Special Contributions, Geophysical Institute, Kyoto University, No. 5, 1965, 73~79

WINTER PRECIPITATION ON HIGH MOUNTAINS

By

Yasushi MITSUTA

(Received November 10, 1965)

Abstract

The results of the test observation of radio isotope snow gauge at Kariyasu Pass in the source region of Kurobe River are discussed. The total winter precipitation at this point is as large as that in summer and does not change year to year as snowfall on lowlands. In case of heavy snow, snowfall distribution on mountains and coast is affected by stability of airflow. Runoff in spring from snowmelting is closely related to rainfall.

1. Introduction

The value of accumulation of snow on high mountains in winter is a matter of great importance in both good and evil senses. But its measurement is much difficult compared to rainfall measurement in warm season. Therefore accurate value of winter precipitation or water equivalent of snowfall on high mountains has not been measured except by snow surveys in early spring. The only but expensive way of obtaining data of daily snowfall in high mountains is telemetering radio isotope snow gauge. A snow gauge of this kind was set up in the source region of Kurobe River which is mountainous area higher than 1500 meters from sea level in the northern part of Japan Alps in 1962. In this paper the results of the test observation of this gauge in the winter from 1962 to 1963 are discussed.

2. Site and Instrumentation

The Kurobe River runs from south to north making a gorge in the northern end of Japan Alps. The general topography is shown in Fig. 1. The snow gauge was placed at Kariyasu Pass (ca 1885 m) which is about the center of the drainage area of the reservoir of the Kurobe IV Hydraulic Power Station. The elevation of the water surface of the reservoir is about 1450 m and that of the surrounding mountains being higher than 2500 m. The total area of the drainage area is about 185 km^2. The position of the station at Kariyasu Pass had been selected as the representative observing point of rainfall in this area (Mitsuta (1962)) and a radio telemetering rain gauge for warm season was placed here.

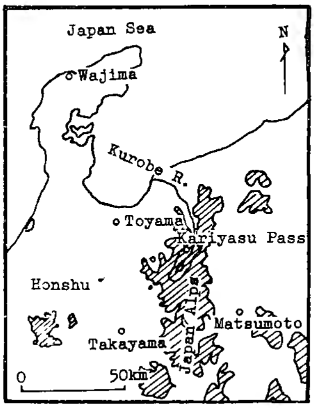

Fig. 1. Genaral topography (Shaded area is higher than 1500 m)

The snow gauge was specially designed by the working group directed by Prof. T. Asada of Osaka University for Kansai Electric Power Company. As it is founded by preceding snow surveys for a few years by our group, the scientific chief of which was Mr. K. Sahashi of Kyoto University, that the equivalent water depth of snow at this point exceeds 150 cm, the radio active source is placed at the hight of 4 meters from the ground surface and two scintilation counters were placed at the hight of 8 meters and on the ground. Intensity of γ ray absorbed by snow is counted for 5 minutes by each counter at 6 oclock in the morning every day and the information is sent through radio telemetering system to the dam control office.

The water equivalent depths of snow for upper and lower path lengths are determined by the experimental formula of γ ray absorbtion by snow. The source of γ ray is 300 mc of Co^{60} isotope. The test observation was started in the beginning of November 1962 and ended in the end of May of the next year. The test was quite satisfactory and daily snow accumulation data of that winter were obtained. There was lasting snow accumulation from the middle of November untill the end of May. The maximum accumulation depth of water equivalent was found to be 144 cm on March 30, 1963.

3. The Total Winter Precipitation

In this area daily mean temperature in winter is almost below freezing point every day and all of snowfalls are accumulated on the ground untill snow melting starts in the next spring. This is easily ascertained by the fact that daily inflow to the reservoir decreases monotonously from November to March in spite of heavy snow in winter.

The maximum value of snow accumulation of 144 cm can be regarded as the total precipitaion from December to March. And this value can be compared to the results of snow surveys in the precedimg years. These total precipitations at Kariyasu Pass are shown in Table 1. In this table the total precipitations in the same period observed at some nearby meteorological stations on the coast or in the inland are also shown in the right columns.

Table 1. Winter Precipitation.
(Total precipitation from December to March in mm)

Year	Kariyasu Pass (h=1885m)	Toyama (10m)	Takayama (560m)	Matsumoto (611m)
1958–1959	1630 (snow survey)	1077	515	997
1959–1960	1460 (snow survey)	997	382	175
1960–1961	1670 (snow survey)	1045	386	164
1962–1963	1440 (R. I. S. G.)	1231	456	183
Mean	1525	1088	435	380

The total precipitations for four years at Kariyasu Pass are not so different in magnitude each other and the averaged value is 1525 mm. While the precipitations at low altitude stations vary greatly year to year. The averaged value of Toyama which is on the coast of Japan Sea is almost 70 % of that of Kariyasu Pass and those of Takayama and Matsumoto, which are inland stations, are only about 30 and 25 % of Kariyasu Pass.

