Examination of hydrological change using WRF output in the Agano River basin, Japan

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Abstract

The Agano River, drains into the Sea of Japan is the second large river in annual runoff in Japan. It is 210 km long with 7700 km^2 watershed. The majority of river flow comes from the Tadami River basin, a source area of the basin with heavy snowfall in winter. The snowfall variation is sensitivity for the water resources of the basin. In this study, a regional climate model application will be carried out to evaluate the snowfall distribution over the basin and make a runoff simulation using a hydrological model in a 30 hydrological years from June 1969 to May 1999. Then, an examination of hydrological processes will be made based on the 100-year global warming potential of greenhouse gases over the basin to determine the possible change with the climate change in future.

1 Introduction

The Agano River (Fig. 1), drains into the Sea of Japan is the second large river in annual runoff (12.9 billion m^3) in Japan. There are two major tributaries of the river, namely Tadami River and Aga River both are located in Fokushima Prefecture. The majority of river flow comes from the Tadami basin, a source area of the basin with heavy snowfall in winter. The lower reaches of the river is the Echigo Plain, located in Niigata Prefecture which is a major rice production area ranking 2nd among the prefectures for total rice output. The area around Uonuma is especially known for its Koshihikari variety of rice, which is widely thought of as the highest quality rice in Japan. Rice-related industries are also very important to the local economy. Niigata prefecture is known throughout Japan for its quality sake (a Japanese alcoholic beverage made from rice),

Figure 1 Map of the Agano River.

senbei (Japanese cracker), mochi (a rice cake), and arare (a bite-sized Japanese cracker). In sake production, Niigata is third in the country after Gunma and Kyoto prefectures. Therefore, rice quantity and quality which is easily influenced by water and water temperature is of great interest every year.

Actually, a climate change has been appeared in the region. Snow depth shows a continuously decrease, which resulted runoff in April decreasing for the last 4 decades since 1960s. Especially, the monthly average discharge in April was 850 m^3/s in 1980s, that had been reduced to 660 m^3/s by 1990s.

To understand the hydrological change in the region, a numerical experment was carried out using WRF model output and a hydrological model (SVAT&HYCY) firstly. A predict test for global warming also was done with the same method.

2 Model setting

WRF model

WRF version 2.2 is used in the study with two-way nesting technique. The coarse mesh domain is set in a wide area between $28-46^{\circ}N$ and $124-148^{\circ}E$ with a grid in 20 km. The nested domain is located in a narrow region between $35.5-39.3^{\circ}N$ and $135.7-141.5^{\circ}E$ with a 5-km grid.

Two type data of lateral boundary is used; one is NCEP reanalysis dataset in 6 hour interval for the last three decades representing experiment from 1969 to 1999, another is MIROC 3.2 data in monthly for the global warming prediction experiment.

The model was run in a half year, from June to November for the first half and Decenber to May for the second half under the SGI Altix 4700 system.

SVAT&HYCY model

Water and energy on the land is simulated by SVAT&HYCY (Fig. 2), a widely used in river basin scale hydrological study model developed by Ma *et al.* (2000). The model consists of three sub models: (1) heat-balance model, (2) runoff formation model and (3) river routine network model.

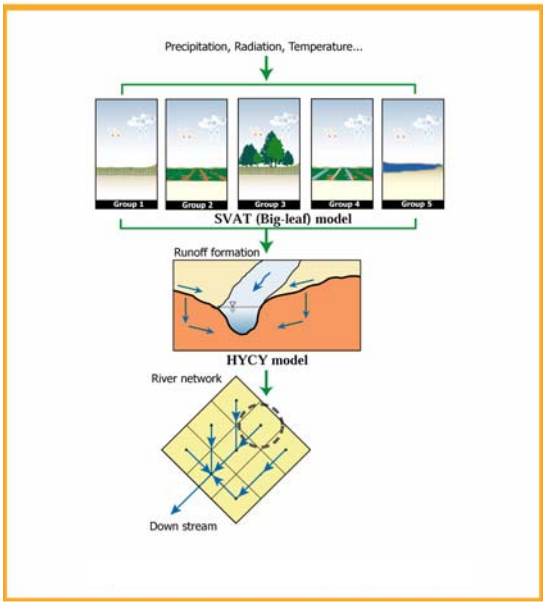

Figure 2 SVAT&HYCY model.

