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Temperature Drops Produced by Microbursts from Snow Clouds in the Winter Monsoon Season in Hokkaido, Japan

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Abstract

In order to investigate the structure of microbursts from snow clouds, radar and surface weather observations were carried out along the west coast of Hokkaido Island, Japan in the winter monsoon season. The distribution of temperature changes and its relation to the radar echo area were analyzed. Temperature drops, 2 to 3°C for ten minutes, are periodic and correspond to the echo movement. Around the maximum temperature drops, the surface wind speed increases suddenly. These are suggestive of the existence of downbursts from snow clouds.

1. Introduction

Under convective snow clouds, strong winds (or gusts) with heavy snowfalls are often experienced along the west coast of northern Japan in the winter monsoon season. Higuchi (1962) suggested the existence of strong downdrafts from snow clouds by photographic observations from an aircraft. The relation between the strong downdrafts from snow clouds and the strong surface wind (gust) has not been studied till now, however. Since the systematic surface weather observation of strong downdrafts from snow clouds has not been carried out, their detailed structure remains unclear.

On the other hand, the structure of downbursts from thunderstorms and squall-lines has been analyzed by many researchers (Houze, 1977; Wilson et al., 1984; Fujita, 1985; and others). Gust-fronts produced by downbursts are also studied by Charba (1974), Goff (1975) and Uyeda and Zrnić (1986) and others. The passage of squall-lines and/or gust-fronts are often accompanied by prominent temperature drops produced by raindrop evaporation in the dry subcloud layer (Zipser, 1977).

According to the knowledges of the downbursts from thunderstorms and to the scale classifications of them by Fujita (1981), the strong downdrafts from snow clouds are considered as microbursts. For the area and duration time are relatively small, precise observation is not made as yet. In the winter monsoon surges, the mixing layer is wet and the temperature is lower than 0°C. Since the melting process has not occurred, the features of the microbursts from snow clouds are considered quite different from the downbursts from thunderstorms.

In order to study the structure of the microbursts from snow clouds as a first step, radar and surface weather observations were carried out along the west coast of Ishikari Plain, Hokkaido Island, Japan in the winter monsoon season. This paper will describe mainly the significant temperature drops, which correspond to the surface wind gust and the radar echo cover; these temperature drops are caused by the downdrafts from snow clouds.

2. Observation method

The observation was made from December 1985 to March 1986 around Sapporo on Hokkaido Island. Sapporo (43°N and 141°E), which is the largest city in northern Japan; it is located about 15 km southeast to the sea coast of Ishikari Bay, Sea of Japan as shown in Fig. 1. Snow clouds usually move from Ishikari Bay to Sapporo by the northwesterly winter monsoon (Kikuchi et al., 1984).

Figure 1 shows observation network around Sapporo. The television tower (the point of TV) is located in the center of Sapporo. Wind and temperature observation points are mostly aligned along northwest to southeast. A conventional weather radar ($\lambda = 3.2$ cm) was set on the top of the highest university building, shown by the + mark in Fig. 1, which is located about 2 km north to the central Sapporo.

Surface weather data were read from recording charts. Most of wind data were averaged for ten minutes. Temperature change at five or ten minute intervals was calculated for each observation point. With these values, distributions of temperature changes were plotted. From these distributions the movement of temperature drop area was analyzed.

Radar echoes (PPI or CAPPI) were superposed on the distribution of temperature changes for ten minutes. The relation between radar echo movements and temperature drop distributions was analyzed.

