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On the Change in the Shallow Ground Water Level (Continued)

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Abstract

In the previous paper[9], the writer described the change in ground water level due to rainfall throughout the seasons excluding winter. In the winter months in Sapporo from January through to March snow abounds with little rain. Accordingly, the precipitation in this period is mainly snow. It follows that the change in the ground water level depends largely on the snow, and the source of the ground water is the infiltration of water from melting snow. Now, since the melting of snow depends chiefly on air temperature, the change in the ground water level may be considered to be related directly with the air temperature. Thus, in this paper, the writer has considered the relation between the change of water level and the air temperature.

5. Change of the ground water level during the winter period

In winter months from January through to March in Sapporo, Hokkaidô very little rain is seen with abundant snow, and generally speaking, the ground surface is covered with snow during these months. Thus, the supply of ground water is chiefly considered to be the infiltration of water from the melting snow. Thus in the present paper, the writer has attempted to express the relation between the change of water level and the air temperature upon which the melting snow depends.

5. 1. *Day by day change of ground water level*

When the water from the melting snow infiltrates into the ground, the ground water level should rise. Fig. 12 shows the progress of the change in the ground water level expressed by the height from the base level. In Fig. 12, let H_0 be the height at time zero. If there is no supply into the ground water table, from (2–4)[9] the water level should follow the broken line in the same figure, and in such a case the height h' after 24 hours may be expressed as

$$\frac{h_0 - h'}{h_0 - H_0} = e^{-\lambda} \qquad (5\text{–}1)$$

Accordingly

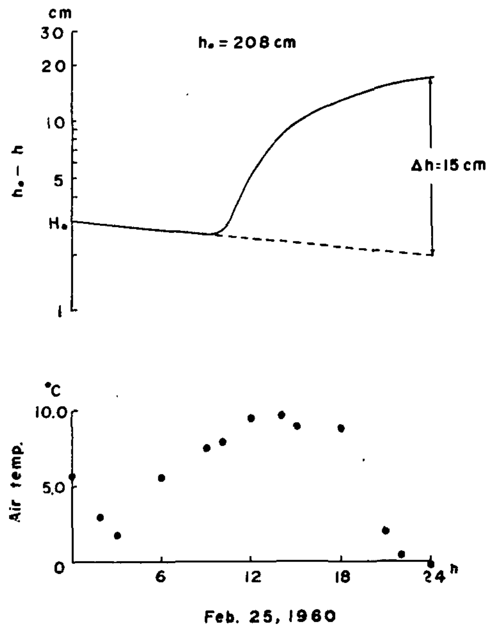

Fig. 12-1.

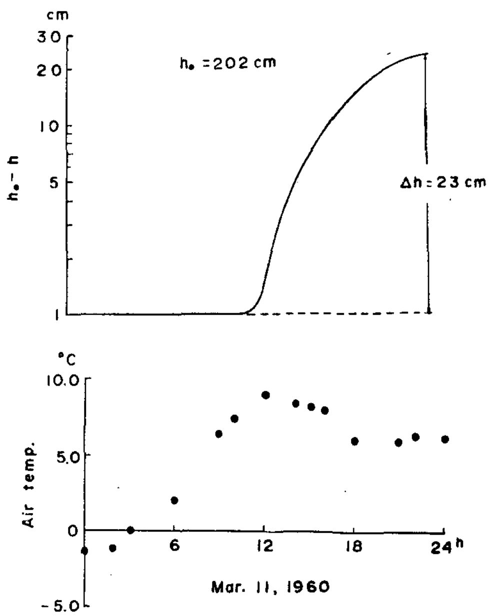

Fig. 12-2.

Fig. 12. Changes of h_0-h and air temperature on Feb. 25 and Mar. 11, 1960.

$$h' = h_0 - (h_0 - H_0)\, e^{-\lambda} \tag{5-2}$$

where h_0 is the base level and λ is 0.25 1/day. The height of the ground water level here and the base level are expressed by the depth from the ground surface, their units being cm as in Fig. 2[9].

