Studies on Blowing Snow II*

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Abstract

In a wind tunnel, several series of measurements of wind velocity were made with small Pitot tubes at different heights above the new fallen snow surface and the surface roughness parameter 0.0045 cm was obtained for the wind speed at the central part of wind tunnel 5.5–10 m/s. In the field, the roughness parameter was the same value 0.0045 cm as in the wind tunnel for the wind speed at 1 m height 5–9 m/s, but it became larger with the wind speed, and it became 0.11 cm for the wind speed 13.2 m/s.

The relation between the temperature and the threshold wind speed necessary for the occurrence of blowing snow was obtained by observation in the field. On this relation, a theoretical explanation was attempted.

It was also observed in a wind tunnel that the turbulence makes the threshold wind speed lower.

The saltation of snow particles was photographed in a wind tunnel and in a field. The illumination by a strobolight made it easy to measure the speed of snow particles on a photograph since a particle made a series of spots on it.

Two parallel trenches in a field, perpendicular to the wind direction gave information on the mechanism of the blowing snow. When the interval of two trenches was about 1 m and wind speed was not more than 6 m/s, no snow drifted into the leeward trench. But, when the interval was 10 m, and wind speed was not more than 5 m/s, the amount of snow drifted in the leeward trench was a half of that drifted in the windward trench.

Three types of blizzard meters were set in a field and were compared with each other on their respective collection efficiency. The type for Antarctica was not good, as its mouth was too small and was easily choked with snow.

I. Introduction

Two of the authors wintered at Syowa Station, in Antarctica and became interested in the blowing snow. After their return to Japan, they intended to study blowing snow in Sapporo, expecting that this would be useful for the study of blizzards in Antarctica. This paper is the work performed in Sapporo, mainly on the mechanism of the generation of the blowing snow, containing theoretical considerations, with observations on the snow field and experimental work in the wind tunnel.

II. Instruments and Methods

Wind tunnel

A circulating type (Göttingen type) wind tunnel set in a cold room was used. The

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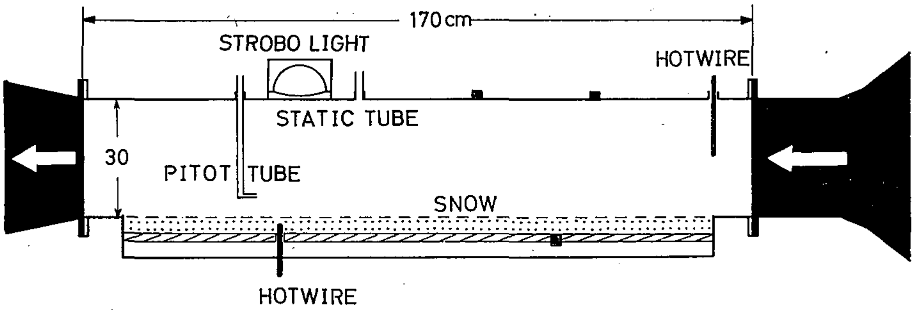

Fig. 1. Working part of wind tunnel

cross-section of its working part is 30×30 cm and the length is 170 cm (*cf.* Fig. 1). The sides and the top of the working part are made of transparent acrylic acid resin plates of 2 cm in thickness. The bed of the tunnel is newly fallen snow carried in from the field.

Anemometer

(a) Pitot tube. In the wind tunnel, the Pitot tube and a hot wire type anemometer was used. The tube was made of glass and its shape was L. The part parallel to the wind was 3 cm in length and its inner diameter was 1 mm. The micromanometer (Göttingen type) with alcohol as the working liquid was used for the Pitot tube. The lowest wind speed which could be measured with this apparatus was about 2 m/s with an error of ± 0.15 m/s. The Pitot tube can be set at four positions along the center of the wind tunnel. At each position, the height of the Pitot tube above snow surface can be changed continuously. The height of tube was measured by a cathetometer.

(b) Hotwire anemometer. A commercial type was used at the windward where no snow particles are flying. Usually this instrument was set at the center of the vertical section of the wind tunnel and indicates the standard wind speed in the tunnel.

(c) Hotwire anemometer (sensitive type). This instrument has a very tiny tip with a thin hotwire made of tungsten of 5 μ in diameter and 1 mm in length. The heat capacity is very small and the heat production is also small. This is used for the estimation of the speed of air motion under the snow surface. This instrument is also used for the measurment of turbulence. It is sensitive for the phenomena of frequency in the range from 2 Hz to 50 kHz.

(d) Three cup anemometers. In the field, five sets of three cup anemometers were used to observe the vertical profile of wind speed. The diameter of the cup was 2.6 cm and the distance from the rotating axis to the center of the cup was 4.5 cm. The number of rotations was counted by the number of the electrical contact of the circuit.

(e) Magneto anemometer. The diameter of the cup was 5 cm and the length of the arm from the axis to the center of the cup was 7.6 cm. The rotation of the three cup wheel generates DC voltage. Instantaneous wind speed can be seen on the indicator. This instrument was used for wind speed at a 20 cm level above the snow surface in the field.

Collector

This is an instrument to collect snow particles blown by the wind and to determine the horizontal mass flux. Three types were compared.

(a) Cyclone type. The shape is shown in Fig. 2. This is a modification of equipment generally used in chemical engineering factory to collect flour.

(b) Metyelemeter. The shape is shown in Fig. 3. This is an imitation of a collector that is illustrated in a Russian text book (Kuzimin, 1960). As the book describes only the external appearance, the internal construction might not be the same. The size is about a half of that described in the text book.

(c) Rocket type. The shape is shown in Fig. 4. This is an imitation of a collector described by Mellor (1960). The rocket type was not suitable for low winds in a warm climate. The opening is too small to collect large snow particles. It is soon choked.

The mass flux calculated from each amount of collection is compared in Table 1. At high wind speed the cyclone type is better than the other. Some snow particles were assumed to have escaped from the outlet of the metyelemeter. At low wind speed

