水工学論文集 第35巻 1991年2月

THE APPLICATION OF SNOWCOVER AREA EVALUATION FROM REMOTE SENSING DATA TO SNOWMELT RUNOFF TANK ANALYSIS

By Kittipong JIRAYOOT*, So KAZAMA* and Masaki SAWAMOTO**

ABSTRACT: Combined snowmelt and rainfall runoff during active snowmelt season is predicted by using tank model and the model parameters are optimized by applying Powell's conjugate direction method. The parameters optimization is conducted for the data of water year 1988. The obtained set of optimized model parameters is used to predict the runoff of water year 1989. The input data for the model are snowcover area evaluated from remote sensing data, daily precipitation, daily mean air temperature and daily observed runoff.

Keywords: active snowmelt season, tank model, conjugate direction, snowcover, runoff

INTRODUCTION

For the purposes of planning, design and operation of water resources development projects, particularly, hydropower projects the well-understanding of the characteristics of river basin is necessary. The relationships of rainfall-runoff and snowmelt-runoff are also needed in order to fulfil the purposes mentioned above. Beside rainfall, snowmelt also can generate the huge amount of runoff during snowmelt season. In Japan snowfall starts from about the mid of December until about the end of March and almost of snowmelt occurs in April and May. At present, remote sensing technique is too powerful, reliable and can be applicable in many fields. In the study, the snowcover area in the basin was evaluated by using NOAA data and was used in snowmelt model.

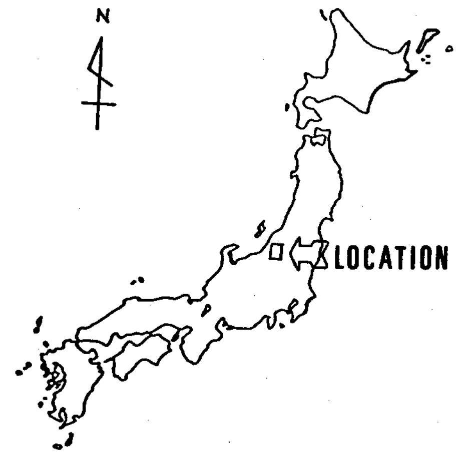
GENERAL DESCRIPTION ON STUDYING BASIN

In this research, the studied area is shown in Fig.1, the Tadami River basin locates between latitude 36° 52′N to 37° 28′N and longitude 139° 4′E to 139° 40′E, catchment area about 1991 km^2 which covers some parts of Fukushima, Niigata and Gunma Prefecture and almost is in Fukushima Prefecture. The Tadami River is originated by Oze Lake in the southern part of the basin and Ina River is the biggest and longest tributary of the Tadami River. Ina River joins Tadami River at the downstream of Tadami Dam(new dam, the operation has been carried on since July, 1989). The elevation of the basin changes from about 300 m in the north to over 2,300 m above mean sea level in the south, almost high mountains are in the south of the basin. The general topography may be said that is mountainous comprises with low mountains at the downstream end and high mountains at the upstream end including some flat areas, such as, Ozegahara in the most upstream part of the catchment area. Soil types of the basin are rock 11.3%, disposed rock 19.6%, brown forest soil 46.6%, podzol 19.2% and others 3.3% of the total area. Almost total basin area is covered by broad-leaved trees about 89.1%, needle-leaved trees 9.5% and 1.4% for the other types of landcover.

---

* Graduate Students of Civil Eng. Dept.,Faculty of Eng.,Tohoku Univ. (Aoba Ku, Sendai 980, Japan)

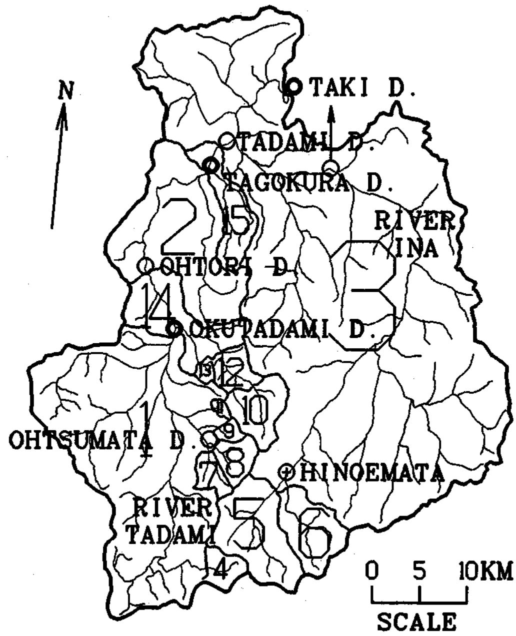
** Professor of Civil Eng. Dept.,Faculty of Eng., Tohoku Univ. (Aoba Ku, Sendai 980, Japan)