On the contrary when there is a positive supply, the water level rises as shown by the solid line in Fig. 12. If h is the height after 24 hours in this case, the rise of the ground water level per day may be given as

$$\Delta h = h' - h \tag{5-3}$$

In winter, the main supply into ground water may be considered as melting snow. In such a case, the water from the melting snow arrives at the ground surface by passing a water route in the snow cover. In regard to this, ISHII[10] demonstrated that the water route is not always perpendicular, but it is frequently horizontal. And investigations on the amount of the melting snow has been made by some investigators. According to these reports, air temperature is the chief factor which governs the transmission of heat to the snow from the atmosphere. Accordingly, the water level changing by the infiltration of the melting snow may be expected to change by the air temperature, and Fig. 12 shows the progress of the change in the water level by air temperature. Further, as to the amount of melting snow due to air temperature, ISHII[11] stated that the melting snow per day was approximately proportional to the sum total of air temperature above 0°C for each hour during one day, and the sum was expressed by degree-hours. WISLER and BRATER[12] described that the melting snow per day was proportional to the difference between the average daily air temperature and the base temperature, both in Fahrenheit.

5.2. *Relation between Δh and degree-hours*

The writer measured the air temperature by self-recording thermometer from Feb. 13, 1960 to Mar. 26, 1960, and obtained the number of degree-hours from the record. And Fig. 13 is the relation between the degree-hours and Δh obtained from (5–3).

The change of the air temperature during a single day comes under the types given as A, B and C in Fig. 14. The air temperature of A type is always less than 0°C, while B type is either over or under 0°C, and C type is always more than 0°C.

When the degree-hours is more than 50°C-hr, the type of the air temperature generally comes under B or C. The open circles in Fig. 13 are the

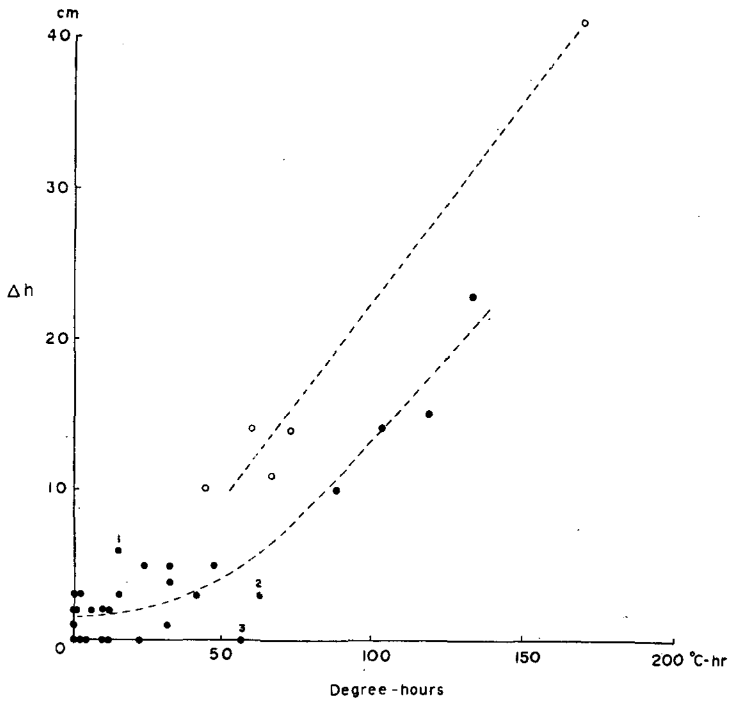

Fig. 13. Relation between Δh and degree-hours.

cases of C type. Moreover at each corresponding midnight, the cloud volume for all open circles was 100%, and the radiation from the snow surface was small. Thus, it may be considered that the snow surface frequently melts even at midnight. The solid circles for the same degree-hours belongs to B type. The air temperature at the midnight was always lower than 0°C, the cloud volume did not come to 100%, and the radiation was considered to be fairly large. Hence, it is considered that the snow temperature at midnight is lowered due to low air temperature and radiation. Thus, the conditions of the melting snow for B and C types are quite different in that the snow for C type often melts at the midnight, while B does not. Inasmuch as the heat of fusion of ice is 80 cal/g, the heat condition of C type should be 80 cal/g above B type, implying that the melting snow for both types are different. While the rise of ground water level depends on the melting snow, the rises for both types should be different as in the case of melting snow.