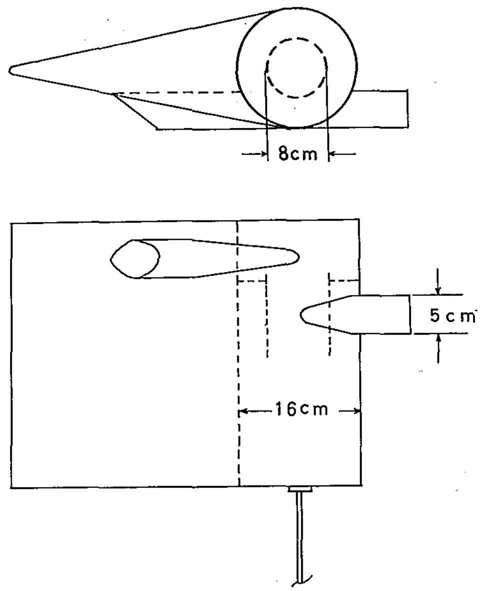

Fig. 2. Cyclone type collector

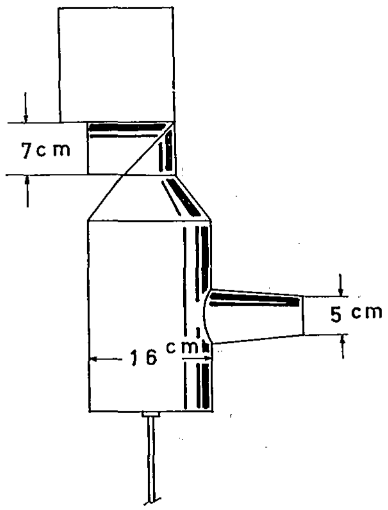

Fig. 3. Metyelemeter

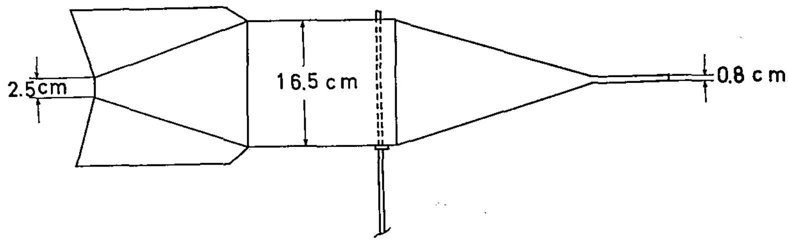

Fig. 4. Rocket type collector

Table 1

Height (cm)	Wind speed at the height (m/s)	Collector	Mass flux at mouth (g/cm²·s)
5.0	5–6	Cyclone type	2.9×10^{-2}
		Metyelemeter	2.4×10^{-2}
2.5	2–3	Cyclone type	3.4×10^{-3}
		Metyelemeter	5.7×10^{-3}

the metyelemeter is better, because the resistance to wind passing through it is smaller than the other.

III. Vertical Profile of Wind Speed and Surface Roughness

It is important to know the wind structure near the surface when the blowing snow is occurring.

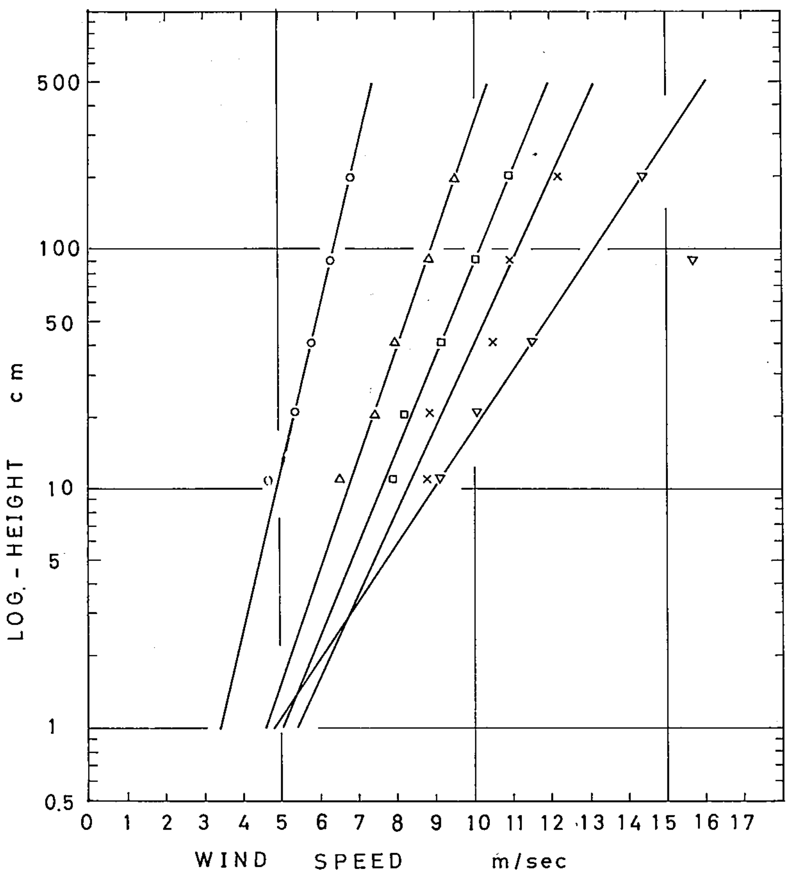

Fig. 5. Vertical distribution of wind speed in the field during blowing snow

We have applied the data of wind speed measured both in the tunnel and in the open to two equations, *i.e.* the logarithmic law and the power law.

Logarithmic law

In a neutral condition of the atmospheric stability the vertical profile of wind speed u is expressed by eq. (1).

$$u = \frac{V_*}{k} \ln \frac{z}{z_0} = 5.75\ V_* \log \frac{z}{z_0}\ . \tag{1}$$

Where V_* is the drag velocity, k is the Kármán constant which is equal to 0.4 and z_0 is the roughness parameter. On December 17, 1965, the vertical profile of wind speed was measured during blowing snow in the First Experimental Farm of the Hokkaido University. The heights of the three cup anemometers were 11, 24, 41, 91 and 201 cm above the snow surface. The vertical distribution of wind speed is shown in Fig. 5. If eq. (1) is applicable, the values of z_0, *i.e.* the height at which the wind speed is zero, becomes 0.0042–0.11 cm. This value tends to increase when the wind speed increases as shown in Fig. 6.

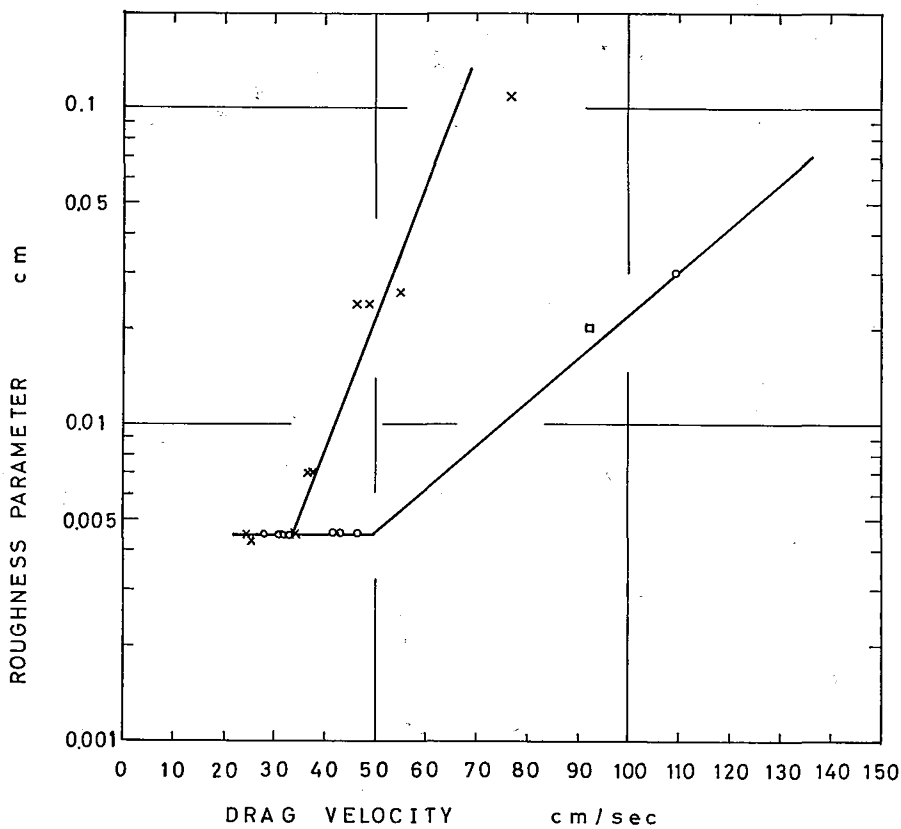

Fig. 6. Roughness parameter z_0 versus drag velocity V_*

○: Wind tunnel
□: Wind tunnel (the value calculated from Fig. 14)
×: Field

In the wind tunnel the distribution of wind speed with height and the movement of snow particles in the air flow were obtained over a new snow surface (the density of surface snow was 0.068~0.104 g/cm^3). In Fig. 7 the measured values of the wind speed and the height have been plotted against a scale of log-height. The values of z_0 converge on 0.0045 cm except when the wind speed at 15 cm level above the snow surface on the central line of the tunnel exceeds 10 m/sec (which correspond to $V_* =$ 50 cm/sec). In the range of high wind speed, roughness parameter z_0 tends to increase as shown in Fig. 6. The difference of the value z_0 between the field and the tunnel may explain the difference of the horizontal mass flux of the blowing snow, *i.e.* in the field when the wind speed is about 5 m/s it was 2.94×10^{-2} g/cm^2·s at 5 cm above the snow surface, on the other hand in the wind tunnel it was a small quantity. If the value of z_0 is 0.0045 cm, the roughness length K can be calculated by the equation $K = 30 \times z_0$, by which $K = 0.135$ cm. This value is comparable to the size of the snow particles.

