ANALYSIS OF AEROLOGICAL DATA AND CLOUD OBSERVATIONS AT SYOWA STATION, EAST ANTARCTICA IN 1979

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Abstract: To analyze the records of upper air observations carried out at Syowa Station in East Antarctica in 1979, characteristic features of Antarctic clouds were surveyed. As a result, vertical structures of clouds were classified into four types. Clouds of type I are defined as clouds which are formed in a nearly moist adiabatic vertical temperature profile. Clouds of type II are defined as clouds which are formed when the temperature profile is isothermal in the lower layer. Clouds of type III are defined as clouds which form in a strong surface inversion layer. Clouds type IV are defined as clouds which form in an inversion layer at middle level.

This paper describes the relationship between these clouds and the synoptic fields in July 1979 as an example of a winter season. Type I clouds are connected with synoptic scale disturbances, type II are connected with subsidence inversions, type III are connected with inversions formed from surface cooling, and type IV often occured before or after a disturbance passed through Syowa Station.

1. Introduction

The mechanism of cloud formation in the Arctic has been studied and some papers have been published (WEXLER, 1936; HERMAN and GOODY, 1976; SCHWERDTFEGER, 1969). Especially in Arctic Canada, a project within POLEX-North (Polar Experiment-North) was carried out and the formation mechanism of clouds and precipitation was studied in the winter season of 1979 (HIGUCHI *et al.*, 1981). The relationship between characteristic features of clouds and vertical temperature profiles and the mechanism of cloud formation are described in those papers.

Lidar measurements of the ice crystal layer were carried out in 1975 at Amundsen-Scott South Pole Station in Antarctica. The results were recently presented by SMILEY *et al.* (1980). They measured the altitude of the cloud formation layer and precipitation particles connected with cloud features by lidar to obtain information on the clear-sky precipitation.

Since the First Japanese Antarctic Research Expedition (JARE-1), amount of cloud and genus of cloud have been observed from the surface at Syowa Station in East Antarctica (MURAKOSHI, 1958). Upper air observations at Syowa Station started in February 1959 and humidity observations using hair hygrometer were also carried out (SEINO and SUZUKI, 1964). However, analysis of clouds or classification of cloud types in the synoptic field near Syowa Station has not been done except by KIKUCHI *et al.* (1976).

As the meteorological radar and lidar equipment have not yet been installed at Syowa Station, cloud types were classified on the basis of the data of upper air observations and surface cloud observations in 1979. This paper describes the relationship between cloud types and synoptic fields at Syowa Station, Antarctica.

2. Method of Analysis

Although cloud layers were defined to be layers of more than 90% relative humidity with respect to water by TAKEDA *et al.* (1981), layers of more than 75% relative humidity are defined to be cloud layer in this paper because the amount of cloud from surface observations is compared with the vertical humidity profile obtained from upper air sounding. On one hand, if the total amount of mid-level and lower clouds in the surface observation was 7/10 or more, it was considered that there was cloud at that time and if the amount was 6/10 or less, it was considered that no cloud was observed. On the other hand, from air humidity observations it was supposed that cloud existed if the observational value of the relative humidity was more than 75% with respect to water and that cloud was not observed if it was less than 75%. A comparisons of the existence of clouds at the same time obtained by both assumptions was made. The percentage of agreement is 82% in January, 87% in February, 81% in March, 87% in April, 86% in May, 82% in June, 82% in July, 67% in August, 67% in September, 90% in October, 66% in November, 90% in December and 80% in annual of 1979. Although observation of humidity is difficult in Antarctica because the quantity of absolute water vapor is small, the agreement of 80% over a year is high, so that the above assumptions are used in this paper.