The solid circle 1 may be considered to indicate the abnormal rise brought

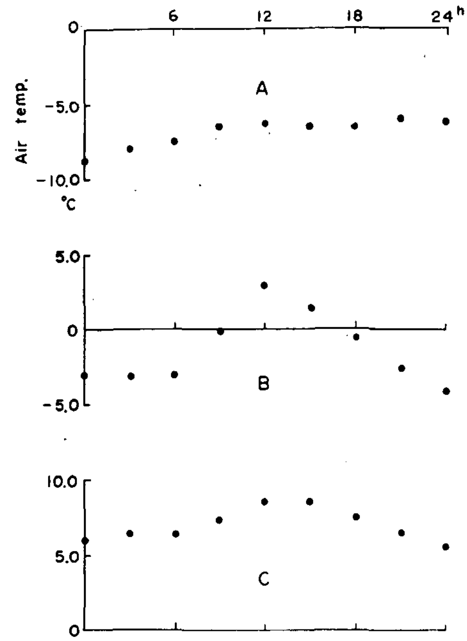

Fig. 14. Various types of the air temperature change during a day.

about by passage of a cyclone of which the minimum value is 1000 mmb. The degree-hours for the solid circles 2 and 3 are more than 50°C-hr, but the values of Δh are very small. In the cases of 2 and 3, the minimum air temperatures at midnight were -9.5°C and -8.0°C respectively, and in both cases the cloud volume at midnight was 0%. Thus it may be said that at midnight the snow temperatures are lowered considerably by the above two factors. In this case, a large quantity of heat is used for raising the snow temperature to 0°C from extreme low temperature, and the rise of water level is very small in comparison with other cases of the same degree-hours.

The air temperatures of the solid circles for 0°C-hr are A type. The air temperature of this type is always less than 0°C. It is considered that the heat transmitted by conduction from the atmosphere does not raise the snow temperature to 0°C, and when solar radiation and the condensation of atmospheric water vapor on the snow surface are small, the snow does not melt. The rise of water level in the case of A type may be considered to depend upon other causes.

5.3. *Relation between Δh and mean daily air temperature*

ISHII[13] described that the mean daily air temperature was related to degree-hours of the day. The writer obtained the relation between the degree-hours and the mean daily air temperature which was obtained by averaging the temperatures measured at three hours intervals for the day. The relation of both factors for the same period as in section **5. 2** is given as in Fig. 15. It was revealled that both are strongly related in this period, also.

Fig. 16 shows the relation between Δh and the mean daily air temperature T_m for the period from Jan. 4, 1960 to Mar. 26, 1960 during which the ground surface is covered with snow and it does not rain. For the values of T_m for the period from Jan. 4 to Feb. 12, the data in "The Weather of Hokkaidô"[14] was used. The numerals attached to the solid circles are the dates. Fig. 16–1 shows the relation in January; the air temperatures belong to A type except for 4, 5 and 31 which are B type, and Δh does not depend upon T_m. Fig. 16–3 which gives the relation in March indicates that Δh is approximately proportional to T_m, and the type of the air temperature is B except for 12, 13,

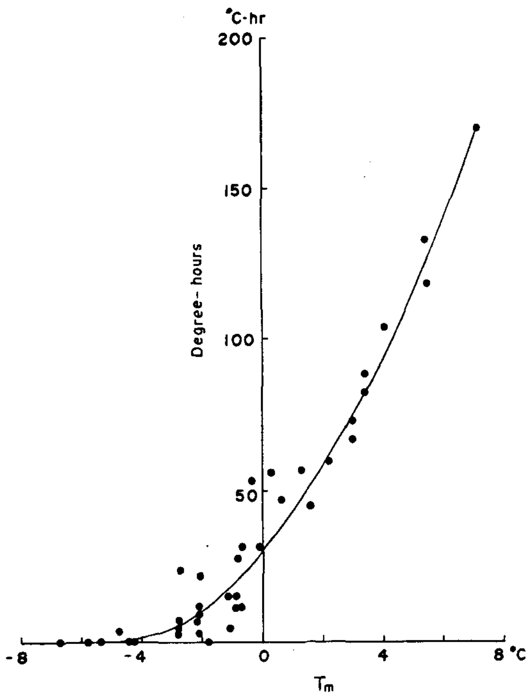

Fig. 15. Relation between degree-hours and T_m.

