Hydrological flood simulation for Tsengwen reservoir watershed (Taiwan) under global climate change with high-resolution atmospheric general circulation model (GCM)

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1. Introduction

Prevention from flood-induced disaster is crucial in Taiwan (North Pacific subtropical region), where several typhoons hit every year. According to the NCDR annual report, the typhoon-induced floods were more severe in last decade. Current IPCC reports warn that an extreme rainfall would occur more frequently. The flood simulation under climate change would provide useful information for disaster prevention. With the use of the high-resolution data for extreme rainfalls, the purpose in this study is to reveal the effect of global climate change on typhoon-induced flooding in a local watershed, Taiwan.

2. Study Site

Tsengwen reservoir watershed, located in southern Taiwan (23° 20’, 120° 40’), is approximately 481 km^2 area, is surrounded partly by plateau areas and primarily by higher mountains, ranging from 233 m to 2,609 m height with approximately 0.54 mean slope (Fig.1). The watershed impounds a part of Tsengwen River (138,500 m long) and involves Tsengwen reservoir, which has the large net capacity of water storage (approximately 0.5 billion m^3) and three flood control spillways (9,470 cms maximum capacity).

3. Method and Data

To simulate river floods by an extreme rainfall, we utilized Integrated Flood Analysis System (IFAS), developed by ICHARM (e.g., Fukami et al. 2009). The IFAS has been practically applied to the past flood events in Asian countries (e.g., Aziz and Tanaka 2011). A conceptual, distributed rainfall-runoff analysis model is employed in the IFAS. The IFAS has a convenient GUI for the rainfall input of ground-based or satellite-based data and has the input function for GIS-based hydrological features. The visualization process is also convenient for the user to make the figures and animations. In this study, the required input data for the hydrological information were the elevation, land-use, and soil-geology data. The elevation data was presented by the Digital Elevation Model from the altitude information with three arc-second resolution (http://gisdata.usgs.gov/website/HydroSHEDS/). The land-use data with 30 arc-second resolution was downloaded from Global Map data (http://iscgm.org/cgi-bin/fswiki/wiki.cgi). The data for the geology and soil type were obtained from the global distribution data for soil water holding capacity with one-degree resolution (http://www.grid.unep.ch/data/data.php). The observed and predicted rainfall data at the gauge stations were used for the rainfall input data, which was distributed into the several divisions of the watershed area using the Thiessen polygon method. For the determination of all parameters in the model, the default values were finally employed after manually tuned with accepted ranges. The extreme rainfall information was obtained by 20 km high-resolution data from the atmospheric GCM (e.g., Kitoh et al. 2008) of Japan Meteorological Agency/Meteorological Research Institute (MRI data) for three periods: Base (1979-2003), Near (2015-2039) and Far (2075-2099). Note that the MRI data was bias-corrected by the difference between the observed data and GCM predicted data

4. Result and Discussion

Fig.2 shows the ratios of Near and Far against Base in the discharge peaks, simulated by IFAS being well-calibrated with the past typhoon-induced flooding. Note that the heaviest rainfall volumes were selected from the 1st to 10th extreme rainfall (hereinafter TP 1 to TP 10). TP 1, TP 2, and TP 10 peaks have the rising ratios of Near/Base and Far/Base. TP 9 peak has the

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most rising ratio of Far/Base by 2.2. TP 4, TP 5, TP 7, and TP 8 peaks of Far are increased by 1.5 to 1.9 of Base peak, but the Near peaks for those are approximately similar to Base peaks. TP 3 and TP 6 for Near- and Far- peaks of discharge are likely not increased. The ranking of rainfall volume is not always consistent with the ranking of the peaks of discharge. Another reason is possibly explained by sharpness of a temporal distribution of discharge. Fig.3 shows the accumulated discharge volumes during each typhoon at the outlet of the dam, using TP 1 to TP 10 extreme rainfalls for Near and Far periods. The thick solid line represents the net capacity of water storage of the reservoir. The dashed line likely indicates realistic flood-control capacity because the reservoir water storage during the flood season is normally close to 40 % of net capacity (hereinafter, realistic capacity for the rest of net capacity). If an accumulated discharge volume is over the realistic capacity of the reservoir, it is necessary to have a flood control by operating the dam spillways. The temporal variations of accumulated discharge volume for Near show that TP 1 to TP 10 volumes are over the realistic capacity (dashed line). All accumulated volumes for Far also overflow in the realistic capacity with more than twice of the net capacity (thick line). Therefore, for the implication of the above estimates, severe floods in Near and Far would overcome the realistic capacity for flood control.

5. Conclusion

The flooding under climate change in a local watershed would be so severe that the inflow will be over dam capacity.