Though the roughness parameter z_0, namely the height where no wind blows was estimated, somewhat curious results were found. The wind speed measured by the hotwire anemometer buried as shown in Fig. 8 at about 0.5 cm below the snow surface was not zero, but more than 0.3 m/s. The results are shown in Fig. 9. It may be

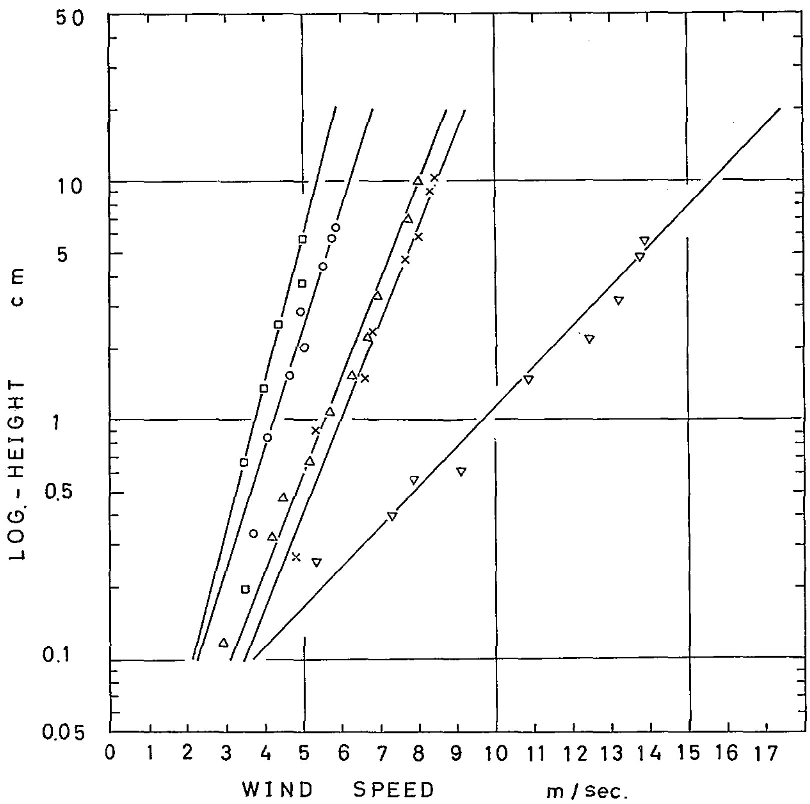

Fig. 7. Vertical distribution of wind speed over snow surface in the wind tunnel

noted that the hotwire anemometer can not detect the direction of the wind. Even if the vector sum of the wind velocity is zero, the scalar sum of the wind speed will not be zero. However, it was confirmed by Pitot tube that the wind velocity under the snow surface is not zero, though the snow around the Pitot tube was soon blown off, and the wind speed could not be measured.

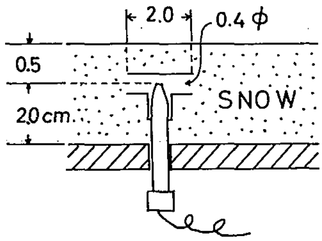

Fig. 8. Scheme of hotwire anemometer under the snow surface. It has a cap of horizontal tube being open at its ends

The drag velocity and shearing force

The distribution of wind velocity gives not only about the roughness of the surface, but also the drag velocity V_* and shearing force $\tau=\rho V_*^2$, where ρ is the density of air. The drag velocity and shearing force determined from the distribution of wind speed both in the tunnel and in the field are shown in Table 2. If the roughness parameter z_0 is a constant at any wind velocity, the relation between V_* and V_s which is the wind speed at height s is theoretically a linear line. The case is found in the wind tunnel as shown by the straight line in Fig. 10. But the curve for the field in Fig. 10 shows that the roughness parameter z_0 changes with the wind speed. At any rate, Fig. 10 is useful to find V_* from the measurement of the wind speed at one convenient known height s.

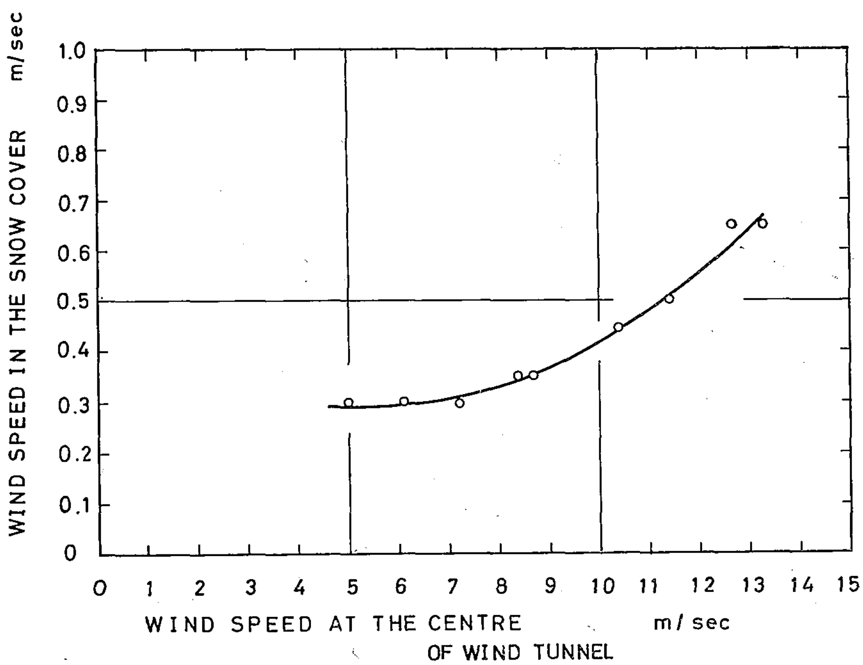

Fig. 9. Speed of air movement in snow with the method as shown in Fig. 8 in relation to the wind speed at the center of the wind tunnel

Table 2 Constants of the logarithmic law

In the field				
V_s (m/s)	V_* (cm/s)	τ (dyn/cm^2)†	z_0 (cm)	Date of observations
6.35	25.2	0.86	0.0043	Dec. 17, 1965
6.4	24.4	0.805	0.0045	"
8.7	33.9	1.55	0.0045	"
8.9	36.6	1.80	0.007	"
9.1	37.4	1.89	0.007	"
9.85	46.1	2.86	0.024	"
10.2	48.7	3.20	0.024	"
11.35	54.8	4.06	0.026	"
13.2	76.6	7.92	0.11	"

V_s: Wind speed at a height of 100 cm above the snow surface.
† In calculation of τ, the air density 1.35×10^{-3} g/cc at 0°C is used.