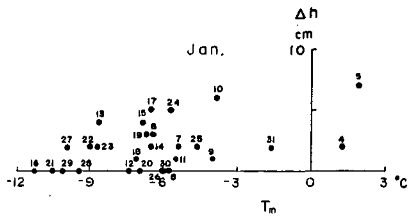

Fig. 16-1

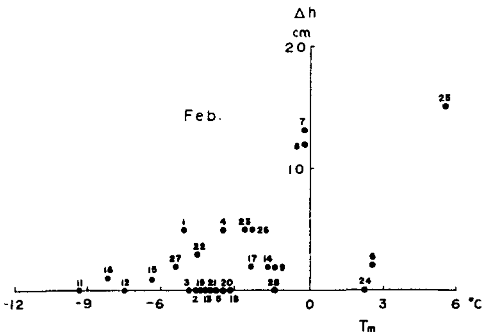

Fig. 16-2

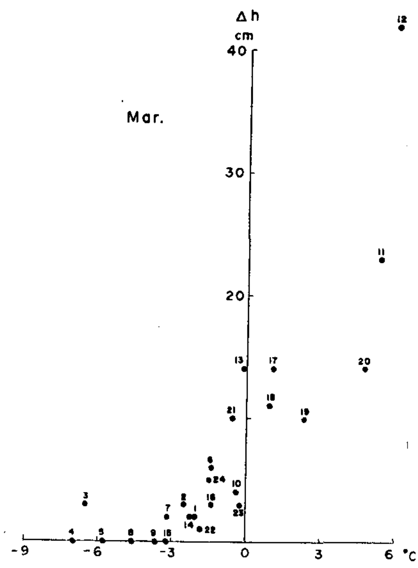

Fig. 16-3

Fig. 16. Relation between Δh and T_m.

17, 18 and 21 which are C type. Fig. 16–2 is the relation in February; the air temperatures belong to A, B or C types with the relation lying between the cases in January and March.

Fig. 17 shows the relation between Δh and T_m in A type, and Δh

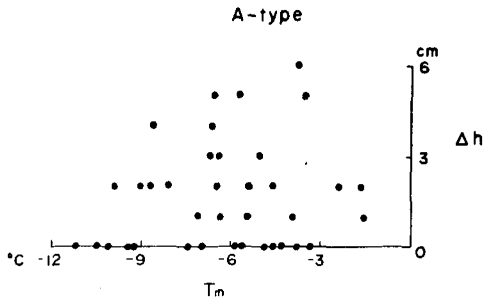

Fig. 17. Relation between Δh and T_m in A type.

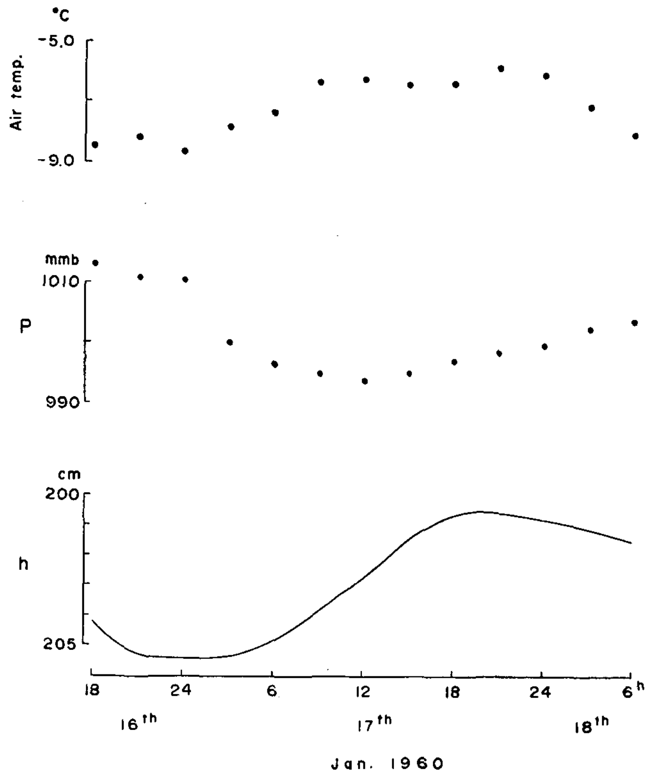

Fig. 18. Changes of air temperature, atmospheric pressure and water level for Jan. 16～18, 1960.

