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Snow Characteristics of Hakkoda Mountain

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***Abstract:* In the present study, the snow quality and snow characteristics in Hakkoda Mountain ware observed, and the snowfall volume of water is forecast by using the theory shown in the present study. In order to investigate the snow covering characteristics on Hakkoda Mountain, we studied the snow depth at the Sukayu Spa. The following have been understood from this. Field observation was density has increased because in both 2017 and 2018 there were layers of firm snow. Forecast of snowfall volume of water was differences in coefficient depending on year.**

Keywords: **Hakkoda Mountain, Sukayu Spa's.**

I. BACKGROUND AND OBJECTIVES

There are two dams in the northern part of Japan. One is a usual dam where water is stored. The other one is a dam for the snow on a mountain. There is large amount of snow on Hakkoda Mountain, which is located in the center of Aomori Prefecture, Japan. The snow on the mountain begins to melt in March in the spring. Melting snow from the mountain penetrates underground and becomes groundwater. Until July, rivers exist on the east and west of the plain in Aomori Prefecture and are enriched due to the water from snow melt. The water from these rivers is used as drinking water and for irrigation. It is very important to clarify the water volume from the snowmelt from the mountain. To predict the snowfall volume of water on the mountain, it is necessary to clarify the density of the snow at all depths.

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Now, it is necessary to show the amount of water that flows into the rivers because the water from the residual snow is important as a water resource. However, snow characteristics such as density and hardness of snow remaining in the mountains are unknown. In the present study, the snow quality and snow characteristics in Hakkoda Mountain ware observed, and the snowfall volume of water is forecast by using the theory shown in the present study.

II. SNOW DEPTH CHARACTERISTIC

The observational date for the depth of snow cover at Sukayu Spa's observation station on Hakkoda Mountain is open to the public on the home page of the Meteorological Agency. In order to investigate the snow covering characteristics on Hakkoda Mountain, we studied the snow depth at the Sukayu Spa. The results are shown in Figure 1. As shown in the snow depth date from 2009-2010 in the figure, snow began to accumulate on November 12, 2009 and the same depth of snow cover continues for 30 days from February 18, 2010. The peak of the depth occurred on February 21. The snow depth dropped to zero on May 19. Next, regarding the snow depth in 2012 and 2013, snow began to accumulate on November 14, 2012. The same depth of snow cover continues for 20 days from January 19, 2013. The peak of the depth occurred on February 26. The snow vanished on June 8, 2013. Next, regarding the snow depth in 2015 and 2016, snow began to accumulate on November 22, 2015. The same depth of snow cover continues for 15 days from January 25, 2016. The peak of the depth occurred on March 2. The snow vanished on May 18, 2016. Next, regarding the snow depth in 2017 and 2018,

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snow began to accumulate on November 11, 2017. The same depth of snow cover continued for 15 days from December30, 2017. The peak of the depth occurred on March 2. The snow vanished on May 19, 2018. (Japan Meteorological Agency)

As shown in the figure, snow starts to accumulate between the end of November and the beginning of December. The depth of snow peakedat 331 cm on February 21, 2010, 496 cm on February 26, 2013, 323 cm on March 2, 2016, and 417 cm on March 2, 2018.The depth of snow vanishes between the middle of May and early June.

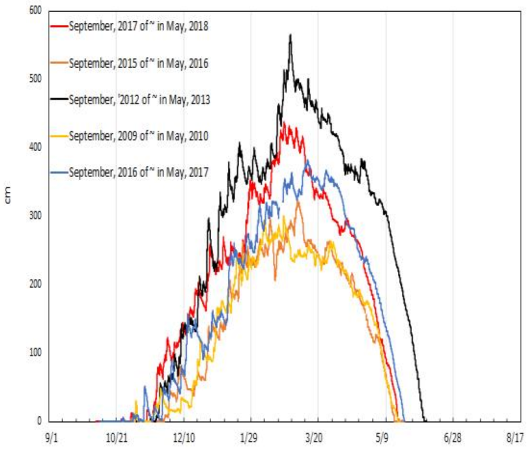

Fig.1. Observation depth of snow cover

III. FORECAST OF SNOWFALL WATER VOLUME

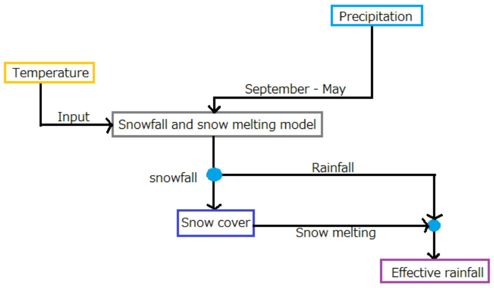

Fig 2. Snowfall and snow melting model

In order to predict the depth of snow water (amount of snow water), we downloaded observation data of Sukayu Spa temperature and precipitation from the Meteorological Agency through the web. The following snowfall and snow melting model, as shown in Figure 2, are used to obtain the snowfall and the snowmelt rate. (Graduation thesis in 2017)

①**Snowfall**

Snowfall, s is given by expression (1) as follows.

$$s = afr \text{Where} \quad a = \begin{cases} 0 & T \geq T_m \\ 1 & T \leq T_i \\ 1 - \frac{T-T_i}{T_m-T_i} & T_i \leq T \leq T_m \end{cases}$$

(1)

f : Coefficient of the amount of snow that increases when the altitude raises

r : Precipitation

T : Temperature

Ti＝Temperature that all precipitation in valley becomes snow

Tm＝Temperature that snow begins to melt in the entire valley

It the present study, Ti is set to 0℃ and Tm is set to 2℃.