DAM LIST:
1:Okutadami; 2:Tagokura; 3:Taki; 4: Oze Lake; 5: Hinoemata Int.; 6:Funanomata Int.; 7:Ohyoppi Int. 8:Ohtsumata; 9: Takinosawa Int.; 10:Minokokurisawa & Okusodesawa Int.; 11:Ichinosawa Int.;12:Sodesawa & Murasugisawa Int.;13:Motosawa & Koyabasawa Int.;14:Ohtori; 15:Tadami

BASIN WATER MANAGEMENT SCHEME

Within the basin, there are totally 6 dams which were constructed for electrical purpose and all of them locate in the west side of the basin along Tadami River except Ohtsumata Dam which locates at Ohtsumata River, a tributary of Tadami River. The series of dams along the Tadami River starting from Ohtsumata, Okutadami, Ohtori, Tagokura, Tadami and Taki Dam at the downstream end of the river. The topographical condition at the east side of the basin is not appropriate to construct dam for electricity, only two intake dams were built at the upstream part of Hinoemata River which is one tributary of Ina River for diversion the water to Ohtsumata Dam by tunnels. Moreover, there are other 9 intake dams in the Tadami sub-basin in order to divert the water to Okutadami Dam. The general view of water management scheme of the basin is shown in Fig.2.



○ FLOW

⊕ TEMPERATURE, RAINFALL

O FLOW, TEMPERATURE, RAINFALL

Fig.1 Tadami River Basin

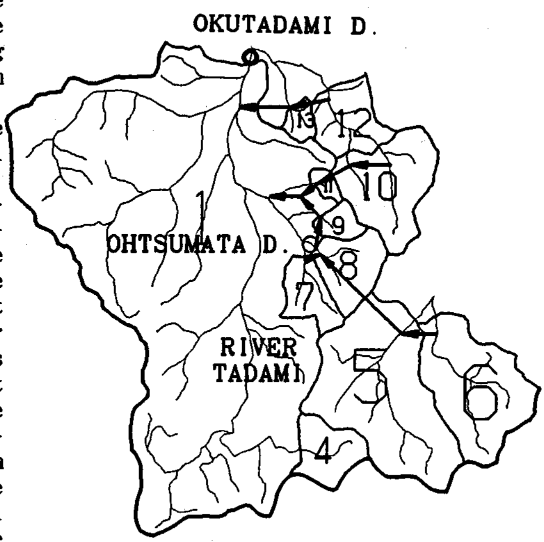


Fig.2 Water Management Scheme

AVAILABLE DATA

Only the data of the observation stations locate within the basin was used in this study, the locations of the observation stations are also shown in Fig.1.

-Inflow and Outflow

The gauging stations which have recorded inflow and outflow data locate at all dam sites and there is one station sites at the downstream reach of Ina River to record diverted flow across the basin.

-Precipitation

There are 4 meteorological stations within the basin and their items are listed in Table 1. The shapes of daily precipitation curves measured by these 4 stations do not show some remarkable difference. In this study, only the average rainfall with the same weight from these all stations is used to represent the areal rainfall of the whole basin for runoff analysis.

