer and the N to E winds in the lower part of the layer. Although the number of analyzed cases in 1979 is different from that in 1980, in WW and MW conditions N to E winds were rather predominant and in WC condition the other winds (the second and third columns) prevailed. In Table 4 wind speeds are grouped into winds stronger than 10 m/s throughout the isothermal layer (S) and winds weaker than 10 m/s (W). The $\binom{\text{W}}{\text{S}}$ column means the number of cases showing weak winds in the upper part of the isothermal layer and strong winds in the lower part. In WW and MW conditions strong winds tend to be found more frequently than weak winds and most of winds in WC condition were weak. Table 4 suggests the tendency that strong N to E winds frequently blew when isothermal layers were observed in WW and MW conditions and weak winds other than N to E winds prevailed when isothermal layers were observed in WC condition.

5. Summary and Discussion

In the previous sections the classification of cloud types which were observed in January and July at Syowa Station was described. At the general features of sounding curves are a little different between January and July, the atmospheric conditions were classified into WW, MW, WC and CC in July and into WW, WC, MC and CC in January. Air temperature is generally higher in January than in July, and the content of water vapor in the atmosphere would be larger in January than in July. However, clouds were observed less frequently in January than in July. In January clouds often appeared in MC and CC conditions and in July they were found in WW, MW and WC conditions. Surely WW and MW conditions in July are related to the activity of synoptic disturbances. In July clouds were observed in more than half of the observation number of these conditions and most of them were type I clouds whose features would be similar to clouds related to synoptic disturbances at middle latitudes. In CC condition in July a high pressure in Antarctica covered Syowa Station and clouds observed in this condition in 1979 and 1980 were very thin. The vertical profile of temperature in type II clouds implies that these clouds were not formed by upcurrents. Type II clouds are characteristic and interesting clouds in the polar regions, but they were not observed in January. They would be formed more frequently in winter. A large part of type II clouds observed in July appeared in WC condition, and some of them were formed in WW and MW conditions.

Isothermal layers were observed in WC condition and sometimes in WW and MW conditions. Winds which were prevailing in the isothermal layer in WC condition were weak and their directions were other than N to E. On the other hand, strong N to E winds were predominant in the isothermal layer in WW and MW conditions. In WW and MW conditions warm air mass of sea origin spreads over Syowa Station at low levels in relation to a synoptic disturbance. When cold air mass, which is called katabatic wind, blows down along the slope of Antarctica in this situation and it is strengthened by the disturbance (MORITA, 1968), an isothermal layer would be formed at middle levels and type II clouds would appear in the layer. Type II clouds in WC condition and those in WW and MW conditions might be different in their formation process and fine structure, though we are unable to make any conclusive remark on this problem at present because of the lack of sufficient data.

Type II clouds observed in the isothermal layer is of the same type as that observed in the Arctic Canada, which was pointed out by TAKEDA *et al.* (1982). A large part of type II clouds at Syowa Station existed at middle levels, though this type of clouds in the Arctic Canada extended down to low levels. It is certain that the type II cloud develops mainly as a result of radiative cooling of the cloud itself. But the initial formation of the cloud might be due to various causes. The cloud observed in the Arctic Canada would have been formed initially due to the heat exchange of the low-level air with cold ground surface. The cloud observed at middle levels at Syowa Station might have been formed initially as a result of some turbulent motion at middle levels.

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