Hydrological simulation using WRF output data

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Introduction

Climate change is having a conspicuous effect on Japan. In particular, the Japan Meteorological Agency (2002) has reported that snowfall amounts have fallen sharply along Japan's eastern seaboard since the mid-1980s, resulting in a noticeable decrease in river discharge in this region in spring.

In recent years, a downscaling method that links atmospheric and hydrological models has been developed for hydrological simulations. Many other authors have also used the downscaling method to investigate changes in river hydrology. To clarify the possible effects of climate change on water resources, we had a numerical investigation of river discharge by using runoff data derived by a regional climate model with a approximately 6-km resolution (Fig.1) as input data to a hydrological model. Two rivers (Fig.1) located in the region were selected in this study. A hindcast experiment , which to reproduce the current climate was carried out for the two decades, 1980s and 1990s. The hydrological responses for future global warming on the 2080s and 2090s were investigated using a pseudo-global-warming method.

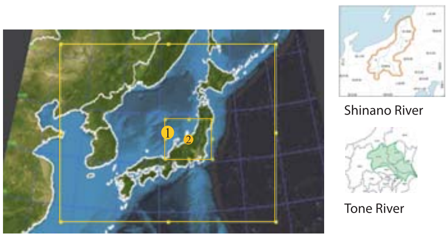

Fig. 1 Domain of the WRF model (a): 1= center of the parent domain (24-km grid); 2= center of the inner domain (6-km grid).

Models and setting

To examine river discharge, we used the Weather Research and Forecasting (WRF) model with dynamic downscaling to simulate input variables for a river routing model. We used the Advanced Research WRF (ARW) version 3.3.1 with a two-way nesting technique and the WRF single-moment 6-class microphysics scheme (Hong and Lim, 2006). Noah-LSM (Chen and Dudhia, 2001) is adopted to simulate the land surface process. The parent domain was set to a wide area on a 24-km grid. The inner domain was located in a smaller area with a 6-km grid (Fig. 1).

We conducted two numerical experiments. One was the hindcast run (CTL) used to reproduce past hydrological events of the 1980s and 1990s. The other was a pseudo-global-warming run (PGW) used to predict the hydrological response in the 2080s and 2090s. The NCEP/NCAR 6-hourly reanalysis data was used as the lateral boundary condition for the CTL. For the PGW, the lateral boundary condition was adopted, following the method of Kawase et al. (2008). A global warming component was added to the NCEP/NCAR reanalysis data for the 1980s and 1990s, respectively. Global warming components were estimated as the monthly average difference between the 20-year average of the 21st century projection, based on scenario A2 of the Special Report on Emissions Scenarios (SRES-A2) (Nozawa and others, 2007), from 2080 to 2100, and the 20th century simulation from 1980 to 2000, from version 3.2 of the Model for Interdisciplinary Research on Climate (MIROC) (hires, approximately 120 km), an atmosphere-ocean coupled general circulation model. The PGW method allows for the comparison of climate in the present year and that in a PGW year that is similar to the control year in terms of interannual variation while including future climatology. Therefore, by the PGW method, we could evaluate the river discharge under a future climate. The output variables used for river discharge simulation from the WRF model were (1) underground runoff and (2) surface runoff.

The river network was constructed using the GTOPO30 dataset with 1-km (Tone River) and 6-km (Shinano River) resolution. The estimated basin area were 8,672 km^2 (Tone River at Kurihashi) and 9,933 km^2(Shinano River at Ojiya), which are close to the reported areas.

The velocity of the river flow was set at 0.7 m/s, in consideration of the mountainous topography. Vegetation in the region is only assumed as one type, forest.

Results

The model performance was checked by past river discharge using the CTL output data for 1980s and 1990s at first. Fig. 2 shows the represent river discharge at Ojiya of the Shinano River in 1980s and 1990s. In general, the simulations were overestimated compared with observed one, but the seasonal variation was represent well; lower discharge in the winter period (Jan. to Feb.) and higher in Spring (April) for both decades of 1980s and 1990s. Discharge projection for the Shinano River using the PGW output data is also shown in Fig. 2. Comparing to the results of current represent experiment CTL, there is increasing in winter and spring from December to March.

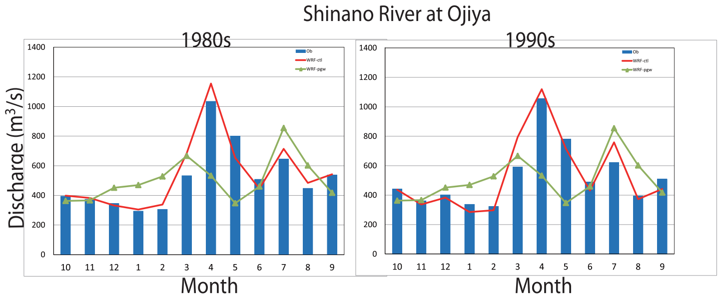

Fig. 2 Comparison of 10-year average monthly mean discharge between the simulation and observations in the 1980s and 1990s in the Shinano River.

For the Tone River (Fig. 3), the CTL runs are overestimated than that observed one, especially in the period of Mar. - Jul. . The results of PGW show that the peaks of April and May will be decreased compared with the results of CTL runs. There is increasing in Autumn and Winter. For this increasing, two factors can be taken into account. One is the part of rainfall increasing due to air temperature rising in condition of 2080s and 2090s. Another is the part of early snowmelt.

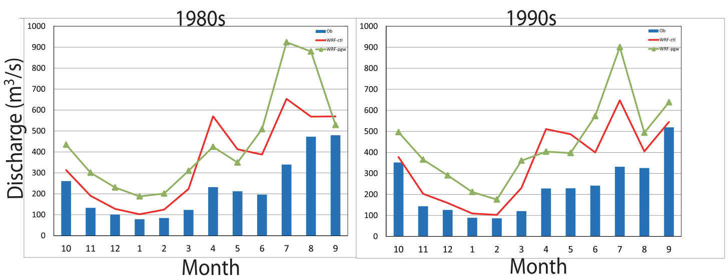

Fig. 3 Comparison of 10-year average monthly mean discharge between the simulation and observations in the 1980s and 1990s in the Tone River.

The difference of the 10-year-averaged global-mean surface air temperature (SAT) of CMIP3 GCM between 1990s and 2070s is 2.19°C in the ensemble mean (with a standard deviation of 0.43°C), and 2.61 C in MIROC, respectively. The difference of SAT around Japan between the 1990s and the 2070s is 2.53°C in the ensemble mean (with a standard deviation of 0.7°C), and 3.36°C in MIROC, respectively. The future global change of SAT in the MIROC is larger than the ensemble mean. Therefore, this projection reflects a climate condition under the relatively high SAT increase in the 2070s between the CMIP3 GCMs. The ratio of snowfall in total precipitation can be greater and the snowmelt season could come later when we use the multi-model ensemble mean as a global warming component.

Acknowledgements

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