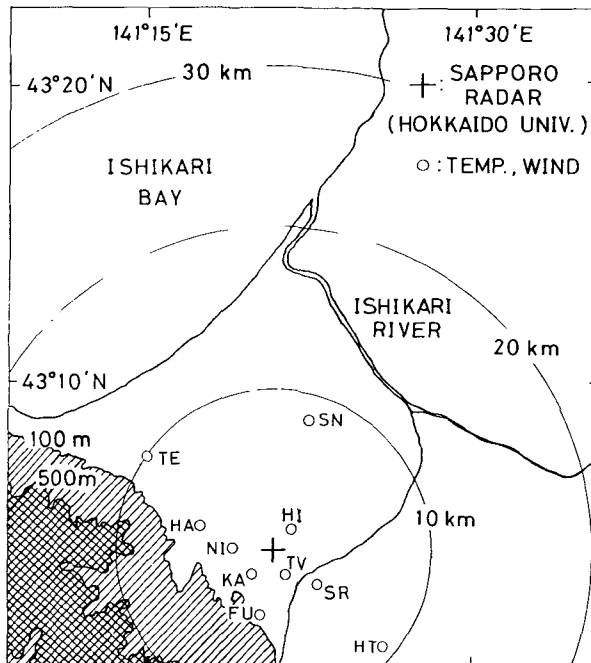


Fig.1 Surface weather observation points (o) and radar location (+) around Sapporo. Mountainous regions over 100 and 500 m above sea level were hatched and crosshatched, respectively.

3. Results

The distribution of temperature change was analyzed precisely for one case and the relations between radar echoes and temperature drop areas were analyzed for three cases.

3.1 Temperature change

a. Case 1 (29 January 1986)

The temperature change at nine points are shown in Fig. 2. The temperature curves cross at -5°C around 1200 JST for each observation point. The curves are arranged by the observational locations from northwest to southeast, except for the point of SN, from the top in this figure. Dashed lines A and B show the same phase of prominent temperature drops through nine points. The significant temperature drop moves from northwest to southeast in both cases in Fig. 2. These indicate the movement of temperature drop area at the interval

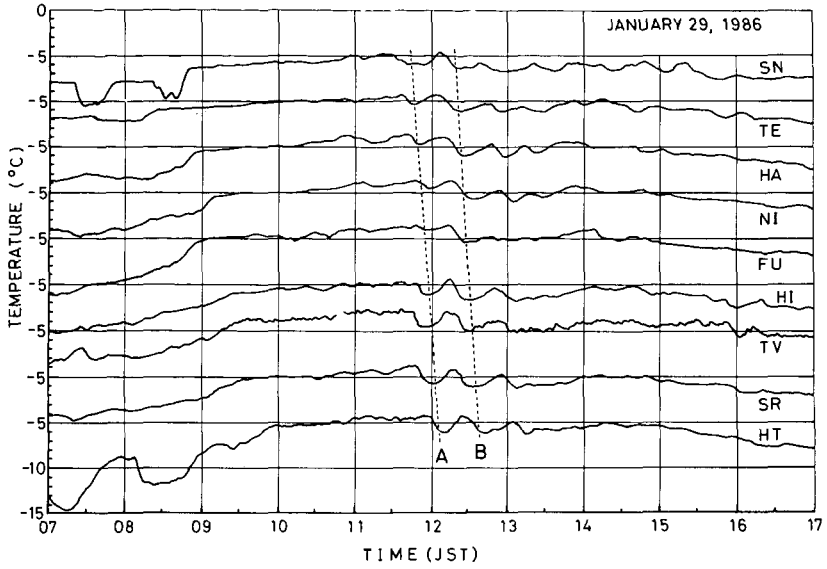


Fig. 2 Time series of temperature change at 9 observation points for the period 0700-1700 JST 29 January 1986.