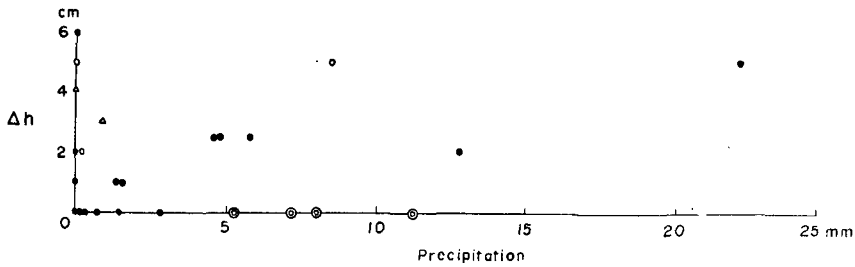

Fig. 19. Relation between Δh and daily precipitation in A Type.

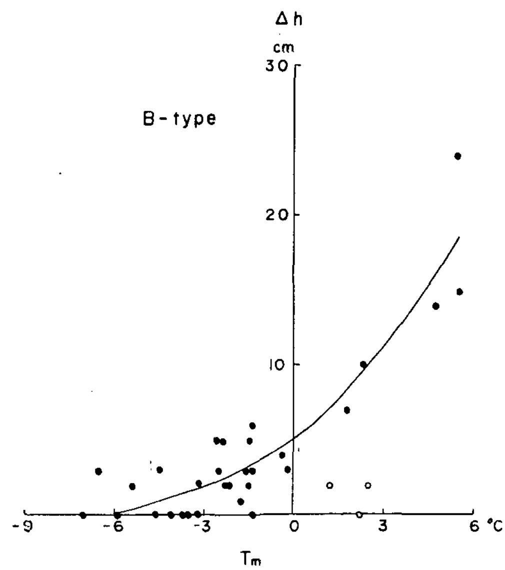

Fig. 20. Relation between Δh and daily T_m in B type in A type.

does not depend upon T_m. The maximum value of Δh in this type shows 6 cm. The cause of the rise for A type is not clear, but some causes are expected. Fig. 18 shows the relation Δh and atmospheric pressure P in the period showing A type. It is considered that the passage of a cyclone raised the water level. Fig. 19 shows the relation between Δh and daily precipitation. In the figure, the triangles indicate such cases where a considerable precipitation was seen on the previous day. The open circles show the case where cyclone passed at the day. The precipitations of the double circles are considerable, but T_m is less than $-10°C$. In such cases each value of Δh is equal to zero.

From the above facts, the passage of a cyclone and considerable precipitation on the day or the previous day may produce high values of Δh. But in the case of lower mean daily air temperature, a large precipitation does not produce high values. For other small precipitations in Fig. 19, the value of Δh occasionaly shows large values. The cause is not clear at present.

The relation between Δh and T_m for B type is shown as in Fig. 20. The open circles take lower values of Δh in spite of $T_m > 0°C$. The dates of the circles are in January or February. The air temperatures during the considerably long period to the previous day were always less than 0°C. Then, a fairly thick snow layer showed low temperature. In this case, even when T_m is more than 0°C, it is surmised that a large quantity of heat is used to produce a water route, the snow is hardly melted by residual heat, and the value of Δh becomes small. Fig. 21 shows the relation for C type. It is clear that Δh takes a higher value as compared with cases of A and B

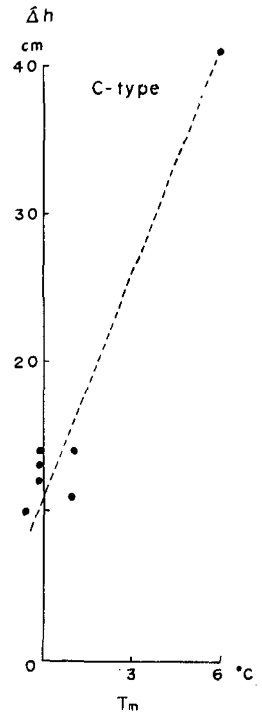

Fig. 21. Relation between Δh and T_m in C type.

types.

Generally, the value of Δh is regarded as the function of air temperature except in the case of A tpye which the air temperature of the day is always less than 0°C, and the air temperature is expressed by the degree-hours or the mean daily air temperature. Further, Δh is related to the type of air temperature change, while Δh in C type shows larger values than other types for the same degree-hours or mean daily air temperature.

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