The clouds which are defined above are classified into the following four types. The vertical temperature profile in cloud layer of type I is nearly moist adiabatic between the surface and about 700 mb. The temperature profile in a cloud layer of type II is isothermal, a cloud layer of type III occurs in a strong inversion layer

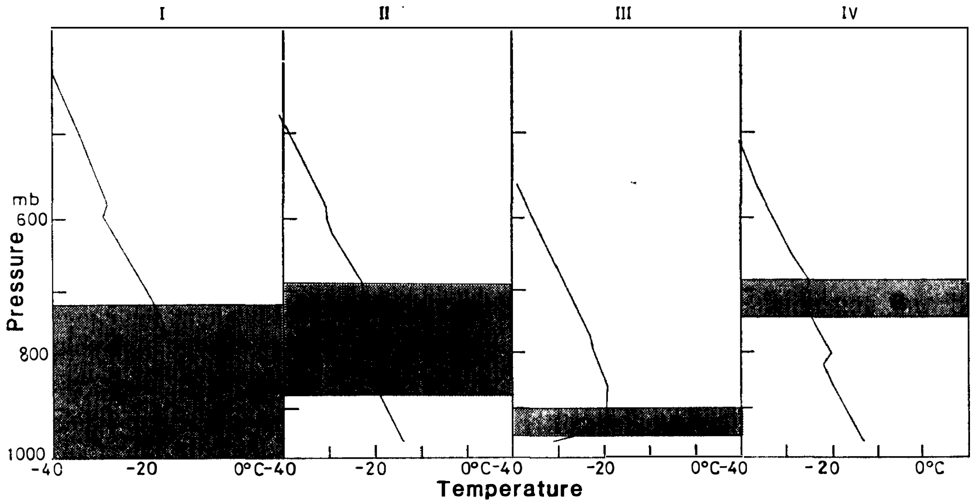

Fig. 1. Temperature profiles in four cloud types. Hatched area shows cloud layer.

Table 1. Frequency of wind direction at 500 mb at Syowa Station in 1979.

	NE	SE	NW	SW
January, February, November, December	85	38	44	61
March, April, May, October	46	24	71	88
June, July, August, September	63	21	70	71
Total	194	83	185	220

above the snow surface. Type IV is a cloud layer which is formed in an inversion layer at mid-level; the thickness of this layer is less than about 1 km. Characteristic vertical temperature profiles of these four types are shown in Fig. 1.

The upper wind direction at 500 mb at Syowa Station was chosen to classify weather patterns. Wind direction was classified into NE (0°–90°), SE (90°–180°), SW (180°–270°) and NW (270°–360°). Upper air observations were carried out twice (00Z, 12Z) almost every day. The frequency of these directions at 500 mb in each season is shown in Table 1. The frequency of the SE direction is the least and that of SW is the most.

3. Relation between Cloud Type and Wind Direction

3.1. Seasonal variation

Relations between clouds and wind directions at 500 mb in each season are shown in Table 2. The summer season is assumed to include January, February, November and December, the transitional seasons are March, April, May and October and the winter season is June, July, August and September.

As shown in Table 2, type I clouds were the most common in all seasons,

Table 2. Frequency of wind direction at 500 mb in each cloud type.

		I	II	III	IV	T*
January, February, November, December	NE	18	0	4	13	40
	SE	6	0	1	2	9
	NW	7	1	2	7	17
	SW	8	1	7	5	23
	Total	39	2	14	27	
March, April, May, October	NE	11	3	1	2	21
	SE	1	0	0	4	5
	NW	30	2	5	3	42
	SW	7	1	4	11	27
	Total	49	6	10	20	
June, July, August, September	NE	18	3	2	9	36
	SE	0	1	0	0	1
	NW	16	3	0	10	30
	SW	6	1	1	9	19
	Total	40	8	3	28	

T*: Total frequency of each wind direction.

type II clouds were often found in winter and the transitional seasons and type III clouds often occurred in the summer season. Type IV clouds occurred in all seasons. When a SE wind was prevailing clouds almost never formed.