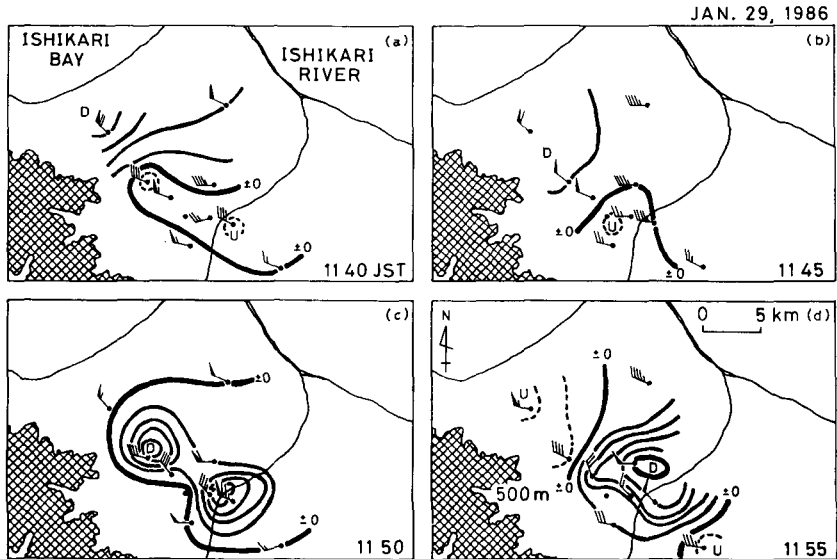


Fig. 3 Distribution of surface temperature change for five minutes and surface winds from 1140 to 1155 JST 29 January 1986. Wind flag is 5 m/s, a full barb 1 m/s and a half barb 0.5 m/s. Solid contours in 0.2°C intervals are temperature drop in five minutes and dashed lines rise at 0.2°C intervals. The symbols of U and D represent temperature Up and Down regions, respectively.

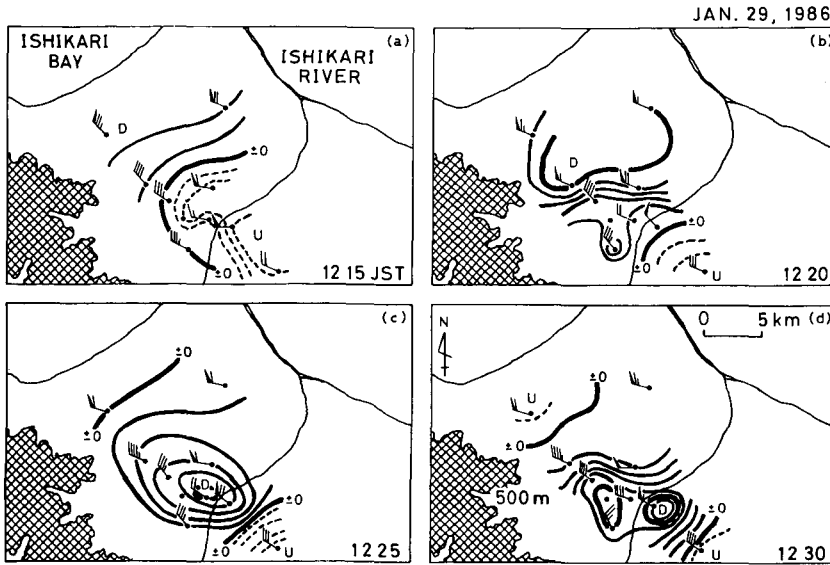


Fig. 4 The same as in Fig. 3 but from 1215 to 1230 JST 29 January 1986.

of thirty minutes after 1100 JST.

Figures 3 and 4 show the surface winds and the distributions of temperature changes corresponding to the dashed lines A and B in Fig. 2. On the dashed line A, the maximum temperature drop of 1.1°C for five minutes is shown in Fig. 3 (d); the case of line B is 1.3°C in Fig. 4 (d). Around the maximum temperature drops, wind speeds increase a few meters per second. However, a divergent signature as an evidence of microbursts is not clear, this was unexpected, and the significant increases of wind speed are notable.

Figure 5 shows the temperatures and winds at the point of TV, corresponding to the cases shown in Figs. 3 and 4. The temperature differences between the height of 30 m and 60, 90 and 120 m show only a small variation after 0930 to 1400 JST. Temperatures at the surface and at a 30 m height also show similar changes against each other. These indicate that temperature drops around 1150 and 1230 JST occurred at the same moment through the heights of 120 m.