The total precipitation in summer (June-September) at Kariyasu Pass is about 1500 mm (Mitsuta (1962)), which is almost the same as that of winter season. Thus the anual rainfall at this point may be over 3000 mm, which shows that this is one of the most rainy places in Japan.

4. Comparison of Mountain and Lowland Snowfall in Case of Heavy Snow

In January, 1963, a heavy snowfall continued for about one month on the Japan Sea side of Honshu Island. As a result of this the region was afflicted with immense snow damages (J. M. A. (1964)). But as is shown in Table 1 the total precipitation at Kariyasu Pass of that winter is even less than those of other winters. Kariyasu pass is only about 50 km from Japan Sea coast. The difference may be caused from difference in elevation. The variation of precipitation in every five days and mean aerological situation at 850 mb of Wajima are shown in Table 2.

The heavy snow on the coastal area arose in the end of January but at Kariyasu Pass heavy snow preceded the period, which shows that the mechanisms of snowfall on the coast and on the mountains are quite different.

Table 2. Variation of precipitation in every five days and mean aerological situation at 850 mb of Wajima.

No.	Period	Kariyasu Pass	Toyama	Takayama	Matsumoto	Wajima (850 mb)		
	1962 XII	mm	mm	mm	mm	°C		kt
71	17–21	40	29	2	0	−3.2	W	12
72	22–26	100	36	8	0	−4.8	W	13
73	27–31	120	45	28	12	−1.7	WSW	10
	1963 I							
1	1–5	200	91	20	5	−7.3	WSW	15
2	6–10	140	66	62	6	−6.5	W	13
3	11–15	150	33	55	3	−9.7	W	13
4	16–20	160	153	40	2	−9.5	W	14
5	21–25	60	146	9	0	−12.0	WNW	11
6	26–30	20	55	6	0	−9.1	W	10
	II							
7	31–4	30	43	5	0	−7.8	WNW	13
8	5–9	0	23	11	10	−9.6	WNW	8
9	10–14	0	18	3	1	−9.0	NW	6
10	15–19	0	7	2	0	−10.2	WNW	8
11	20–24	20	17	8	0	−7.3	W	10
	III							
12	25–1	80	18	11	6	−7.5	SE	12
13	2–6	60	26	7	3	−9.3	WNW	8
14	7–11	20	22	16	17	−8.7	N	7
15	12–16	50	27	27	23	−1.7	SE	8

From 72 th semi-decade of 1962 to 4 th semi-decade of 1963 snowfall at Kariyasu Pass exceeded 100 mm and the maximum snowfall was 200 mm on the 1 st semi-decade. And in this period snowfall at Kariyasu Pass is more than twice as large as that at Toyama except the 4 th semi-decade, when the coastal snowfall increased to the same extent on the mountains. On the 5 th semi-decade mountainous snowfall decreased but coastal snow was still heavy and the ratio reversed. Snowfalls at inland stations are less than mountainous and coastal stations but the trends are intermediate of both.

The difference of precipitation patterns on high mountains and on lowlands is often discussed for rain. Mitsuta (1962) has pointed out in the analysis of rainfall pattern of this area that rainfall patterns are different depending on weather situations and cold frontal rainfalls are almost the same both on the mountains and on the lowland while warm frontal rain is much greater on the mountains and, moreover, additional large rainfall peak appears on the mountains when they are in the warm sector of the cyclone. This suggests that mountain slope of this scale plays as a effective trigger of releasing of instability of airflow. The similar situation is also expected in case of snow.

Detailed study of synoptic situation in this case is difficult because data are incomplete, but climatological study is posible by the data shown in Table 2. Average wind flow at 850 mb of Wajima which represents airflow aproaching the mountains is almost constant in speed and direction throughout the heavy snow period. Airflow is from west, that is from Japan Sea, and its stability can be estimated from air temperature at 850 mb because sea surface temperature is almost constant. It can be concluded from this table that mountainous snowfall exceeds lowland when air current is more stable and vice versa in less stable case. This means that moist current from sea releases its water contents very easily even if it is triggered by differential friction on the coast when it is unstable. But if it is stable it does not release its water contents untill it is forced to release by uplift on the mountain slope. And almost all of the water contents are released in the process of crossing the mountains and snowfall at Matsumoto is very small.