3.2. Case study in July 1979

A more detailed analysis was carried out on the data of July in 1979, and the relation between cloud types and weather conditions was investigated. As considered from the wind direction at 500 mb, the following three groups are taken. SW is the prevailing wind direction in group A, NW is the direction in

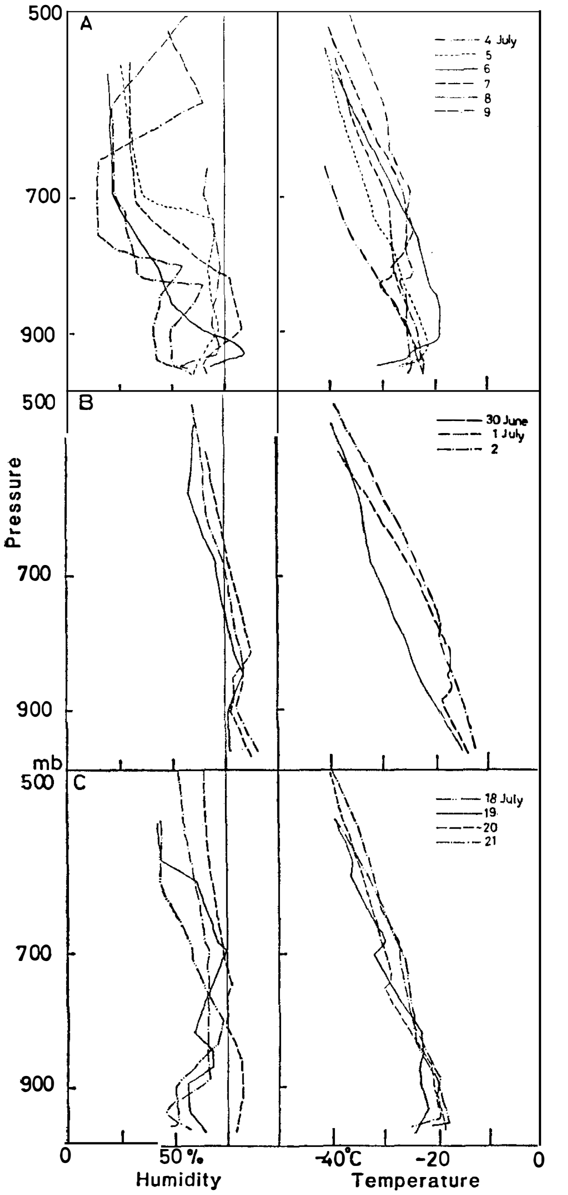

Fig. 2. Variation of temperature and humidity profiles of three groups.

Table 3. Wind direction and periods of each group were shown.

Group	Wind direction	Periods
A	SW	July 4–9 July 10–14
B	NW	June 30–July 2 July 27–28
C	W	July 18–21

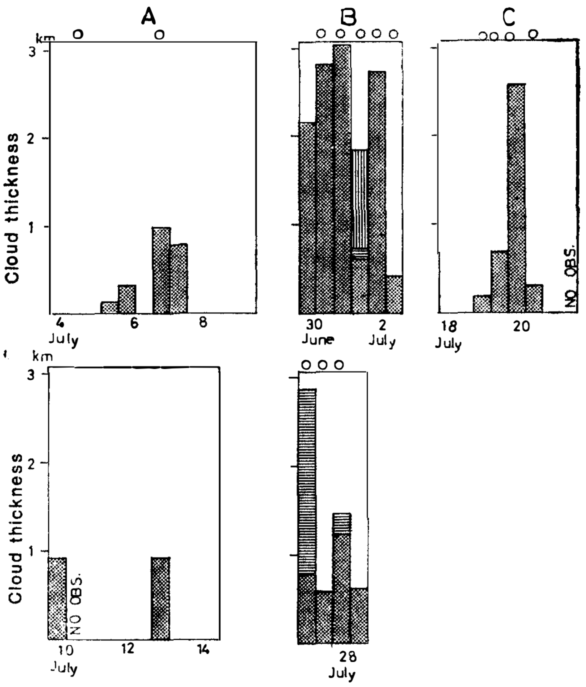

Fig. 3. Cloud thickness calculated from humidity profiles of upper air observation (00, 12Z) are shown in each period. When more than two cloud layers were observed, cloud thickness was drawn with more than two patterns. Circles at the top of each graph show the records of snowfall from surface observations.

