Analyzing the impact of bias correction of ensemble rainfall forecasts on streamflow prediction skill of a hydrodynamic model

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Abstract

Use of ensemble rainfall forecasts has gained popularity in providing detailed uncertainty information and improving hydrologic prediction skill. India Meteorological Department (IMD) provides medium-range multi-model ensemble (MME) forecasts for all over India with 1- to 5-day lead time. In this study, we bias correct the IMD MME rainfall forecasts using a modified version of Kohonen Self-Organizing Maps (KSOM) and analyse the effect of bias correction on the streamflow prediction skill of MIKE 11 Hydrodynamic (HD) model for the years 2012-2014. We have selected the upper region of the Mahanadi River basin as the test bed. The results indicate improvement of rainfall forecasts after bias correction. Subsequently, use of bias corrected rainfall forecasts as input forcing to the MIKE 11 HD model provides better streamflow forecasts at all the lead times (Nash Sutcliffe Efficiency, NSE ranging from 0.89 to 0.41) compared to the use of raw forecasts (NSE ranging from 0.89 to -0.51). To further improve the streamflow forecasts, we have applied the recently developed robust wavelet-based non-linear autoregressive with exogenous inputs dynamic neural network model, WNARX. This post-processing operation tends to improve the streamflow forecast quality to an acceptable range (NSE = 0.92-0.71). The results encourage us to conclude that the IMD MME forecasts has great potential to improve streamflow prediction skill of a hydrodynamic model.

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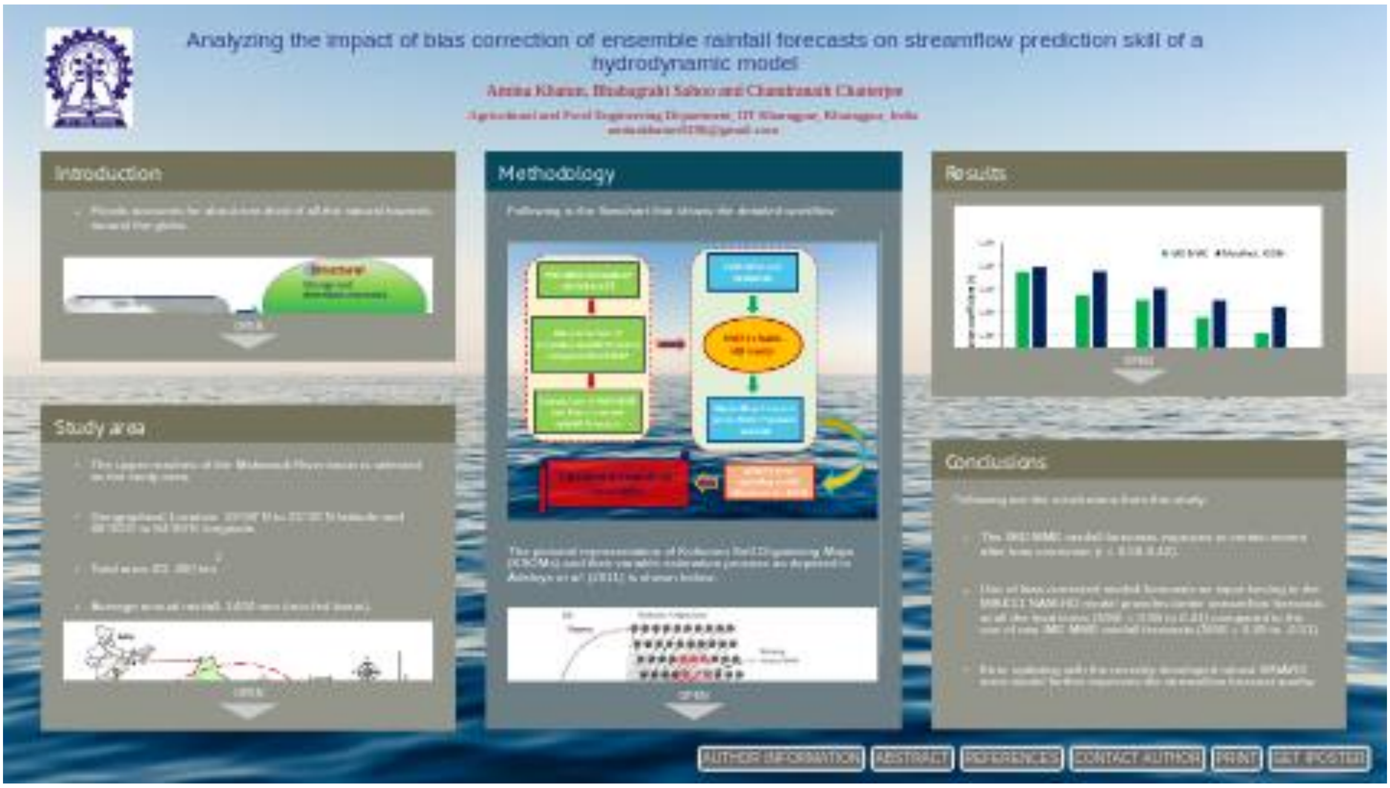

