気候変動が積雪森林山地域の水循環に与える影響

Influence of climate change on the hydrological regime in a headwater basin, Niigata

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1. Introduction

The IPCC (Intergovernmental Panel on Climate Change) has reported that Japan will likely warm 2-3°C by the year 2100, with changes in precipitation dependent on the season. This will cause the seasonal patterns of river runoff to change, and will influence the planning of agricultural water use and disaster prevention planning. The objective of this study is to forecast the change in the hydrological regime and seasonal runoff resulting from climate change scenarios, especially, changes in snowpack and snowmelt in a mountain region. This information is necessary for the administrative planning of water resources.

2. Model Calibration and Validation

The Snowmelt Runoff Model[1)] was applied to the Takiya River basin (Figure 1) to simulate daily runoff over the period 2000-2007. Snow accumulation and melt was simulated separately in three elevation zones using air temperature data to estimate the lapse rate, and daily basin discharge simulated using a recession coefficient:

$$Q=[c_{Sn}\cdot a_n(T_n+\Delta T_n)S_n+c_{Rn}P_n]\frac{A\cdot 10000}{86400}(1-k_{n+1})+Q_n k_{n+1} \quad (1)$$

Where Q = average daily discharge (m^3/s)

c = runoff coefficient c_S = snowmelt c_R = rain

a = degree-day factor (cm/°C/d)

T = temperature (°Cd), ΔT = temperature lapse rate, S = ratio of snow covered area,

P = precipitation (cm), A = area of zone (km^2),

k = recession coefficient, n = sequence of days.

This model can simulate daily streamflow in mountain basins where snowmelt is a major runoff factor, and evaluate the effect of a changed climate on seasonal snow cover and runoff. There are over 100 application examples.

Each model parameter is determined by comparing measured and simulated discharge and snow water equivalent. Model calibration and validation results are shown in Table 1. An orographic coefficient α is applied to winter season precipitation (Dec-Apr). T_{crit} is the threshold temperature, which determines rainfall or snow. The model performance (R^2) is lower in years when localized heavy rainfall caused large summer floods.

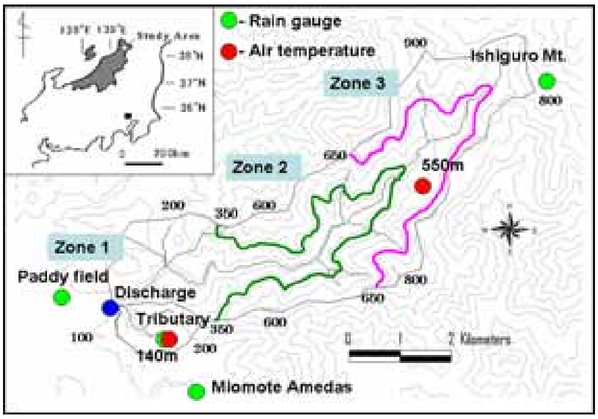

Figure 1. Takiya River basin located in northern Niigata Prefecture, Japan

Table 1. Calibration and validation result

Year	R^2	Volume Difference (%)	Precipitation factor α (orographic coefficient) Zone 1	Zone 2	Zone 3	Critical Temperature T_{crit} (°C)
Calibration						
2001	0.7894	-3.63	1.25	1.55	1.75	1
2002	0.7617	5.95	1.13	1.45	1.94	1
2003	0.7202	10.97	1.18	1.5	2.3	1.5
2004	0.6184	7.29	1.28	1.49	2.15	1.5
Validation						
2005	0.5111	8.80	1.06	1.45	2.15	0.5
2006	0.4601	7.26	1.21	1.45	2.3	0.5
2007	0.7174	3.15	1.06	1.43	1.85	1.5

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3. Scenario Simulations

The Japan Meteorological Agency[2] has published regional scenarios that are based on IPCC Scenario A2 (Table 2). The study site is on the boundary of EJJ and NJJ regions.

Simulation results are shown in Figure 2. Winter monthly runoff increases by over 100% in Scenario 1 (S1), and by over 200% in Scenario 2 (S2). In contrast, spring monthly runoff decreases by more than 50%. In S1, January and February precipitation decreases, but runoff increases because warming changes snowfall to rainfall that rapidly becomes runoff. On the other hand, in S2 April and May precipitation is unchanged, but runoff decreases because warming reduces snowpack size and the amount of snowmelt in spring. Therefore, it was found that temperature change has a greater influence on runoff than precipitation change.