group B and W is the direction in group C. As shown in Table 3, two periods of July are involved in group A, two periods are involved in group B and only one period is connected to group C. These periods of each group are shown in Table 3 and Fig. 2 shows vertical temperature profiles and relative humidity profiles of each group, obtained from upper air observations at Syowa Station. Vertical temperature profiles of group A were isothermal in the middle layer (700–900 mb) except July 4, 5 and 6, and an inversion layer in group A was formed in the surface layer. Vertical temperature profiles in group B were nearly moist adiabatic and a strong inversion layer was not found at the surface. Vertical temperature profiles on July 18, 20 and 21 in group C were nearly moist adiabatic above the 850 mb level and the vertical temperature profile on July 19 was isothermal from the surface to 800 mb.

As seen in Fig. 2A, vertical temperature distribution rose up from July 4 to 6 and then the temperatures between the surface and 700 mb was nearly constant, about $-25°C$, from July 7 to 9. The value of relative humidity during the period from July 4 to 9, except for the level between 800 and 900 mb on July 7 and the level between 900 and 950 mb on July 6 from Fig. 2A were shown to be less than 75%. As seen in Fig. 2B, the temperatures of the near surface layer were about $-15°C$, and the relative humidities in the layer below 700 mb were more than 75%. Fig. 2C shows that the four profiles of temperature distributions are almost same, that is, the temperature in the layer below 700 mb are distributed between about $-20°$ and $-30°C$.

Figure 3 shows the data of cloud thickness which are decided by relative humidity of upper air observations in each group. Cloud thickness is defined here to be the thickness of the layer of more than 75% relative humidity with respect to water from humidity profiles. If two or three layers of more than 75% humidity were observed, each cloud thickness is shown with a different pattern in Fig. 3. Cloud thickness of group A as was thin, the thickness being than 1 km; only one cloud was found from this group A. However, cloud thickness of group B was thick, sometimes as much as 3 km, and sometimes three cloud layers were found. The cloud thickness of group C was thicker than that of group A but not as thick as that of group B. Whether snowfall was observed or not is shown at the upper part of each graph in Fig. 3. From these observations, snowfall was observed very rare in group A, very frequentry in group B and sometimes in group C.

4. Discussion

Type II clouds which were described above were found in clouds of group A. This case may occur when a subsidence inversion which was connected to a cold air mass from Antarctica was formed. And then when the inversion was very strong and much water vapor was supplied, the cloud layer was formed, but when the inversion was not so strong or much water was not supplied, the cloud was not found.

Cloud of group B corresponded to type I cloud. Considering the cloud thickness and vertical temperature profile or structure in the clouds of group B, it was concluded that a synoptic scale disturbance approached Syowa Station and much water vapor was supplied.

Clouds of group C were similar to those of group B. However, the effect of the disturbance at Syowa Station was small, so that cloud thickness became thin and snowfall was weak. The fact that the prevailing wind direction was W and was not NW might show the effect of the disturbance. It was suggested that type I cloud were connected to the disturbance (low pressure system or front) and the cloud thickness or snowfall rate depended on the strength or the path of them.

Type III cloud was seen in the profile on July 6 in Fig. 2A. The temperature distribution of all the layers from upper to surface became low on July 4 and then it rose up. When radiative cooling became strong, in this condition the surface was cooled, a strong surface inversion was formed and humidity rose, so that type III cloud was formed.

Type IV occurred often and its type of cloud would be formed before or after a disturbance passed through Syowa Station, but it was not sure how the inversion layer at middle level formed.

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