ASSESSMENT OF CLIMATE CHANGE IMPACT ON HYDROLOGY THROUGH ADDRESSING MODEL PARAMETER-RELATED UNCERTAINTY: CASE STUDY ON GANGES-BRAHMAPUTRA-MEGHNA (GBM) BASIN

International Centre for Water Hazard and Risk Management, GRIPS Student Member ○ Muhammad Masood
National University of Singapore, Singapore, Pat J.-F. Yeh
National Institute for Environmental Studies, Japan, Naota Hanasaki
International Centre for Water Hazard and Risk Management (ICHARM), Member, Kuniyoshi Takeuchi

1. INTRODUCTION

The intensity, duration, and geographic extent of floods in Bangladesh mostly depend on the combined influences of three river systems, Ganges, Brahmaputra and Meghna (GBM). In addition, climate change is likely to have significant effects on the hydrology and water resources of the GBM basins and might ultimately lead to more serious floods in Bangladesh. However, the assessment of climate change impacts on basin-scale hydrology by using well-constrained hydrologic modelling has rarely been conducted for GBM basins due to the lack of data for model calibration and validation. In this study, a hydrologic model has been calibrated and validated on the basin. And then future simulation has been conducted. The impact of climate change on not only the runoff, also the basin-scale hydrology including evapotranspiration, soil moisture and net radiation has been assessed through three time-slice experiments; present-day (1979–2003), near-future (2015-2039) and far-future (2075–2099) periods.

2. METHODOLOGY

A global-scale hydrologic model H08 (Hanasaki et al., 2008) has been applied regionally over the basin at a relatively fine grid resolution (10-km) by integrating the fine-resolution (~0.5-km) DEM data for accurate river networks delineation. The hourly dataset from the Water and Global Change (WATCH) model-inter-comparison project (WFD) (Weedon et al., 2011) is used as the climate forcing data for the historical simulation and the model has been calibrated via analyzing model parameter sensitivity and validated based on a long-term (1980-2001) observed daily streamflow data provided by the Bangladesh Water Development Board (BWDB). A Monte Carlo-type of simulation is conducted to investigate the sensitivity of H08 model parameters to simulation results. 10 optimal parameter combinations according to Nash-Sutcliffe coefficient of efficiency (NSE) has been selected for uncertainty analysis from total 625 simulations.

For the future simulations, the high-resolution (20-km) forcing data obtained from the Meteorological Research Institute Atmospheric General Circulation Model (MRI-AGCM3.2S) (Mizuta et al., 2012) of the Japan Meteorological Agency (JMA) is used. Simulation results for future periods have been then compared with that of base line period (1979–2003) forced by MRI-AGCM3.2S to assess the effect of climate change on the hydrology and water resources of GBM in terms of precipitation, air temperature, evapotranspiration, soil moisture and net radiation by graphical and statistical methods.
.

3. RESULTS AND DISCUSSION

Fig.1 (c1-f3) plots seasonal cycle as well as uncertainty band (color shading) of hydrological quantities and net radiation of present-day, near-future and far-future periods. It is observed that uncertainty band of runoff is relatively narrow (coefficient of variation ranges from 2%-15%), which means model parameter-related uncertainty is less in estimation of runoff compared to that of other hydrologic variable (Fig.1 d1-d3). In addition, it is observed that there is no significant uncertainty in simulated peak discharge for Brahmaputra and Meghna river. This is quite expected as model is validated against observed discharge data at basin outlet. Besides runoff, uncertainty in estimation of evapotranspiration and net radiation is also relatively less. However, uncertainty in estimation of soil moisture is quite large (coefficient of variation ranges from 11%-33%). Larger uncertainty in predicting soil moisture might be significant while precise estimation of soil moisture is necessary. This finding highlights the necessity of physical identification of model parameter.

Results (Fig. 2) shows that, by the end of 21st century (a) the entire GBM basin is projected to be warmer by ~3°C (b) the changes of mean precipitation are projected to be +14.0%, +10.4% and +15.2%, and the changes of mean runoff to be +14%, +15% and +18% in the Brahmaputra, Ganges and Meghna basin respectively (c) evapotranspiration is predicted to increase significantly for the entire GBM basins (Brahmaputra: 14.4%, Ganges: 9.4%, Meghna: 8.8%), which might be due to increase of net radiation (Brahmaputra: 6%, Ganges: 5.9%, Meghna: 3.3%) as well as warmer air temperature. (d) changes of soil moisture (ranging from 1~8.7%) are less compared to other hydrological quantities. However, changes of hydrologic variables will be larger in dry season (Nov-Apr) than that in wet season (May-Oct). It is observed that climate change impact on the hydrology of the Meghna basin is larger than that of the other two basins. For example, in the near-future runoff of Meghna is predicted to increase 11.5% whereas it is 6% and 2.1% for Brahmaputra and Ganges respectively. Larger increase of precipitation (15.2%) in far-future and lower increase of ET (8.8%) and

Keywords: uncertainty, model parameter, climate change impact, hydrology
Contact address: ICHARM, 1-6, Minamihara, Tsukuba, Japan, 305-8516, Tel. 029-879-6809

consequently larger increase of runoff (18%) lead to higher possibility of flood in this basin. Sea level rise due to climate change will also cause higher floods in this basin as it has tidal influence.