Table 1 Meteorological stations

Station	Location		Elev. (m)
	Lat.	Long.	
Hinoemata	37° 00′N	139° 23′E	997.50
Okutadami	37° 09′N	139° 15′E	782.00
Tagokura	37° 19′N	139° 17′E	398.00
Taki	37° 24′N	139° 23′E	335.00

-Air temperature

The present study, air temperature is assumed to be the main factor which effects to snowmelt and the amount of snowmelt is proportion of air temperature. The temperature used for snowmelt model is the average temperature from these 4 meteorological stations after adjusted by temperature lapse rate, the average temperature of the basin as shown in Fig.3 for years 1988 and 1989. The basin temperature lapse rates of the first six months were derived by using average 11-year mean monthly temperature data of these 4 stations. The temperature lapse rates of January to June are -0.40, -0.34, -0.30, -0.20, -0.32 and -0.38 degrees celcius for every 100 m increasing elevation respectively. The derived curves of temperature lapse rates are shown in Fig.4.

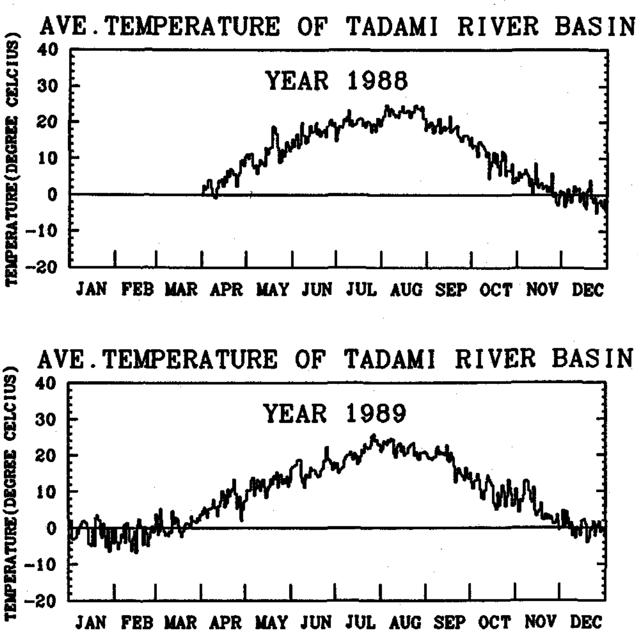


Fig.3 Air Temperature

WHOLE BASIN RUNOFF ESTIMATION

The total runoff of the basin as shown in Fig.5 was estimated by using inflow and outflow data from every gauging station, the runoff within the catchment area of the most upstream dam is equal to total inflow into the dam and the runoff within the catchment area of the other dams can be estimated by using the simple equation as follows:

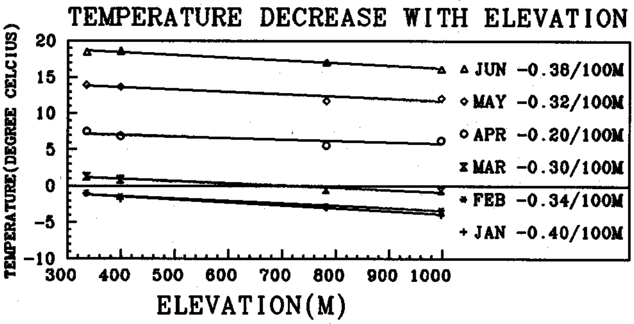


Fig.4 Temperature Lapse Rate

$$RO_2 = IF_2 - OF_1 + LOSS$$

where RO_2 = runoff within the catchment area of dam no.2; IF_2 = total inflow into dam no.2; OF_1 = outflow from dam no.1 which locates upstream of dam no.2; and LOSS = total losses.

If LOSS is neglected, the total runoff can be estimated directly by using available inflow and outflow data at dam sites.

TANK MODEL WITH SNOW COMPONENT

At the first study of the authors on runoff analysis of Tadami River basin the tank model with snow component developed by Sugawara(1984) was applied during snowmelt period.The model consists of five tanks, the top tank represents snowmelt model and is explained in details at the next section, the second top tank has two side-outlets and one bottom-outlet, for the other tanks one side-outlet and one bottom-outlet are set except the lowest tank only one side -outlet is set at the bottom.