The large increase of wind speed coincides with the beginning of the step decrease of temperature around 1150 and 1225 JST. At the same time, the wind direction shifted from west to northwest. The gust occurs ahead of the minimum temperature appearance. Since the prominent temperature drop

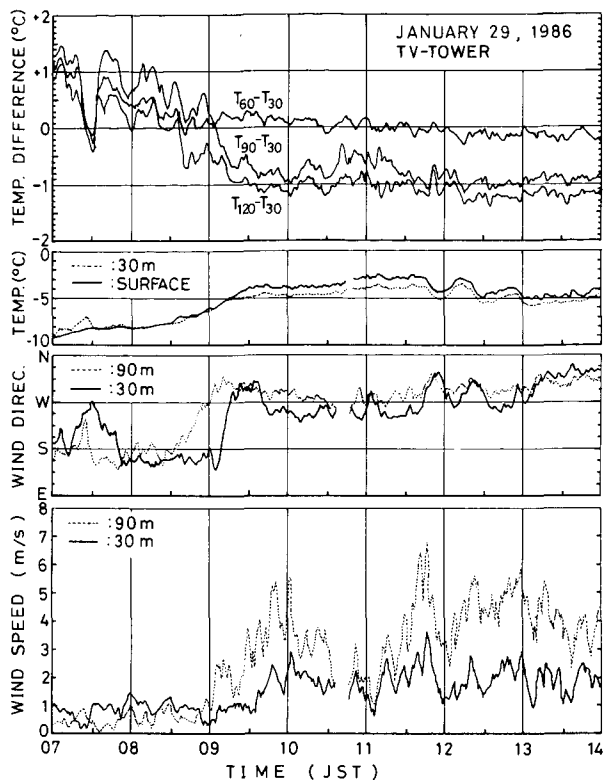


Fig. 5 Time series of temperature, temperature difference and wind at the point of TV for the period 0700-1400 JST 29 January 1986. The temperature differences between the height of 30 m and 60, 90 and 120 m are shown $T_{60}-T_{30}$, $T_{90}-T_{30}$ and $T_{120}-T_{30}$. Solid and dotted lines in temperature indicate the surface and a height of 30 m data. In wind speed and direction, solid and dotted lines indicate the height of 30 and 90 m, respectively.

occurred at the same time through the depth of 120 m and the beginning of temperature decrease coincided with the shift of wind direction and the increase of wind speed, the existence of strong downbursts from snow clouds is suggested.

3.2 Radar Echo and Temperature Drop

a. Case 2 (24 December 1985)

The distribution of surface temperature changes and radar echo areas are shown in Fig. 6 (from 1046 to 1131 JST) and Fig. 7 (from 1346 to 1431 JST). The maximum temperature drop for ten minutes of each case was 1.5°C at 1101

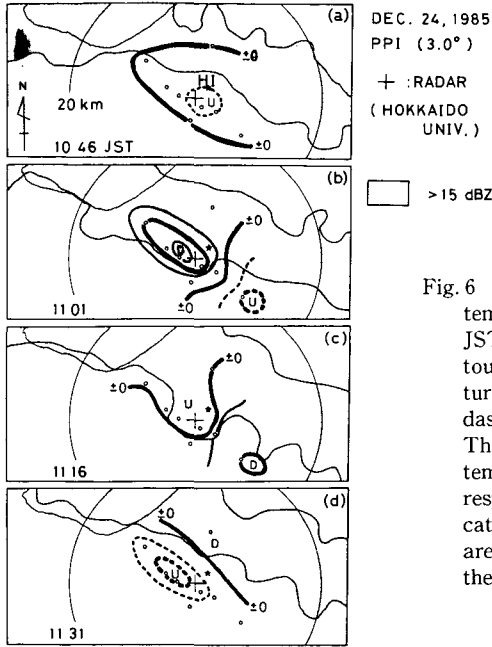


Fig. 6 Radar echo and the distribution of temperature change from 1046 to 1131 JST 24 December 1985. Solid contours in 0.5°C intervals are temperature decreases for ten minutes and dashed contours rose at 0.5°C intervals. The symbols of U and D represent temperature Up and Down regions, respectively. The symbol of star indicate the point of HI. The shaded areas show the radar echo larger than the reflectivity of 15 dBZ.