5. Snow Melting and Runoff

Snow melting and runoff, especially the date of initiation and peaks, are of

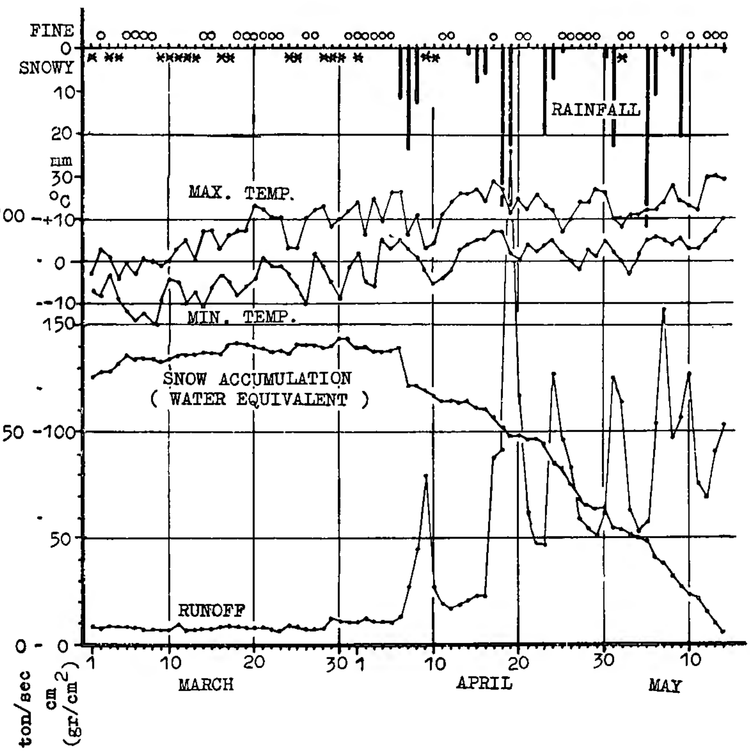

Fig. 2. Snow melting and runoff.
(Temperature. rainfall and weather are observed at the dam control office near the dam site (1460 m))

great interests in spring. The data of the R. I. snow gauge show the process of decreasing of water equivalent on high mountains, which is shown in Fig. 2 with other data obtained at the dam site of about 1460 m in hight, where water equivalent of snowfall is not measured.

Deep snow retains water from melting snow untill its capacity for retention is filled, whereupon water is released. Therefore even snow melting meight start in the end of March when fine weather was settled and mean temperature meight become above freezing point, water equivalent did not begin to decrease nor runoff increase untill 6th of April. According to the study of snow melting of deep snow by our group (Yamamoto et al. (1964)) the most effective energy source of snow melting is solar radiation and one or two gr/cm^2 of snow may be melted on every fine day. While the capacity of retention of snow layer has been founded to be about 30 % in weight rate, therefore the snow layer at Kariyasu Pass in the end of March can retain about 40 gr/cm^2 of water, which is equivalent to the total snow melting for more than a month of fine days.

But it rained before saturation on 6 th of April. Rainfall at Kariyasu Pass is not clear but it was sufficient to saturate and excess water became to discharge into the river. Here, we must not overlook the sudden decrease of water equivalent on this day. This means that once discharge begins water retained in the snow layer or snow itself is carried off by water flow. After this peak of runoff, daily runoff began to increase and sharp peaks are seen on every rain cases. It is clear that intiiation of decreasing of water equivalent and runoff is caused by the first rainfall in spring and water flow carries water retained in the snow layer therefore the amount of runoff is larger than that expected from rainfall. This relation of runoff and rainfall on the snow layer is already pointed out by many authors, for example Foster (1949) and Hoshiai (1965).

6. Conclusion

Results of tests observation of radio isotope snow gauge at Kariyasu Pass have presented many interesting information about snow on high mountains in Japan Alps. The total winter precipitation on high mountains does not change greatly year to year as those on lowlands. And winter precipitation on this area is as large as that in summer. In case of heavy snow in January of 1963, snowfall on the high mountains is quite different from snow on the coastal area. When airflow from Japan sea is unstable we have a lot of snow on the coastal area but if it is more stable water contents are not released untill it reaches on the mountains. Runoff in spring from snow melting is closely related to rainfall as is mentioned before.

Acknowledmement

This study was started as a part of the hydrometeorological study of Kurobe River directed by late Prof. K. Seno sponsored by Kansai Electric Company. The author is indebted to Mr. H. Kudo of the company for his kindness in preparation of the data.

References

Foster, E. E., 1949 ; Rainfall and runoff, The MacMillan Company, 343～347.

Hoshiai, M., 1965 ; Movement of water in the accumulated snow (in Japanese), Suion no Kenkyu (the Journal of the Society for River Temperature Study), 9, 11～15.

Japan Meteorological Agency, 1964 ; Report on the phenomenal snow of January 1963, Technical Report of J. M. A., 33.

Mitsuta, Y., 1963 ; Rainfall distribution in the Kurobe Valley (in Japanese), Quarterly of the Power and Weather Coordinatinating Committee, 13, 2, 94～103.

Yamamoto, R., K. Sahashi, Y. Mitsuta and M. Mizuma, 1964; A meteorological study on snow melting (in Japanese), Disaster Prevention Research Institute Annuals, 7, 218～228.