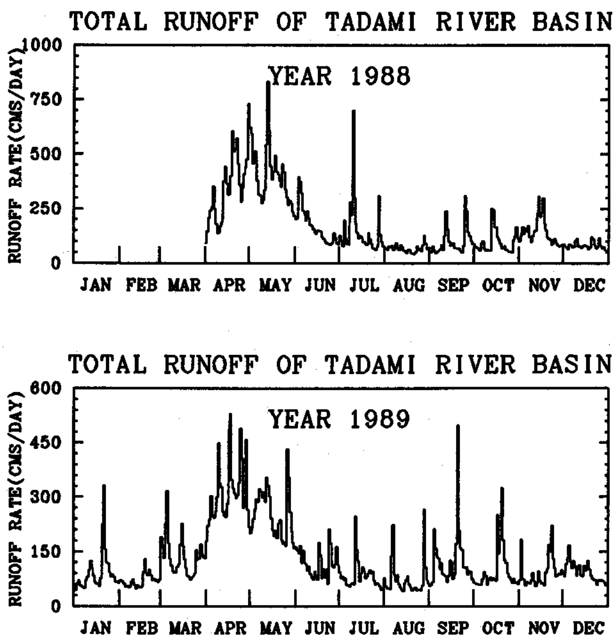


Fig.5 Basin Runoff

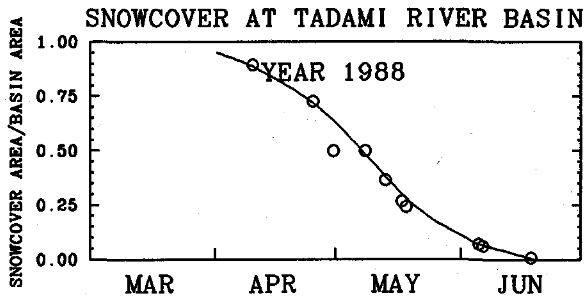
SNOWMELT MODEL

As mentioned before, only air temperature is the main prominent factor effects to snowmelt in this simple model, the heat gained from precipitation is also considered by assuming that the temperature of precipitation is equal to air temperature. The air temperature used for snowmelt process is considered at the hypsometric elevation of snowcover area by adjusting the average temperature of the basin at the average elevation of observation stations with temperature lapse rate. During active snowmelt season, the snow line is assumed in horizontal plane and changes upward direction. The basin snowcover curves which were evaluated by using remote sensing NOAA data are shown in Fig.6. The hypsometric elevation of snowcover area is defined as the elevation that snowcover area above this elevation is equal to the snowcover area under this elevation, the elevation can be approximated by using snowcover area and area-elevation curve of the basin as shown in Fig.7. The depth of daily snowmelt is calculated from the equation hereunder:

$$QSM = SCR \times T_{he} \times \left(CSM + \frac{1}{80} P \right) \quad \text{when} \quad T_{he} \geq 0$$

$$= 0 \quad \text{when} \quad T_{he} < 0$$

where QSM = snowmelt depth; CSM = snowmelt factor; T_{he} = temperature at hypsometric elevation of snowcover area ; SCR = the ratio of snowcover area to basin area; P= precipitation.



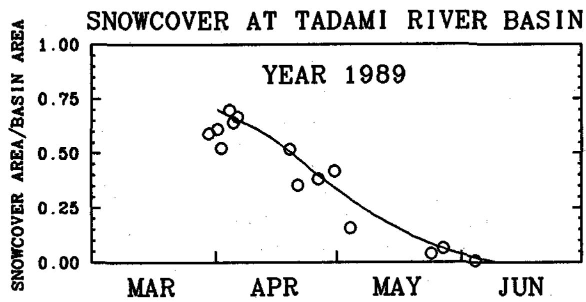


Fig.6 Basin Snowcover

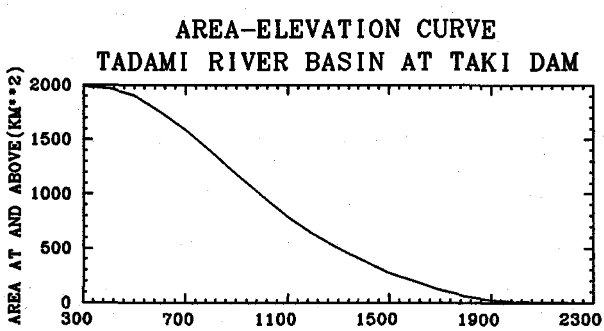


Fig.7 Area-Elevation Curve

MODEL PARAMETERS OPTIMIZATION

The best set of tank model parameters was obtained by applying the well-known Powell's conjugate direction optimization technique(Powell M.J.D., 1964 and Zangwall W.I.,1967). The procedure applies to a function of several variables without calculating derivatives and bases on changing one variable or parameter at a time. The optimization technique was developed to minimize the objective function which can be divided into two parts, the first part is average relative absolute error between observed runoff and calculated runoff obtained from tank model and can be defined as follows:

$$ARAE = \frac{1}{N} \sum_{i=1}^{i=N} \frac{|Q_{ci} - Q_{oi}|}{Q_{oi}}$$

where ARAE = average relative absolute error; Q_{ci} = calculated runoff; Q_{oi} = observed runoff and N=number of observations.

The second part contains the set of penalty functions(Kobayashi S. and Maruyama T., 1976) which limit the values of parameters to be reasonable and realistic values.

RESULT AND DISCUSSION

The result from optimization for the data of water year 1988 is shown in Fig.8, even the average relative absolute error between observed and calculated runoff of the whole period of simulation is small but during high snowmelt season, the model shows some deficiencies. The predicted hydrograph of water year 1989 is shown in Fig.9, the prediction was conducted by using the set of optimized parameters obtained from the calibration of water year 1988 data, generally, the model can predict at some degrees of accuracy.

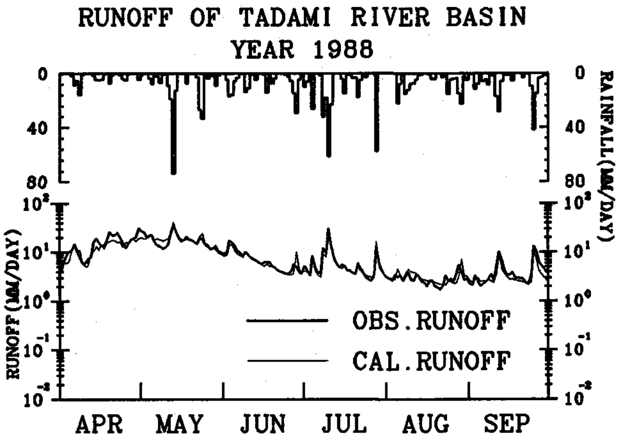


Fig.8 Model Calibration

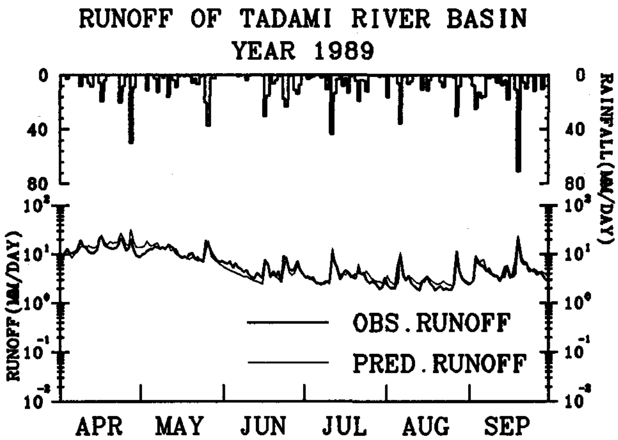


Fig.9 Model Prediction

ACKNOWLEDGEMENTS

The authors wish to express their sincere gratitude to the Electric Power Development Company and Tohoku Electric Company for their assistance and provided them the necessary data, special thanks also are extended to Ogawa Memorial Foundation for the publication.

This study is partially supported by the Grant in Aid for Scientific Research.

REFERENCES

Kobayashi,S. and Maruyama T.,1976. Search for the coefficients of the reservoir model with the Powell's conjugate direction method, Trans. JSIDRE, oct : pp. 42-47 (in Japanese).

Powell, M.J.D., 1964. An efficient method for finding the minimum of a function of several variables without calculating derivatives, Computer Journal, 7:pp.155-162.

Sugawara,M.,Watanabe,I.,Ozaki,E. and Katsuyama,Y., 1984. Tank model with snow component, Research notes of the national research centers for disaster prevention, no. 65.

Zangwall,W.I., 1967. Minimization a function without calculating derivatives, Computer Journal, 10:pp.293-296.