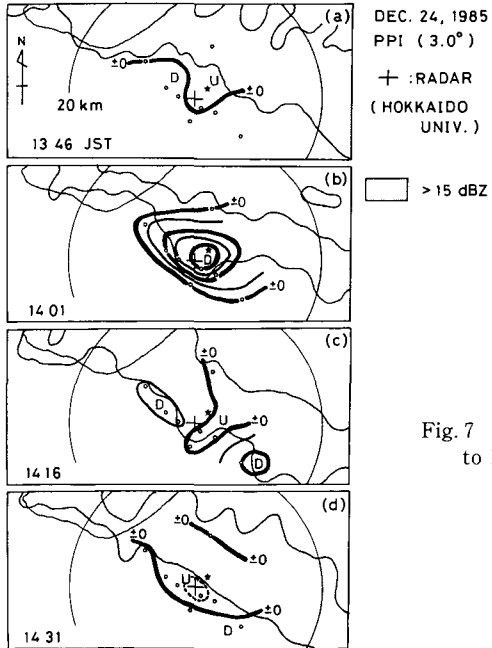


Fig. 7 The same as in Fig. 6 but from 1346 to 1431 JST.

JST (Fig. 6(b)) and 2.3°C at 1401 JST (Fig. 7(b)). The area of temperature drop (more than 1°C for ten minutes) corresponds to the swell of southern edge of the echo band. The wind speed maximum recorded at the point of HI was 7.0 m/s at 1100 JST, which accompanies the echo intrusion as shown in Fig. 6(b). When the echo covers just above HI at 1116 JST, the wind speed descends to 4.5 m/s. Corresponding to the temperature drops and the echo band movement, the wind speeds of HI from 1345 to 1430 JST at fifteen minute intervals are 5.0, 8.5, 4.2 and 7.5 m/s, respectively. These indicate that the surface horizontal wind ahead of the approaching snow storm is gusty and just under the snow storm it is not so strong.

The temperature drop was observed when the echo band spreads south to the temperature observation network. The echo cells moved from west-north-west to east-southeast with the speed of 60 km/h. The area of temperature drop also moved together with the radar echo movement by the same speed as seen.

The temperature changes at nine points are shown in Fig. 8 in comparison to Fig. 2. The temperature drops shown by the dashed lines A and B correspond to that of Figs. 6 and 7. The maximum temperature drops appear behind the wind gusts. The interval of temperature drops was about three hours. In Fig. 8, the temperature changes at SN and FU are not prominent. At the point of SN, where the radar echo overcasts from 0900 to 1600 JST, temperature

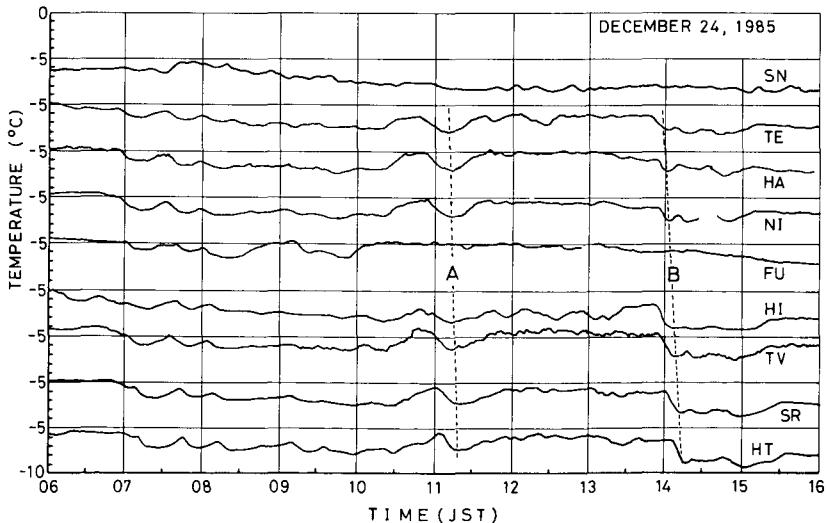


Fig. 8 The same as in Fig. 2 except for the period 0600-1600 JST 24 December 1985.