Model input data, output from WRF model includes: (1) downward long wave flux at ground surface, (2) downward short wave flux at ground surface, (3) surface air pressure, (4) water vapor mixing ration at 2 m height, (5) accumulated total grid scale precipitation, (6) air temperature at 2 m height and (7) wind speed at 10 m height.

River network (Fig. 3) was derived from GTOPO30 in 0.05°-grid resolution and the flow speed is set at constant in 0.6 m/s.

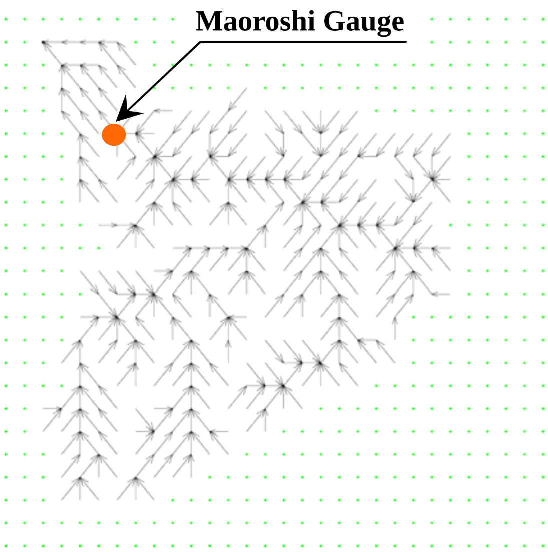

Figure 3 River network system of the Agano River basin, showing the hydrological gauge at Maoroshi.

3 Results

Vegetation in the region is only assumed as one type, forest. Discharge measured at Maoroshi is used to compare the calculated one by the model at the outlet of the river. Although, there is difference in drainage areas, but it is neglected in this step.

Fig. 4 shows a comparison of monthly mean discharge in different decades, 1970s (Fig. 4a), 1980s (Fig. 4b) and 1990s (Fig. 4c). In the 1970s, the first half period from 1969 to 1974 shows a good agreement in seasonal variation with a underestimation in peak value, but there is inconsistent in 1975, 1976 and 1977. In the 1980s, there is underestimation in peak values, while overestimation in other values. The peak values are decreased clearly compared with 1970s and 1980s.

10-year monthly mean discharge is shown in Fig. 5. There is underestimation in winter season, especially in the period of snowmelt. Although there is overestimation in summer season of 1980s, however, the calculation in winter is still underestimating. It is shown that a good agreement in 1990s, peak value in April reduced from more than 800 m^3/s in 1970s and 1980s to below 700 m^3/s.

Fig. 6 shows a prediction of case in the 1990s will be changed by the global warming in 2070s level. It is clear that the snowmelt will be forward in one to two months and the runoff in April to be drastically reduced.

Reference:

X. Ma, Y. Fukushima, T. Hiyama, T. Hashimoto and T. Ohata, 2000: A macro-scale hydrological analysis of the Lena River basin, *Hydrol. Process.*,**14**, pp. 639-651.