In the wind tunnel				
V_c (m/s)	V_*' (cm/s)	τ (dyn/cm^2)††	z_0 (cm)	Date of experiments
5.5	27.8	1.08	0.0045	Mar. 19, 1966
6.0	31.3	1.37	0.0045	Jan. 24, 1966
6.1	31.3	1.37	0.0045	Feb. 19, 1966
7.3	33.1	1.53	0.0045	Mar. 19, 1966
8.0	41.7	2.54	0.0045	Feb. 10, 1966
8.5	43.5	2.65	0.0045	Feb. 10, 1966
10.0	47.0	3.09	0.0045	Mar. 19, 1966
14.0	109.5	16.8	0.03	Jan. 11, 1966
6.0	30.5	1.30	0.00076	Above wooden surface
8.0	31.3	1.37	0.00014	May 25, 1966
15.0	53.0	3.93	0.00002	

V_c: Wind speed at the center of the wind tunnel, namely at a height of 15 cm above the snow surface.
†† In calculation of τ, the air density 1.40×10^{-3} g/cc at -10°C is used.

Power law

The power law is usually written in the form

$$\frac{u}{u_1}=\left(\frac{z}{z_1}\right)^{\frac{1}{n}}, \tag{2}$$

where u is the wind speed at height z and u_1 is the wind speed at the constant reference height z_1. In order to find the power parameter n, the values of wind speed ratio u/u_1 at various heights with a ratio of z/z_1 are plotted in Fig. 11 in log-scale both in

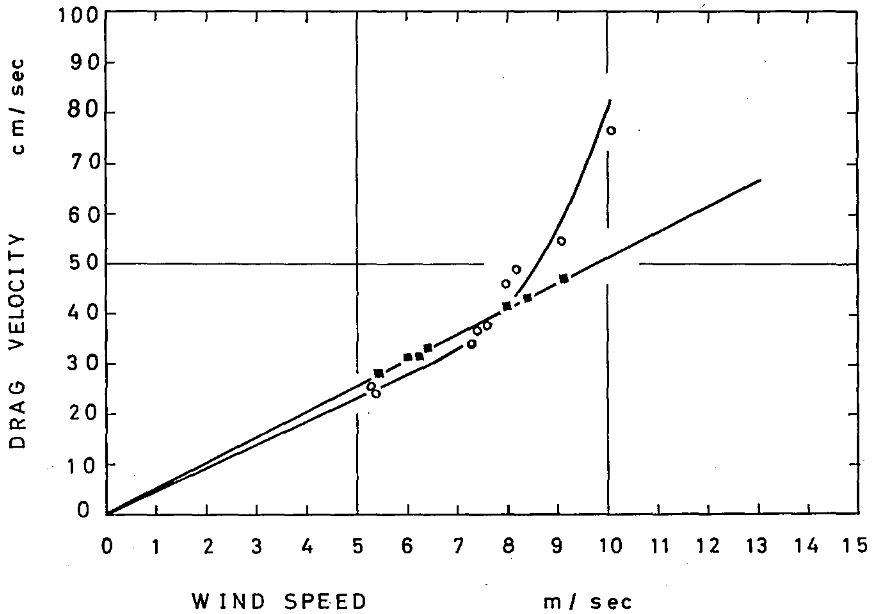

Fig. 10. Drag velocity V_* versus wind speed V_s at height s

■ : Wind tunnel, $s=10$ cm; ○ : Field, $s=20$ cm

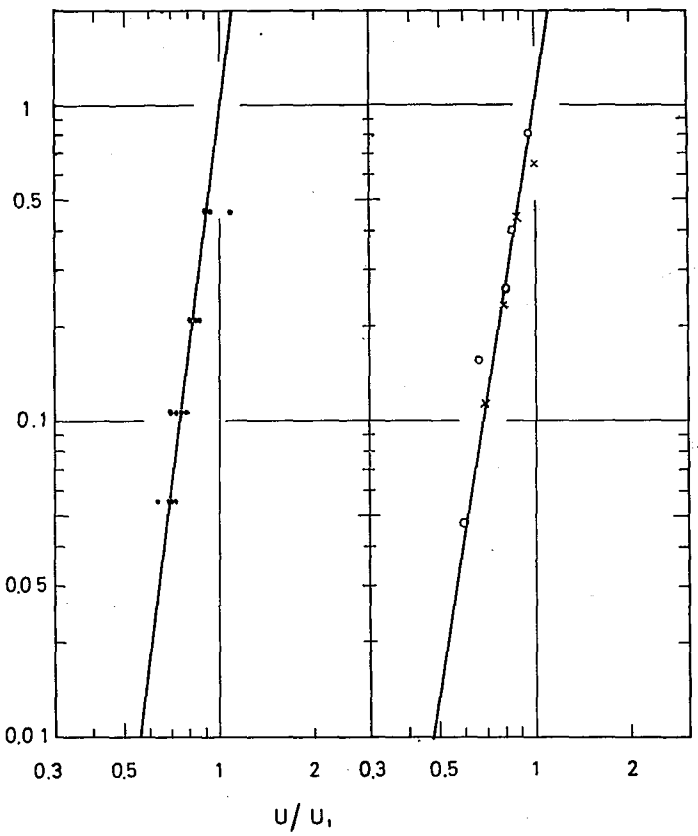

Fig. 11. Relation between wind speed ratio u/u_1 and height ratio z/z_1 in log scale

the tunnel and in the field. In the field the speed at the height of 201 cm is taken as a standard. When the values of drag velocity are 25.2 to 76.6 cm/s it was roughly in neutral condition, *i.e.* the value of n equals 8. In the tunnel the velocities at the center of the tunnel, namely at 15 cm above the snow surface is taken as a standard and the value of n is found to be equal to 7, therefore, its condition is in neutral stability.

IV. Behaviour of Snow Particles Blown by Wind

a) *Height of blowing snow.* The height of the blowing snow was observed with the aid of a black metal plate set up as a background. We tried to observe the height of blowing snow for only two days, so that the numerical data are not sufficient. The first observation was on January 1, 1966. The weather was fine and there was no snow fall. The temperature of snow at the surface layer was $-4.8°C$. The results are tabulated as follows.

The instantaneous wind speed at the heigh 20 cm (m/s)	3	4	5	7–8
The height of the blowing snow (cm)	1–2	2–3	20	more than 200

The second observation was on March 30. There was also no snow fall and the temperature of snow was $-10°C$. We observed very low blowing snow at wind speeds of 4.5 m/s and the level of the top of blowing snow became higher than 30 cm as soon