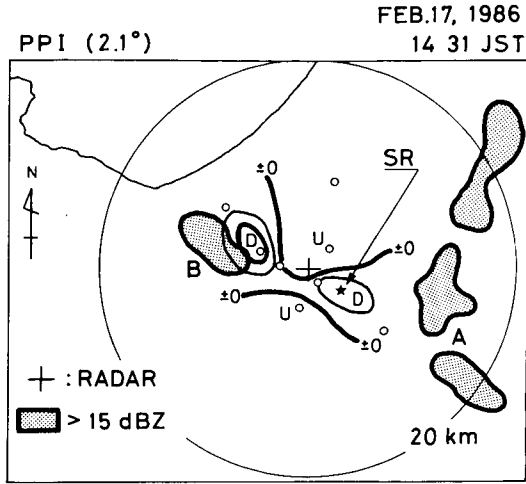


Fig. 9 The same as in Fig. 6 but at 1430 JST 17 February 1986. The symbol of star indicate the point of SR.

shows constantly low about -8°C ; at the point of FU, where the radar echo did not intrude, temperature shows constantly high about -5°C .

b. Case 3 (17 February 1986)

The distribution of temperature changes and the radar echo area at 1430

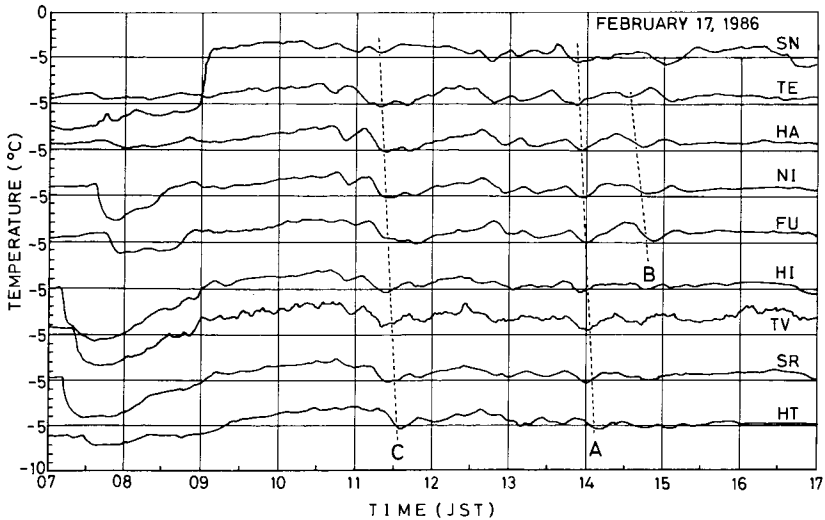


Fig. 10 The same as in Fig. 2 except for the period 0700-1700 JST 17 February 1986.

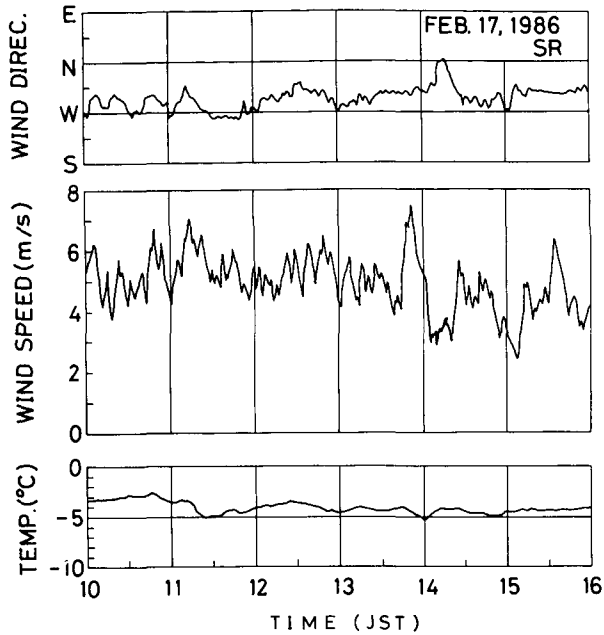


Fig. 11 Time series of wind and temperature at the point of SR for the period 1000-1600 JST 17 February 1986.

JST are shown in Fig. 9. The maximum temperature drop was about 1.0°C . The echo size was about 10 km in diameter and moved from northwest to southeast with a speed of 10 m/s. Figure 10 shows the temperature variations at nine points. Prominent temperature drops were linked by dashed lines A, B and C. These temperature drops of A and B correspond to the radar echoes A and B in Fig. 9. The maximum temperature drop was over 2°C for ten minutes together with C. Wind and temperature at the point of SR are shown in Fig. 11. At the passage of echo A, the wind of SR represents a significant change, as if by gusts, at 1350 JST. In this case, the cycle of the surface temperature drop was about one hour.