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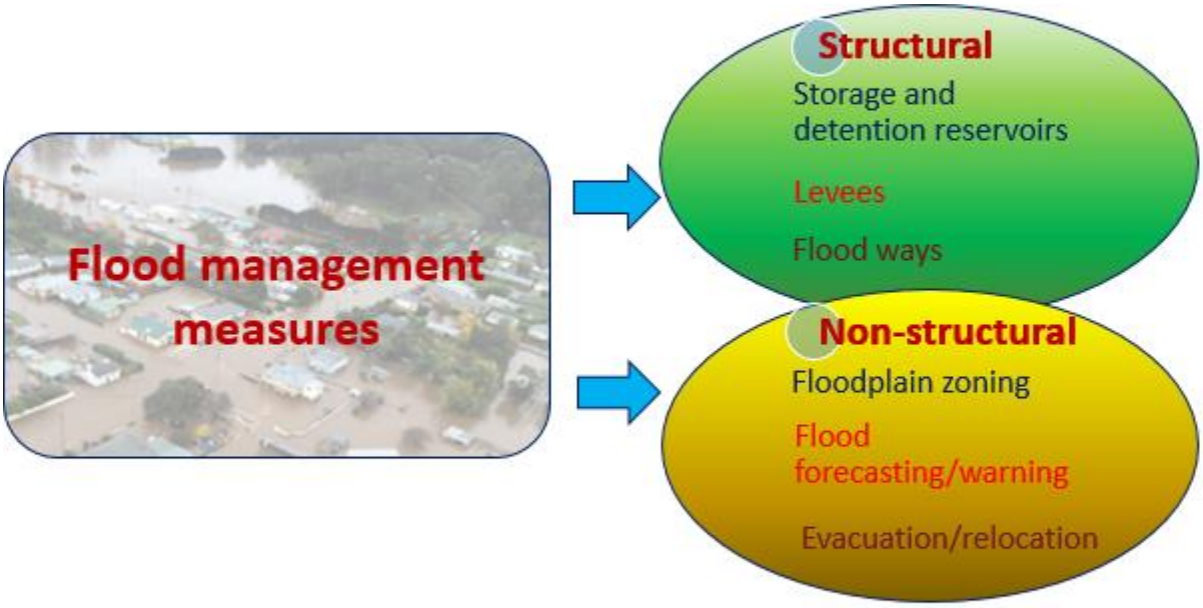
INTRODUCTION

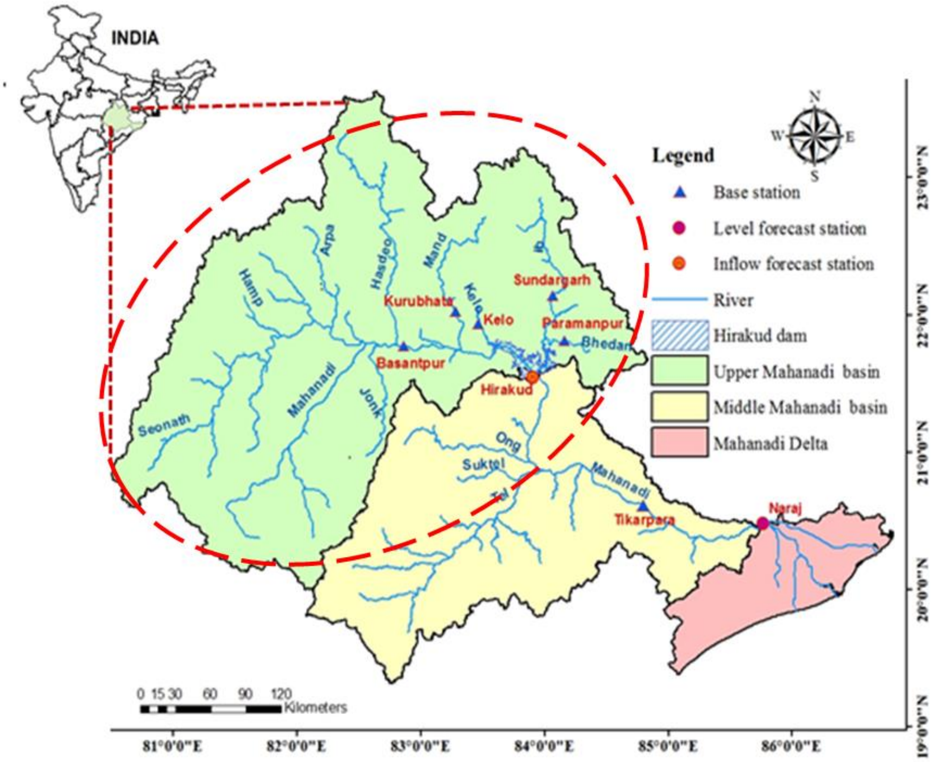
- Floods accounts for about one-third of all the natural hazards around the globe.