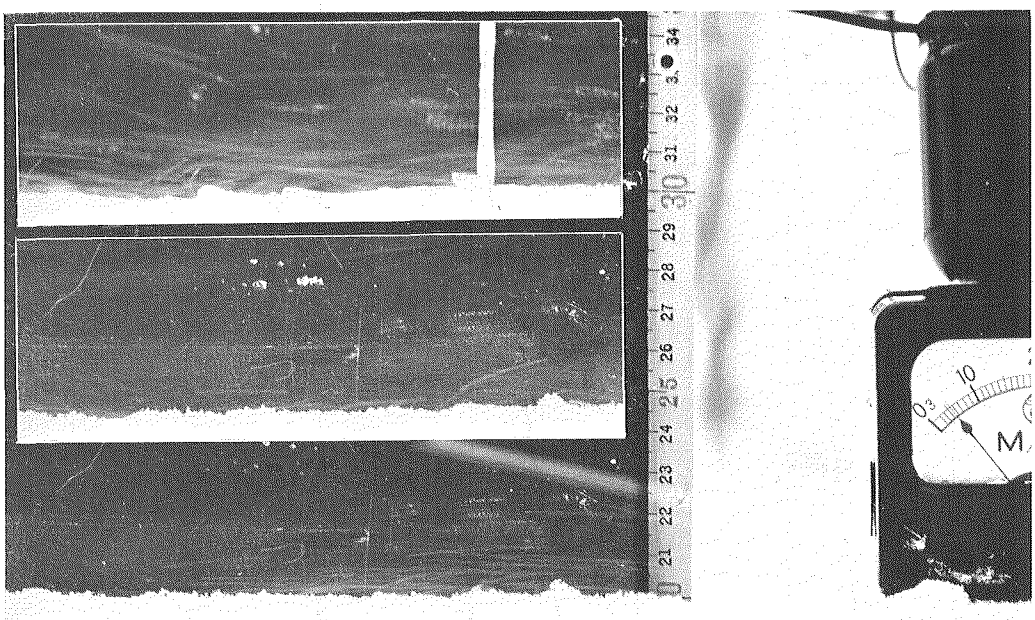

Fig. 12. Trajectory of snow particles in field. The indicater of the wind speed and the trajectory of snow in front of the black plate are photographed on a same film. Two other photographes which show only the part of trajectory, are attached on the upper left of this photograph

as wind speed exceeded 6 m/s. According to these few numerical data, it seems that when the wind speed at 20 cm level above snow surface exceeds about 5–6 m/s, the suspension of snow particles take place and when the speed is lower than 5 m/s transportation occurs mainly by creeping or by saltation.

b) *Trajectory of blown snow particles.* There are two ways for a snow particle to be removed from the surface of snow cover. One way is the removal by the direct drag of wind and the other way is by the impact of a snow particle flying down the wind. It is said that the latter way prevails in a sand storm (Bagnold, 1954), but it is not certain in blowing snow. At first we intended to take photographs of the paths of snow particles and to confirm the existence of the latter phenomenon referred to as *saltation* by Bagnold. We also intended to find the velocity of snow particles in the same photograph with the aid of illumination by strobolight. We used a black plate as a background and a lens of a long focal length of 135 mm, because it can make a image of large magnitude from long distance.

In Fig. 12, photographed at the field, we can see the indicator of the magneto anemometer and the black plate standing on the snow surface with a scale. Near the

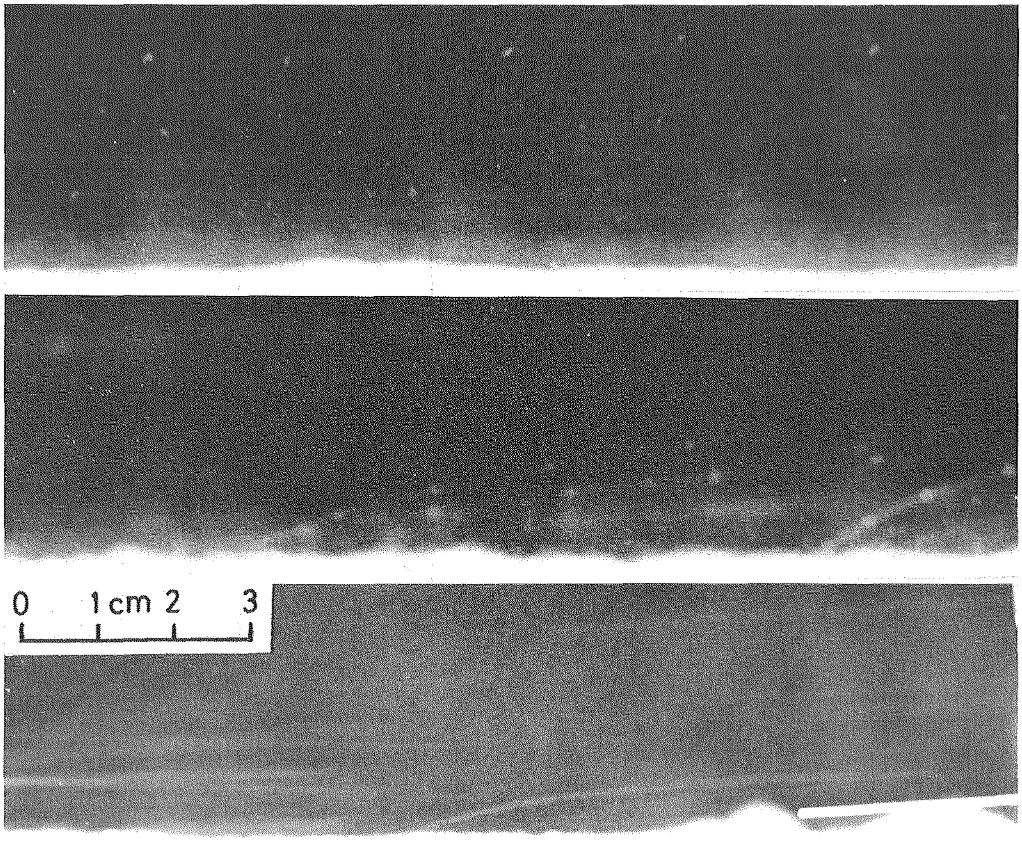

Fig. 13. Trajectory of snow particles in wind tunnel. Series of spots were made by strobolight flashing every 5 ms

snow surface, we can find some trajectories of snow particles which we think are evidence of the saltation. Since the speed of the descending particle is so high and the angle between the direction of incidence and the snow surface is so small, the process of the collision followed by the ejection can not be traced. As the number of the trajectories which start from the snow surface of 15 cm in length is about 5, and the exposure time of the photograph is 1/60 s, the number of the particles ejected from the surface when the wind speed at a level of 20 cm above the surface is about 5 m/s, is about $20/cm^2 \cdot s$.

The photographs taken in the wind tunnel are shown in Fig. 13. Two of them are taken under the illumination of incandescent light and the strobolight which flashes for 5 μs every 5 ms. The light is introduced in the wind tunnel through a slit, in such a way that only the bounded space is illuminated. In favour of the strobolight, the positions of a particle at every 5 ms are found as a series of white spots on the photograph. From the distance of spots on the trajectory, the speed of the particle can be calculated. The acceleration can also be obtained for the particle which does not have a constant speed and constant direction. For a particle which has a constant velocity, that is, for a particle which has a parallel trajectory to the snow surface and for which the distances between the neighbouring spots on its trajectory are the same on the photograph, we assume that the velocity of the particle is the same as that of the