Figure 12 shows TV tower data. Temperature through 120 m height represents the same change as in the case 1 after 0900 JST. Wind changes also correspond to temperature drops.

In Figs. 10 and 12, large temperature drops are observed before 0900 JST. These are, however, associated with the cold outflow from inland as the temperature is very low under -10°C . The temperature inversion and easterly weak winds, as shown in Fig. 12 before 0900 JST, also indicate a cold outflow.

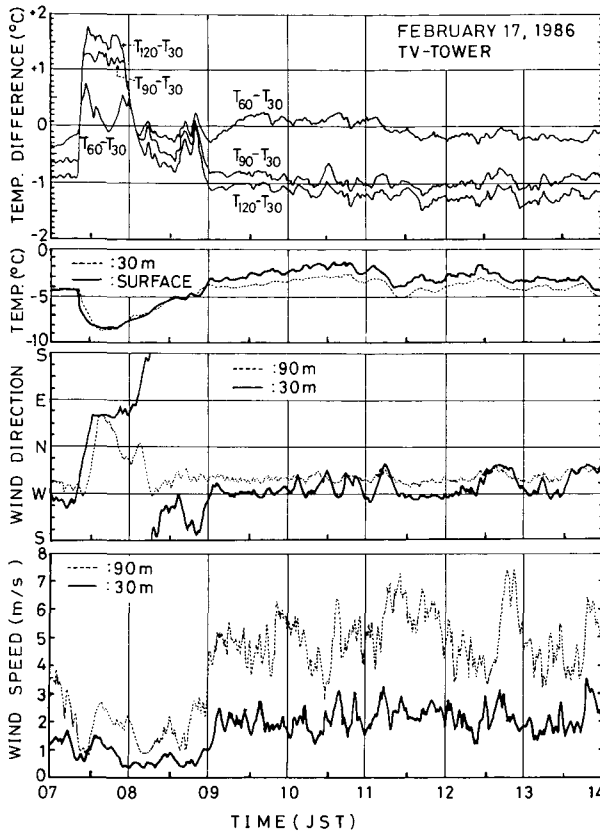


Fig. 12 The same as in Fig. 5 except for the period 0700-1400 JST 17 February 1986.

In this cold outflow region, significant temperature drops and gusts have not been identified except at the front of northwesterly monsoon surge. The structure of this front type gust causes a difference to the downbursts from snow clouds. The prominent temperature drops after 1100 JST occurred in northwesterly wind from sea, namely in the convective mixing layer of winter monsoon. The same was adopted in the case 1 (Figs. 2 and 5).

c. Case 4 (17 March 1986)

The distributions of surface temperature change and radar echo area are shown in Fig. 13. The echo area has a diameter from 2 to 10 km. The echo and the temperature drop area movement showed a good coincidence. The echo moved rapidly from northwest to southeast with the speed of 100 km/h.