References

Aziz, A. and S. Tanaka, 2011: Regional Parameterization and Applicability of Integrated Flood Analysis System (IFAS) for Flood Forecasting of Upper-Middle Indus River. Pakistan J. Meteorol., **8**, 21-38.

Fukami, K., Y. Sugiura, J. Magome, and T. Kawakami, 2009: Integrated Flood Analysis System (IFAS Ver. 1.2), User’s manual. Japan PWRI-technical note, No.4148, 223 pp., ISSN 0386-5878.

Kitoh, A., A. Yatagai, and P. Alpert, 2008: First super-high-resolution model projection that the ancient “Fertile Crescent” will disappear in this century. Hydrol. Res. Lett., **2**, 1-4, doi: 10.3178/hrl.2.1.

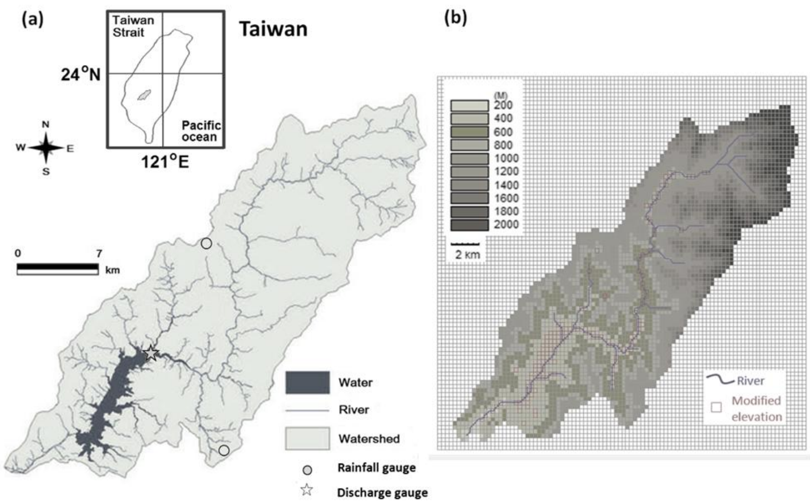

Fig. 1 Map of Tsengwen reservoir watershed (a), and model grid with 400m×400 m size and 91×96cells (b).

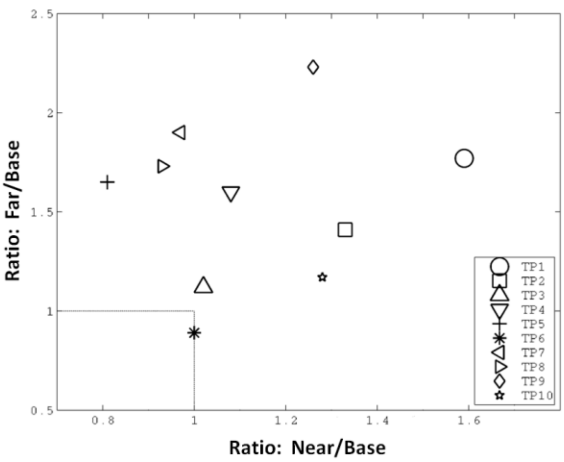

Fig. 2 Ratio of Near and Far against Base for rainfall ranking from TP 1 to TP 10.

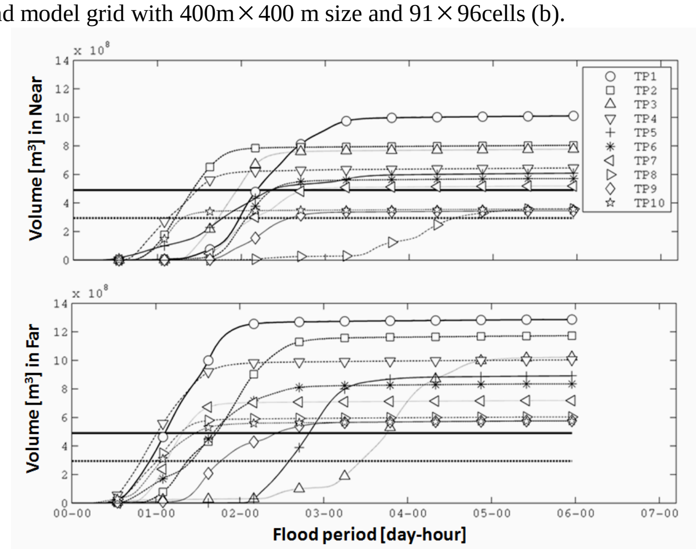

Fig. 3 Accumulated discharge volumes from TP 1 to TP 10. thick line = net capacity, dashed line = realistic capacity.