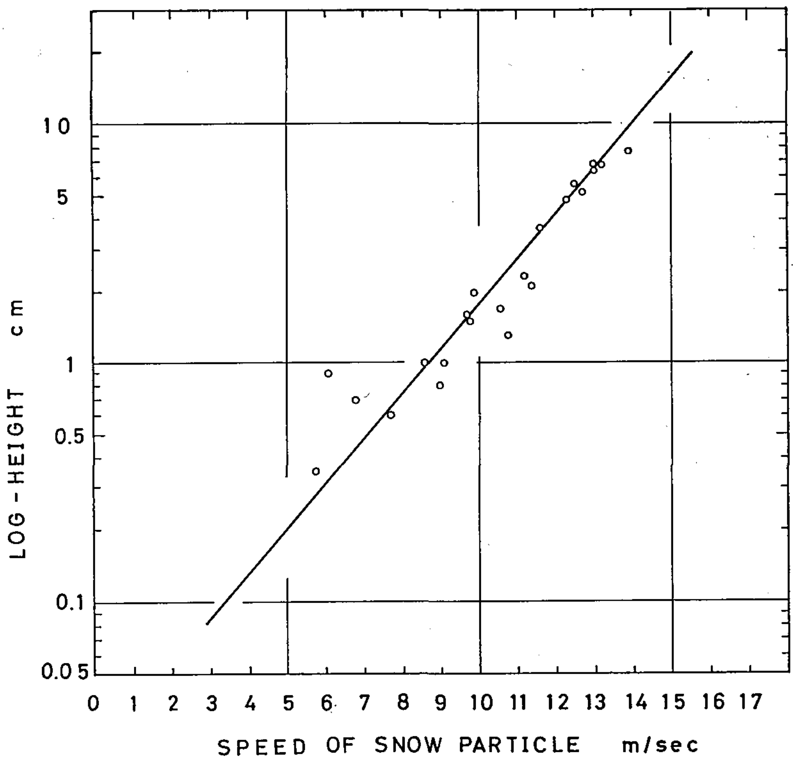

Fig. 14. Vertical distribution of wind speed calculated from the motion of snow particles

velocity of the surrounding air. Thus, the wind speed at each height can be obtained. The results are shown in Fig. 14. If we adopt the logarithmic law, the roughness parameter z_0 becomes about 0.02 cm. As the drag velocity for this experiment is about 92 cm/s, the point for this experiment drops just on the curve for the wind tunnel in Fig. 6 (*cf.* mark □).

V. Relation between the Temperature and the Generation of the Blowing Snow

It is a well known fact in Antarctica that the blizzards blowing in winter, hardly occur in summer, even in days when a strong wind is prevailing.

The temperature and the wind speed in blowing snow with no snow fall which was recognized in the meteorological observations made every three hours at the Syowa Station, are plotted in Fig. 15. In the figure, there is nothing to indicate whether it snowed three hours before or whether it had not snowed for several days. On the temperature and the wind speed diagrams, there is the domain of the blowing snow

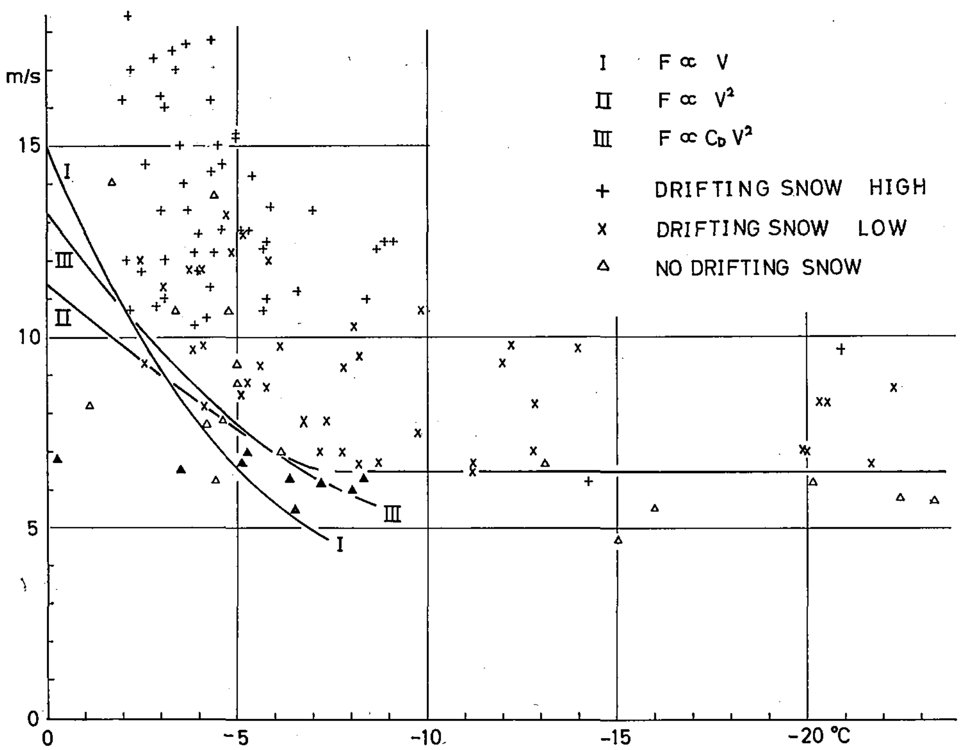

Fig. 15. Domains of no-blowing snow and blowing snow with no snow fall on air temperature—wind speed diagram. Data of August, December 1961 and 1962 January at Syowa Station are plotted. Curves I, II and III are drawn under the next assumptions.

Curve I: $F \propto V$, Curve II: $F \propto V^2$, Curve III: $F \propto C_D V^2$

F: Force necessary to separate a snow particle from snow surface, V: Wind speed, C_D: Drag coefficient and the domain of no blowing snow. Though the boundary is not clear, we can draw a lowest boundary line of the domain of the blowing snow (described as the drifting snow in Fig. 15). This line consists of two parts. One part is made of a curve showing the decreasing wind speed with decreasing temperature for a temperature range of 0 to about $-7°C$. The other part is made of a horizontal straight line showing a constant wind speed of about 6.5 m/s for a temperature range of about -7 to $-23°C$ or a much lower temperature. In a temperature range of a straight line, the mechanism of the blowing snow is thought to be similar to that of a sand storm, that is, it is thought that there is no cohesive force between the snow particles as in the sand particles or even when there is a slight force, it does not affect the mechanism of the blowing snow. Considering that the wind speed is the value at a level of 5 m above the ground surface and assuming that the vertical distribution of wind speed obeys the logarithmic law and that the roughness parameter for the law is 0.0045 cm, then the wind speed 6.5 m/s corresponds to the drag velocity 22.4 cm/s. This is the same as the drag velocity corresponding to the fluid threshold of sand whose mean diameter is 0.2 mm (Bagnold, 1954). Though the mean diameter of the blown snow is not certain, according to the observation of Ôura (1966), the size corresponding to the median of cumulative frequency is about 0.1 mm and the size corresponding to the median of cumulative volume was 0.2 mm. Thus, the threshold values of the drag velocity for both snow and sand of the same size are found to be of the same magnitude. In higher temperature, the cohesive force can not be neglected. As the cohesive force increases with the air temperature, the threshold value of wind speed also increases with the air temperature.* Using the experimental relation between the cohesive force of ice and the temperature which was obtained by Hosler, Jensen and Goldshlak (1957), the relation between the threshold wind speed and the temperature was calculated. As the real mechanism of the occurrence of the blowing snow is not known, the absolute values can not be calcurated. But the relative value is able to be calculated. We expect three types of relations between the forces exerted on snow particles and the wind speed. The first is the case in which the force is proportional to the wind speed. The second is the case in which force is proportional to the square of the wind speed. The third is the case in which the force is proportional to the product of the drag coefficient C_D and the square of the wind speed. The drag coefficient is a function of the Reynolds number Re. Therefore it is a function of the wind speed. The Reynolds number in this case is about 100. In this range of the Reynolds number, $\Delta C_D/C_D \doteqdot -0.52\,(\Delta Re/Re) = -0.52\,(\Delta v/v)$ for the same snow surface. Three curves are shown in Fig. 15, but as the observation is not so accurate, it is difficult to select the best. If we are compelled to make a choice, the second relation will be selected. In other words, the force necessary to separate a snow particle should be proportional to the square of wind speed. Sato (1962) presented a similar diagram Fig. 16 which was obtained in the Asahigawa area in Hokkaido; Sato selected a day of the blowing snow with no snow fall. From the rela-