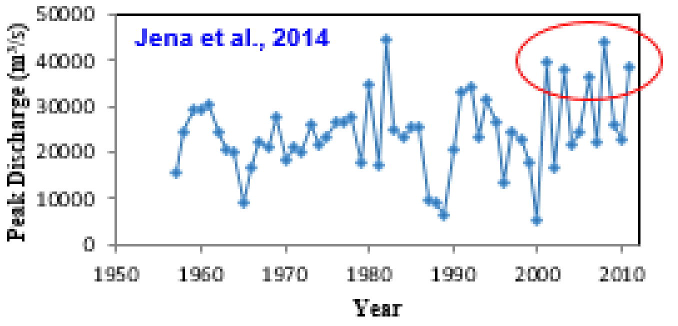
- Reliable inflow forecasts into a reservoir with a sufficient lead-time could serve for effective flood management.
- Regardless of the flexibility of KSOM, very few applications are studied in the field of hydrological modeling (Nanda *et al*., 2017).
- As a state-of-the-art, the MIKE11 model has been applied across many river basins worldwide.
- The data-driven models, though does not have a clear physical significance of the elements of hydrologic cycle, have ease of calibration to result in effective flow forecasts.

STUDY AREA

- The upper reaches of the Mahanadi River basin is selected as the study area.
- Geographical Location: 19°90′N to 23°35′N latitude and 80°30′E to 84°80′E longitude.
- Total area: 83, 400 km^2.
- Average annual rainfall: 1400 mm (rain-fed basin).



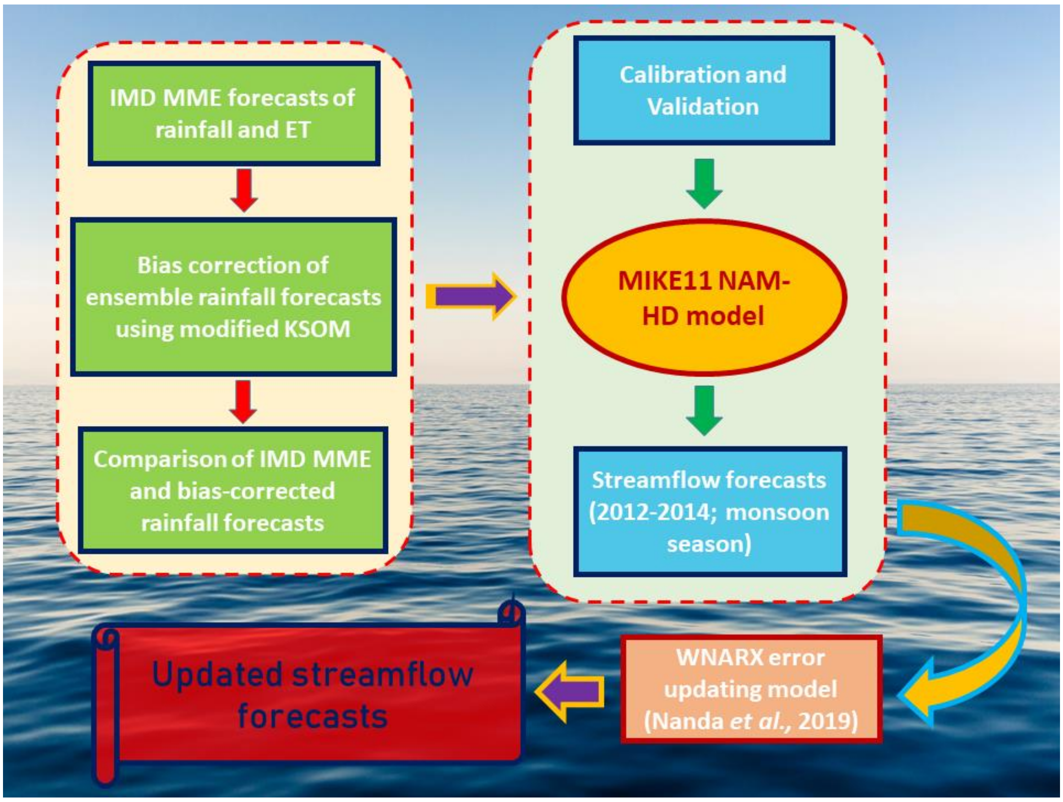
- Recent study by Jena *et al*. (2014) reveals that five out of the six major floods in the Mahanadi River basin occurred in the past decade.