②**Snow melting**

Snowmelt rate, Rm is given from expression (2) as follows.

$$R_m = bcT \quad b = \begin{cases} 1 & T \geq T_m \\ 0 & T \leq T_i \\ 1 - \frac{T-T_i}{T_m-T_i} & T_i \leq T \leq T_m \end{cases} \quad (2)$$

Where,

c : Coefficient of snow melting per each temperature

③**Depth of snow cover**

Depth of snow, St on t day is given from expression (3) as follows.

$$S_t = S_{t-1} + s_t - R_{mt}$$

(3)

IV. FIELD OBSERVATION

The field observation was made on Hakkoda Mountain. The 2017 observation was carried out on April 22. The 2018 observation was made on April 21. Table 1 shows the conditions of the field observation. The snow cover surface to be observed dug perpendicularly, and

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measured the density and hardness. The snow cover surface to be observed was made by digging vertically into a snow layer for the measurement of the density and the hardness. The measurement was done at the depth of 2.5m along the vertical snow surface.

(1) Density

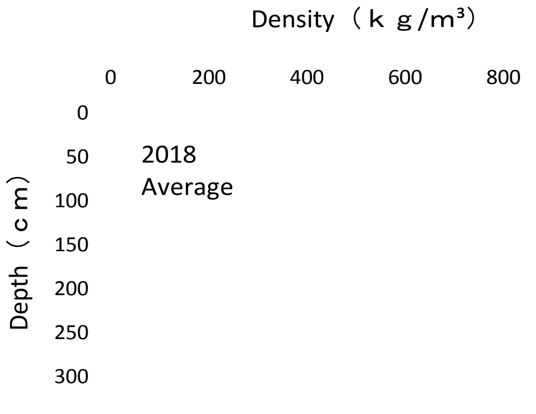

Fig.3. Density (April 21, 2018)

Figure 3 shows the results of the measurement of the averaged density in each depth in 2017 and 2018. The following can be said from the figure. The difference in 2017 and 2018 seems to be due to the temperature. The normal temperature from April 1, 2017 to the 22nd was 2.4℃.However, the normal temperature from April 1, 2018 to the 21st was 2.6℃ a little warmer than the normal temperature of 2017.

(2) Hardness

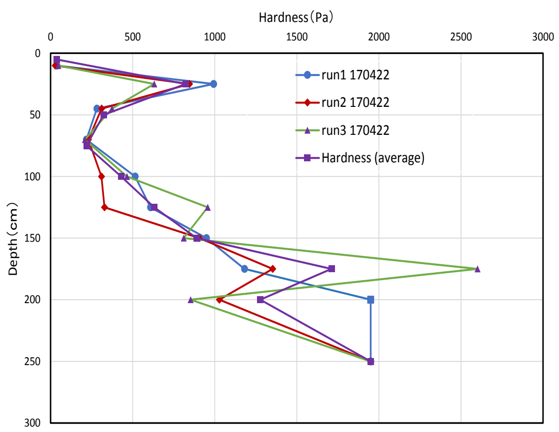

Fig.4. Hardness (April 22, 2017)

Figure 4 shows the results of a measurement of the hardness in 2017.The hardness increases significantly at the depth of 175cm because it is faced with the hard snow which occurs due to the temperature decrease as previously stated. Hardness seems to go up gradually as depth increases.

This is due to the increase of the snow pressure due to the weight of the snow. The hardness in 2018 was not measured.

As shown in Figure 1, the snow depth on April 22, 2017 is 253cm at Sukayu Spa on Hakooda Mountain. Then, we can calculate the snow depth water volume if the averaged density is given. The average density ρ can be obtained as follows. The entire depth is 250cm in the observation of 2017. The snow density is 456 at a depth of 5cm. The snow density is 676 at a depth of 25cm. The snow density is 611 at a depth of 50cm. The snow density is 627 at a depth of 75cm. The snow density is 693 at a depth of125cm. The snow density is 676 at a depth of 150cm. The snow density is 627 at a depth of 175cm. The snow density is 644 at a depth of 200cm. The snow density is 660 at a depth of 250cm. Then, the snow density of the total depth is given as follows.

$$\rho = (5 \times 456 + 20 \times 676 + 25 \times 611 + 25 \times 627 + 25 \times 693 + 25 \times 676 + 25 \times 627 + 25 \times 644 + 50 \times 660)/250 = 644\,kg/m^3$$

As a result, the snow depth water volume, St can be obtained.