* The surface tension must be considered for the particles which have such a small radius as 0.1 mm. But, the change of surface tension with the temperature is not sufficiently remarkable to explain a large change of threshold wind speed by the changes of surface tension. An experiment for the cohesive force between such small particles is desirable.

tion between the threshold wind speed and the temperature, the first relation between the force and wind speed seems to be the best. That is, the force seems to be proportional to the wind speeds. The authors observed the threshold wind speed in the field by setting up a black metal plate for the detection of flying snow particles and also used a wind tunnel with a black background and made a similar diagram Fig. 17. The temperature shown in Fig. 17 is that of the snow surface measured by an alcohol thermometer. The wind speed was measured at a level of 20 cm above the snow surface in the field with a magneto anemometer which indicates instantaneous wind speed, and 15 cm above the snow surface in the wind tunnel with a hotwire anemometer or a Pitot tube. The threshold wind speed in the field seems to be constant at temperatures lower than $-2.5°C$. As the observations were made just after the snow fall, the conditions are different from that for Figs. 15 and 16. All observations in the wind tunnel were made at a temperature

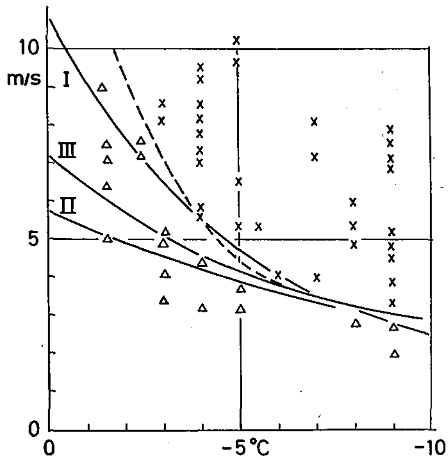

Fig. 16. Domain of blowing snow (×) and no blowing snow (△) on air temperature—wind speed diagram after Sato. Observation on the day of no snow fall in the Asahigawa area

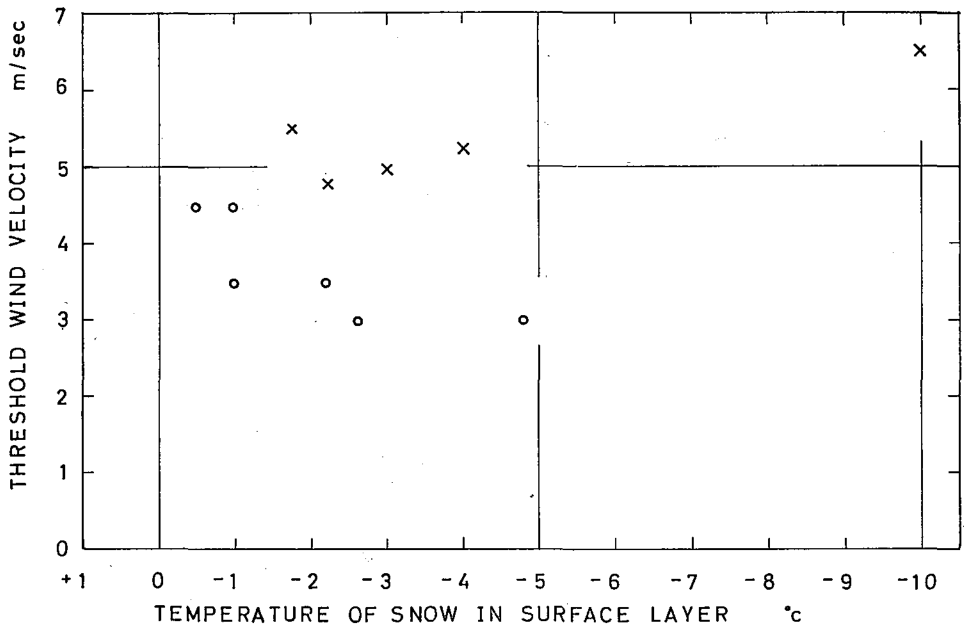

Fig. 17. Threshold wind speed versus temperature of snow surface

×: Wind tunnel, ○: Field

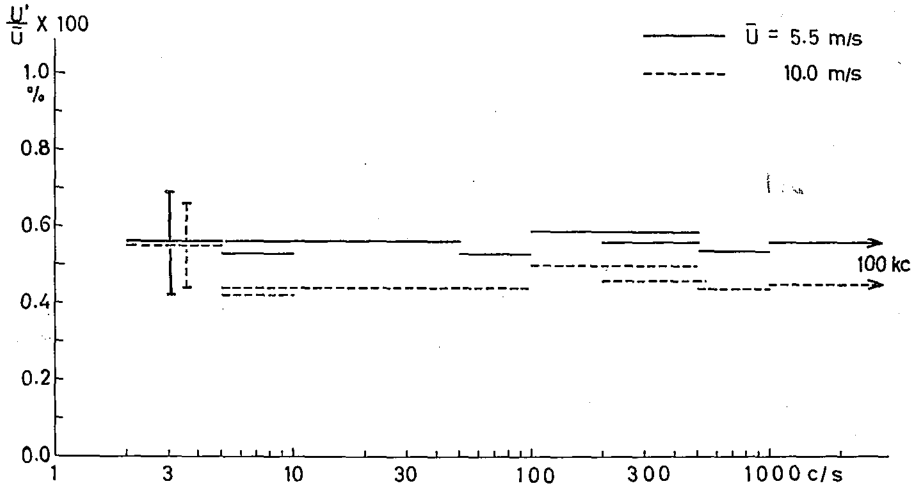

Fig. 18. Intensity of turbulence in wind tunnel

of $-10°C$, however, the temperature of the snow sample at the time when it was taken in the wind tunnel was plotted in Fig. 17. Each run of experiments was commenced about one hour after the sampling. The threshold wind speed is 3 m/s in Fig. 17 and corresponds to the drag velocity 15 cm/s. This value is a little lower than the value for Fig. 15. There are two different conditions between the phenomena in the field and that in the wind tunnel. Firstly, the turbulence in the wind tunnel is smaller than that in the field, so that it is more difficult for the wind in the tunnel to pick up snow particles. The intensity of turbulence in the wind tunnel is not more than 1% as shown in Fig. 18, whereas that in the field is usually 20–30%. Secondly, there is no supply of snow particles in the wind tunnel from the upper wind, so that there are no snow particles ejected by bombardment at the windward part in the wind tunnel. When snow particles were fed into the wind of tunnel, the particles on the snow surface are ejected out and drifted away even though the wind speed is below the critical value found in the case without the additional supply of snow particles. In these observations, we have not checked the texture of snow cover, so we could not know the force for direct disaggregation. In any event, it is desirable to make numerous observations and to determine the relation between the threshold wind speed, the air temperature, the humidity, the size and the history of snow particles.