Simulation of the discharge hydrograph for a warming scenario of +0.6°C shows little change, but for +2.0°C runoff changes greatly (Figure 3). Changes in monthly runoff volume are most sensitive to warming in the range +1.0~3.0°C because large shifts occur in the proportions of snow versus rain (Figure 4). In May, the change in runoff volume for warming of +2.0~4.0°C is roughly equal, because the snowmelt season has already ended.

4. Conclusions

Simulation of the IPCC Scenario A2 using a snowmelt model showed that runoff would be 2-3 times greater in winter, and decrease by half in spring. Change in runoff is particularly large with warming of up to 3.0°C, and in May snowmelt has already ended with warming of over 2.0 °C.

For a small rise in temperature, there will likely be large changes in the seasonal distribution of runoff. Therefore, it is necessary to review disaster prevention and water supply planning.

References

1) Snowmelt Runoff Model User's Manual, J. Martinec, A. Rango, and R. Roberts, 2005.

2) Global Warming Prediction Vol. 6, 1~19p, Japan Meteorological Agency, 2005.

3) Whitaker, A. C., Sugiyama, H., and Hayakawa, K., (in press). Effect of Snow Cover Conditions on the Hydrologic Regime: Case Study in a Pluvial-Nival Watershed, Japan. Journal of the American Water Resources Association.

Table 2. IPCC A2 regional scenarios for eastern and northern Japan Sea region 2081-2100 in relation to 1981-2000 values

Month	Scenario 1 (Eastern Japan Sea region)		Scenario 2 (Northern Japan Sea region)	
	⊿T (°C)	Precip (%)	⊿T (°C)	Precip (%)
10	3.00	+10	3.00	+10
11	2.80	-5	2.90	0
12	3.10	-15	3.40	-20
1	2.55	-10	3.05	+20
2	2.60	-15	3.10	0
3	2.75	-15	3.10	0
4	2.90	-15	3.10	0
5	2.80	-5	2.90	+5
6	2.20	+20	2.25	+20
7	1.80	+30	2.25	+20
8	1.30	+40	2.00	+20
9	2.25	+20	2.40	+10

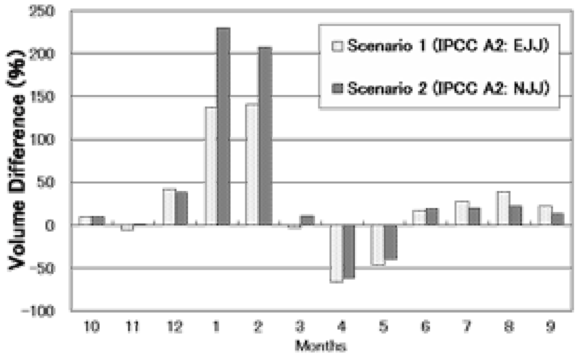

Figure 2. Change in monthly runoff volume for IPCC A2 regional scenarios in relation to 2000-2007 values

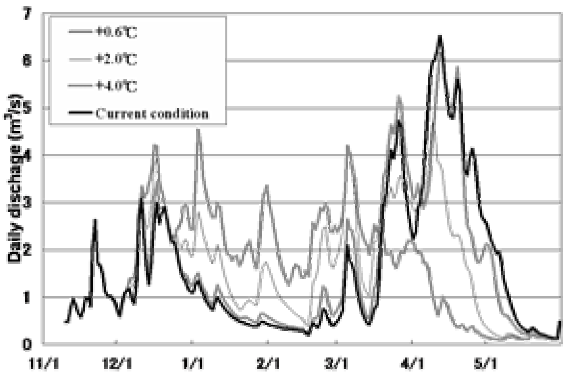

Figure 3. Change in discharge hydrograph with warming scenarios for winter to spring 2001 (precipitation unchanged)

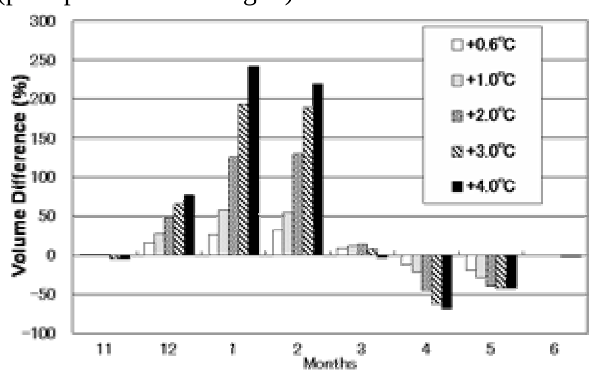

Figure 4. Change in monthly runoff volume for warming scenarios in relation to 2000-2007 values (precipitation unchanged)