$$S_t = 2350mm \times 0.644 = 1513mm$$

As shown in Figure 1, the snow depth was 230cm on April 21, 2018. The average density ρ can be calculated as follows. The entire depth is 250cm in the observation of 2018. The snow density is 725 at a depth of 10cm. The snow density is 546 at a depth of 25cm. The snow density is 644 at a depth of 45cm. The snow density is 595 at a depth of 70cm. The snow density is 693 at a depth of 100cm. The snow density is 595 at a depth of 125cm. The snow density is 600 at a depth of 150cm. The snow density is 611 at a depth of 175cm. The snow

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density is 644 at a depth of 200cm. The snow density is 660 at a depth of 250cm. Then, the snow density of the total depth is given as follows.

$$\rho = (10\times725 + 15\times546 + 20\times644 + 25\times595 + 30\times693 + 25\times595 + 25\times660 + 25\times611 + 25\times644 + 50\times660)/250 = 639\,kg/m^3$$

As a result, the snow depth water volume, Stcan be obtained.

$$S_t = 2300mm \times 0.639 = 1469.7mm$$

V. COMPARISON BETWEEN THEORY AND MEASUREMENT FOR SNOW DEPTH WATER VOLUME

Figure 5 shows the snow depth water volume given by the present theory and the snow depth observed by Meteorological Agency of Japan. In the calculation, the coefficient f for the precipitation in equation (1) and the snow melting coefficient c per temperature in equation (2) are set to f = 4.1 and c = 0.26.These values are adjusted so that the predicted value for the snow depth water volume and the observed snow depth water volume are corresponding, and the beginning and the end between the calculation of the snow depth water volume and the observation of the snow depth coincide. (Graduation thesis in 2017)

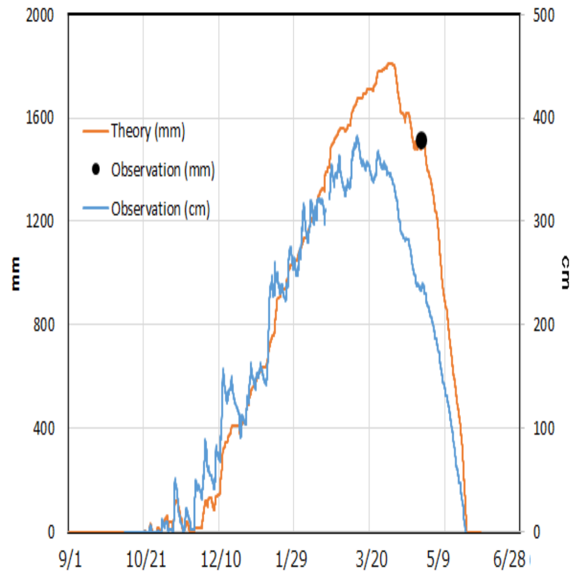

Fig.5. Water conversion depth of snow cover and water conversion observation depth of snow cover (April 22, 2017)

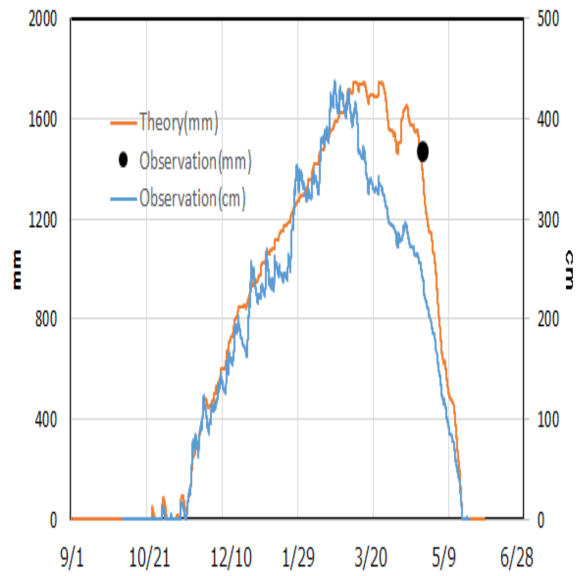

Fig.6. Water conversion depth of snow cover and water conversion observation depth of snow cover (April 21, 2018)

Figure 6 is a result on April 21, 2018.The coefficient f in equation (1) and the snow melting coefficient c in equation (2) are set to f = 3.6 and c = 0.28.

VI. CONCLUSION

Field observation

(1) The density in 2017 had period where the density went up suddenly due to a temperature decrease. A minimum maximum of the density doesn't relate to depth.

(2) The temperature decrease impacted the hardness in 2017 just like the density, and hardness increased.

(3) The density has increased because in both 2017 and 2018 there were layers of firm snow.

(4)The snow peak in Hakkoda mountain was 383 cm on March 10, 2017, and 429 cm on March 2, 2018.

Forecast of snowfall volume of water

(1)The coefficient f of the amount of snow is 4.1 in 2017 and 3.6 in 2018, which has a large coefficient range.

(2)The coefficient of snow melting c per hour has a small coefficient of variation of 0.26 in 2017 and 0.28 in 2018.

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(3)There are differences in coefficient depending on year.

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