VI. Effect of Parallel Trenches on Drifting Snow

It would be interesting to know the required length of a snow field surface for the wind to develop into blowing snow. If we could remove all snow particles floating in the air at a vertical imaginary plane perpendicular to the wind, in other words, if we could produce a hypothetical wind containing no snow particles on the plane, the leeward snow field of the plane would become an ideal field for the investigation of generation of blowing snow. The authors observed two parallel wheel tracks of a tractor on a snow road with the windward wheel track partly buried by the drift snow,

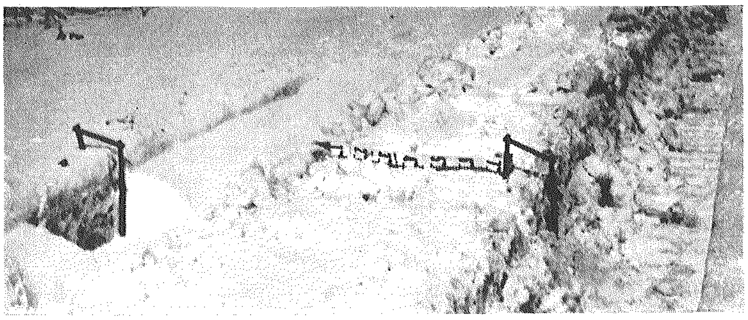

Fig. 19. Vertical section of track of wheels. Only left trench is buried by drifted snow

while no drift snow was found in the leeward wheel track. The vertical section is shown in Fig. 19. The maximum wind speed was 6 m/s* after the tracks were made, till we took the photograph. The road led due north and the wind direction was NNW. The air temperature was about −2°C. This photograph shows that the distance of the wheel was about 1 m, therefore the length of the snow field along the wind direction was about 2.5 m. Therefore, it was found that under such a meteorological condition, no apreciable drifting snow was generated in the course of wind on the snow field 2.5 m in length.

The authors dug two parallel trenches in the snow field perpendicular to the prevailing wind direction. The size of the trench was 2 m in width, about 0.7 m in depth and 20 m in length. The distance of the two parallel trenches was 10 m. These trenches were made on the Experimental Farm of the Hokkaido University. The windward space was about 500×500 m and the leeward space was about 250×250 m. In the vertical profile of horizontal mass flux of the blowing snow, the value at low level is very large. About 90% of all snow particles blown by the wind are drifting in the layer, lower than the level of 20 cm above the snow surface. Therefore the above mentioned trenches were expected to catch about 90% of blown snow.

The wind speed became strong from 0000 hours on January 30, and lasted until February 2. Almost all parts of the windward trench were buried with drifted snow at 1400 hours on January 30. During the time, the maximum value of wind speed which is the mean for 10 minutes was 5.3 m/s*, the maximum instantaneous wind speed was 13.0 m/s* and the prevailing wind direction was WNW. The air temperature was in an range of −6.2 to −8.5°C. At 0200 hours ashes were sprinkled over the snow field. At 1400 hours blue water was sprayed over the snow. The duration of the wind with a speed larger than 4.5 m/s* was about 2 hours from the time of the beginning of the drifting snow to 0200 hours, and it was about 4 hours from 0200 hours to 1400 hours. After the snow storm abated, a vertical section of trenches was made as shown in Figs. 20 and 21. In these sections, we were able to see a brown line and a blue line as the time mark at 0200 hours and 1400 hours. By the measurement of snow density,

* This is the observed value at Sapporo District Meteorological Observatory. The height of the anemometer is 19.9 m. The value 4.5 m/s at this height seems to correspond to the threshold wind speed 3 m/s at the 20 cm level above snow surface.

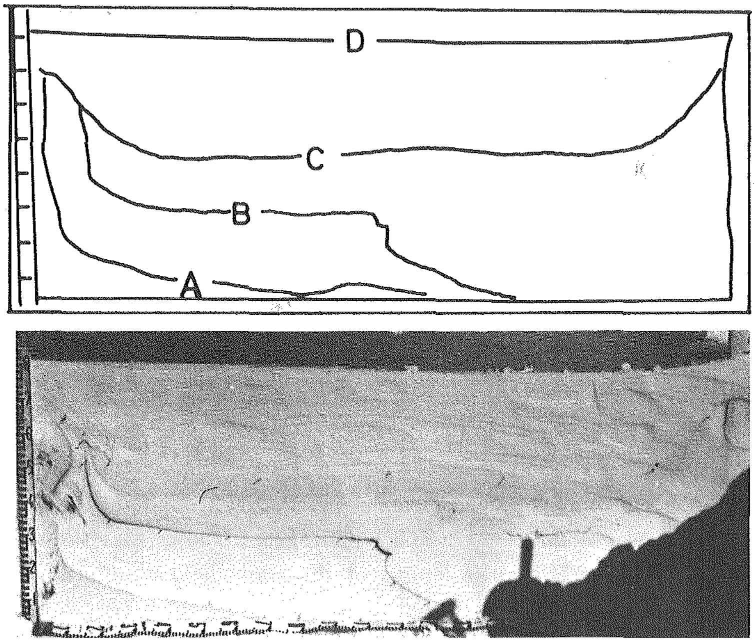

Fig. 20. Vertical section of windward trench

A:	January	30	0000	hours	
B:	"	"	0200	"	Ash line
C:	"	"	1400	"	Blue line
D:	"	31	1500	"	Blue line

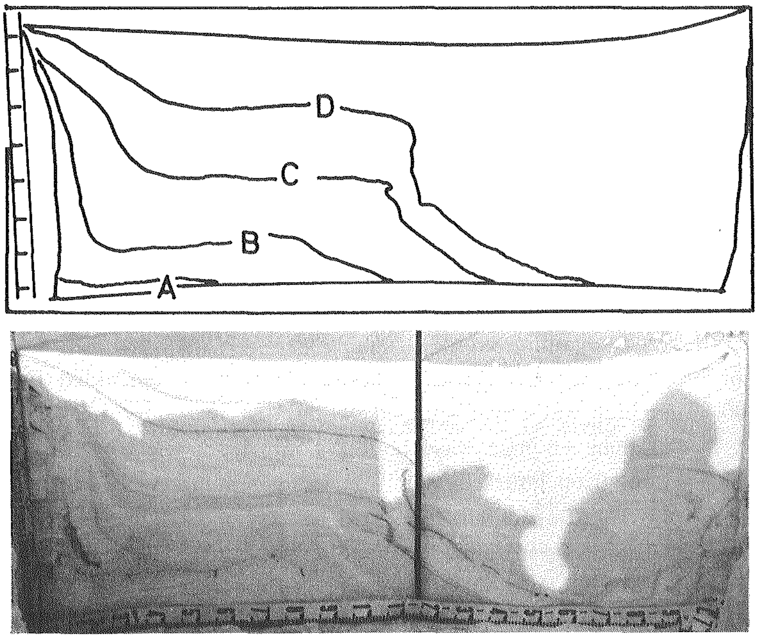

Fig. 21. Vertical section of leeward trench.
A, B, C and D are equal to that in Fig. 20

the weight of drifted snow could be estimated. It was found that the amount of drifted snow in the leeward trench was about 0.55 times as much as that in the windward trench in the first stage, and 0.40 in the second stage. Thus the rate of amount of snow drifted in these trenches seemed to be in a range of 0.4 to 0.55. The distance of these trenches in the wind direction was about 11 m ($\fallingdotseq$10 m/cos 22.5°). A course of about 20 or 30 m on a snow field seems to be sufficient for the wind to develop into a stationary state of blowing snow.

If we assume that the amount of snow drifted in the leeward trench is equal to the amount of snow removed from the snow field lying between the two trenches, we can calculate the weight of snow removed from a unit area of snow surface in one second from the estimated amount of drifted snow. This was about 4.6×10^{-5} g/cm$^2\cdot$s. If we assume that the mean particle is a sphere which has a radious of 0.1 mm, the weight of the particle is about 3.7×10^{-6} g. Using this value, we can calculate that the number of particles removed from a unit surface area in one second is about 12/cm$^2\cdot$s. This is approximately equal to the value 20/cm$^2\cdot$s obtained from the photograph Fig. 12 in section IV.

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