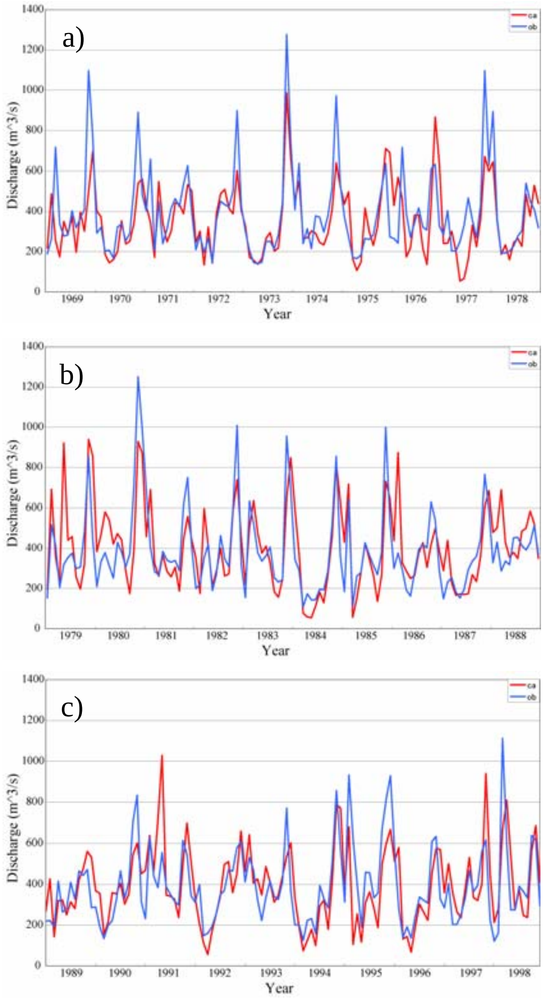

Figure 4 Comparison of monthly mean discharge in the 1970s (a), 1980s (b) and 1990s (c) between observation and calculation.

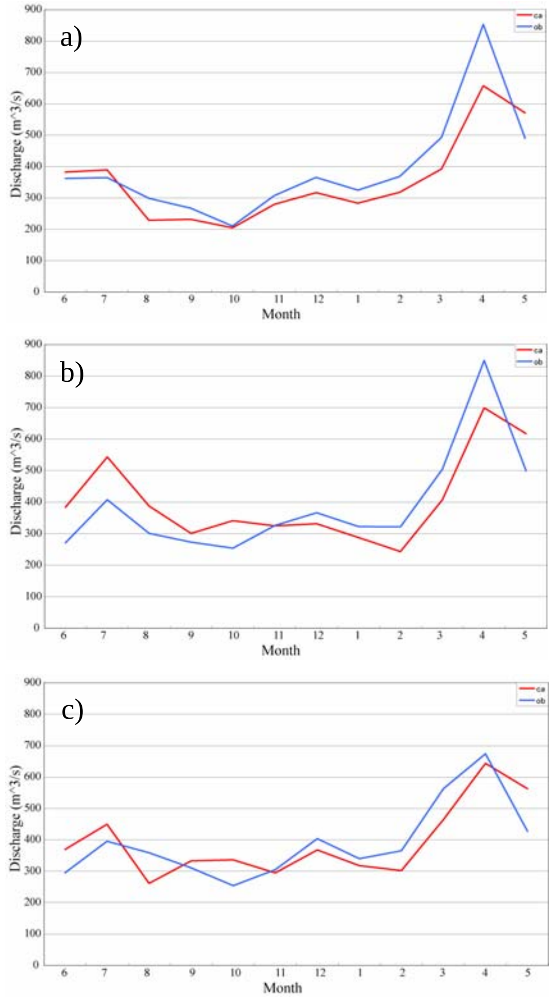

Figure 5 Comparison of 10-year average monthly mean discharge in the 1970s (a), 1980s (b) and 1990s (c) between observation and calculation.

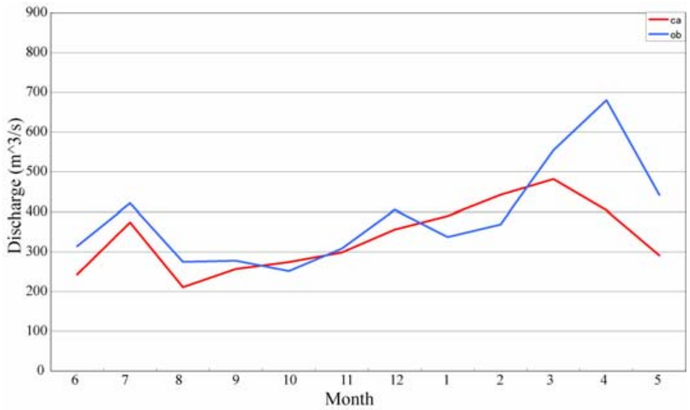

Figure 6 Comparison of 10-year average monthly mean discharge between observation in the 1990s and calculation in the 2070s.