In this case, the temperature drops were identified repeatedly with the

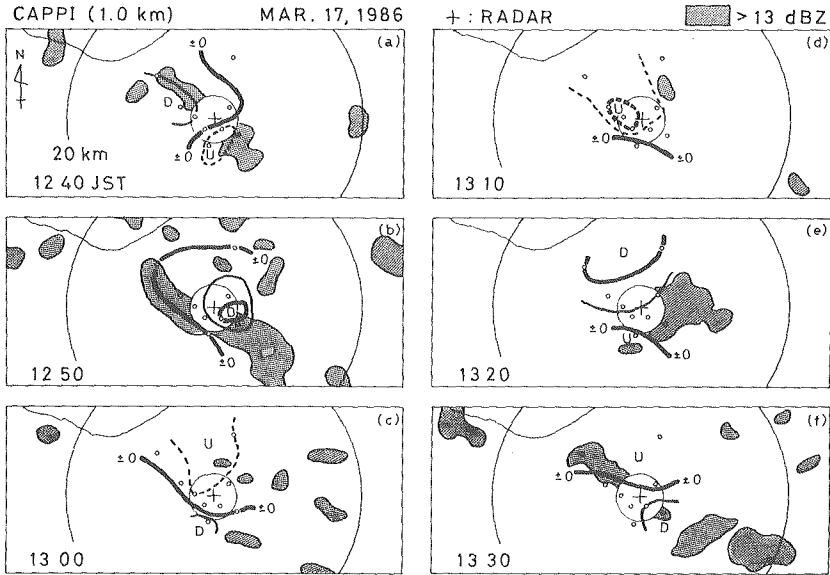


Fig. 13 The same as in Fig. 6 but from 1240 to 1330 JST 17 March 1986 and the radar echo larger than the 13 dBZ.

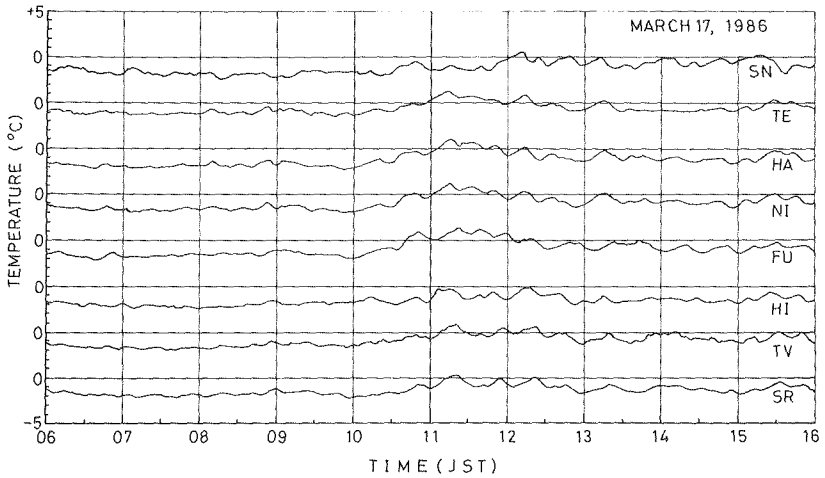


Fig. 14 The same as in Fig. 2 except for the period 0600-1600 JST 17 March 1986 and at 8 observation points.

interval of about twenty minutes from 1030 to 1600 JST, as shown in Fig. 14.

4. Concluding remarks

Periodic temperature drops, at intervals varying from few tens minutes to a few hours, were analyzed for four cases. The relations between temperature drops and echo areas were examined. The echo cover corresponded to the temperature drop area. The prominent temperature drop was 1 to 2°C for ten minutes. These are suggestive of the existence of downbursts from snow clouds.

The approaching echo coincided with the beginning of temperature drop and the rapid increase of wind speed. At the moment of maximum temperature drop in the area of echo cover, the wind speed decreased as shown in cases 2 and 3. The evidence of wind divergence was not identified, however. One of the reasons for this would probably be that the wind measured by aerovanes are recorded as ten minute averaged values. Another reason is that wind shift is not clear as it is superposed onto a strong northwesterly wind. The echo over the temperature drop area moved from northwest to southeast with the speed of about 10 m/s; this is the characteristic of snow cloud movement in the winter monsoon season along the west coast of Hokkaido, Japan.

Aside from the above four cases, there exists the gusty snow storms that have no significant temperature change in the winter monsoon surges. For example, on 14 January 1986 during our observation period, wind records (not shown) showing continuously strong values without prominent temperature drops. Examined the record carefully, the wind from west to northwest was gusty all day long and the radar echo band was overcasted the whole time from west-northwest to east-southeast. Therefore these storms would be different from microbursts from snow clouds.

Fujita (1985) classified thunderstorm downbursts as wet-burst and dry-burst. In the present study, humidity was not measured. However, we analyzed what seems to be wet-type microbursts because they have snow trails reaching to the ground. It is necessary to ascertain whether the temperature drop is produced by the evaporation of falling snow under the clouds or not. For a study of further details of the burst, two dimensional arrangement of surface observation is necessary. In the next observation, photographical morphology is expected to be taken and classified for types in order to increase the understandings of microbursts from snow clouds.

Acknowledgments

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