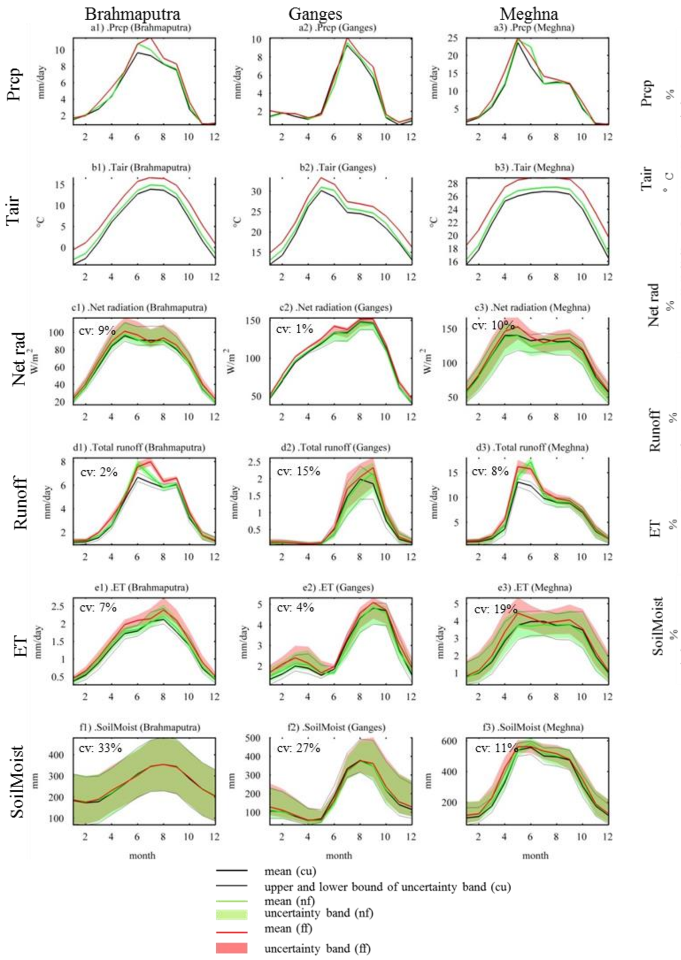

Fig. 1 (a1)-(f3) Uncertainty band of hydrological quantities (d-f) and net radiation (c) components of present-day (grey line), near-future (green shading) and far-future periods (red shading) found from 10 simulation result with considering 10 best parameter set according to NSE. Black, green and red solid lines represent mean of 10 simulation results of current, near future and future respectively. (cu: presend-day, nf: near-future, ff: far-future). Correlation variation (CV) is noted at top-left corner in each sub-plot.

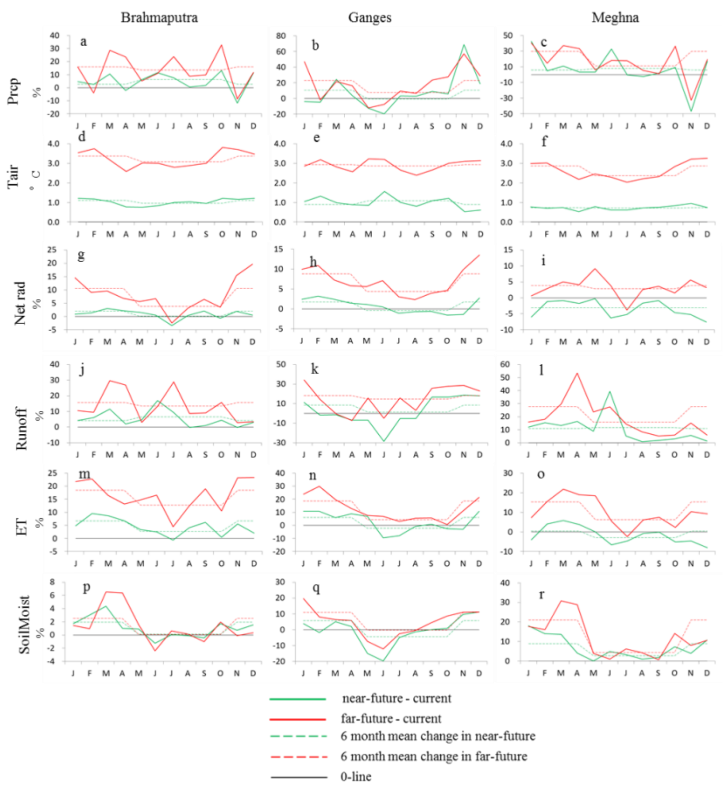

Fig. 2 (a)-(r) Percentage changes of monthly means of climatic and hydrological quantities of near-future and far-future periods from current periods. Dashed line represent 6 months' mean changes in dry season (Nov-Apr) and wet season (May-Oct).

4. CONCLUSION

It is observed from the uncertainty analysis, amongst hydrological variables, runoff is well predictable through hydrologic model simulation, however, uncertainty in estimation of soil moisture is quite large. Larger uncertainty in predicting soil moisture might be significant while precise estimation of soil moisture is necessary. This finding highlights the necessity of physical identification of model parameter. From the future climate change impact assessment it is observed that among three basins, Meghna shows larger hydrological response which leads to higher possibility of flood in this basin. Sea level rise due to climate change will also cause higher floods in this basin as it has tidal influence.

REFERENCES

Hanasaki, N., S. Kanae, T. Oki, K. Masuda, K. Motoya, N. Shirakawa, Y. Shen, and K. Tanaka (2008), An integrated model for the assessment of global water resources –Part 1: Model description and input meteorological forcing, Hydrol. Earth Syst. Sci.(12), 1007–1025.

Mizuta, R., et al. (2012), Climate Simulations Using MRI-AGCM3.2 with 20-km Grid, Journal of the Meteorological Society of Japan, 90A(0), 233-258.

Weedon, G. P., S. Gomes, P. Viterbo, J. Shuttleworth, E. Blyth, H. Osterle, J. C. Adam, N. Bellouin, O. Boucher, and M. Best (2011), Creation of the WATCH Forcing Data and its use to assess global and regional reference crop evaporation over land during the twentieth century, J. Hydrometeorol, 12, 823–848