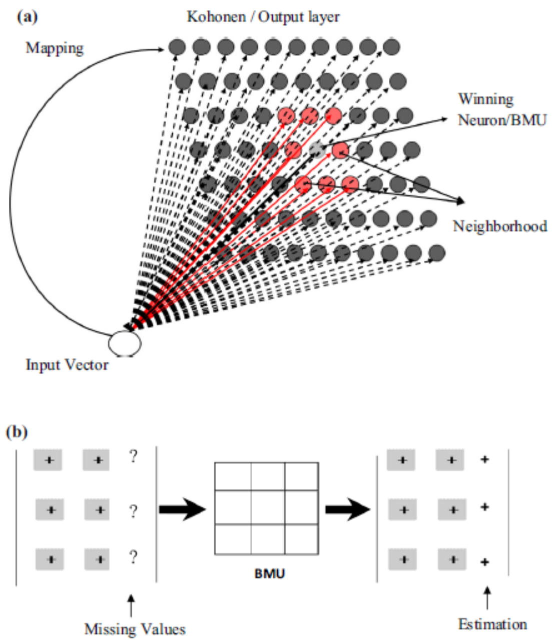
- These floods caused huge financial and crop losses.

METHODOLOGY

Following is the flowchart that shows the detailed workflow:



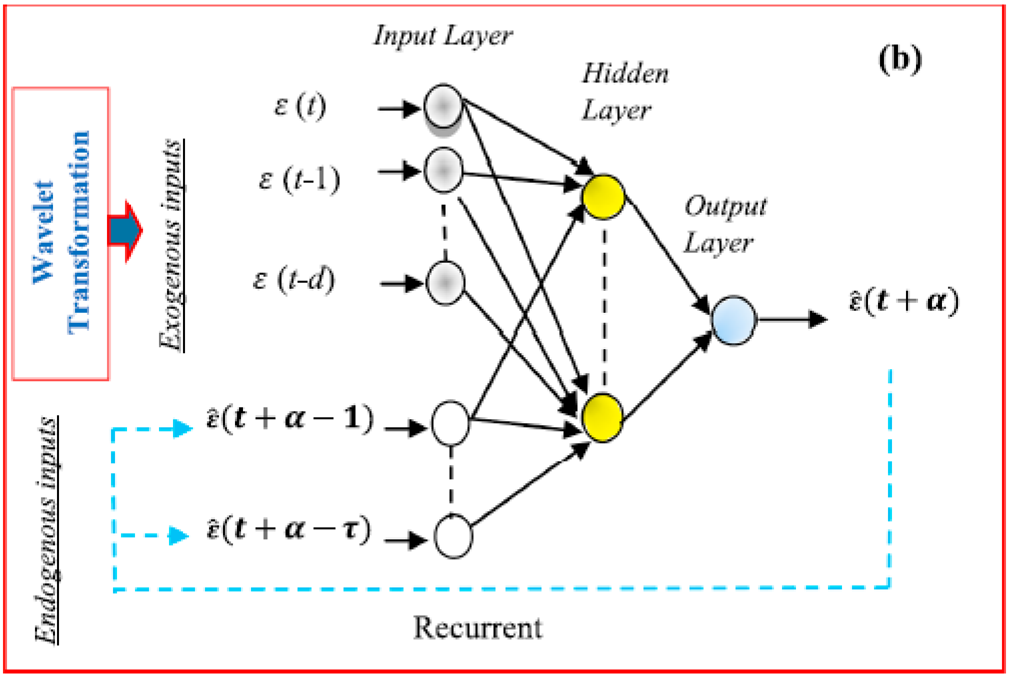
The pictorial representation of Kohonen Self-Organising Maps (KSOMs) and their variable estimation process as depicted in Adeloye *et al*. (2011) is shown below:



(a) Kohonen self-organizing feature map (KSOM) and (b) Variable estimation from best matching unit (BMU) search in KSOM (Adeloye et al., 2011).

- However, here the enhanced KSOM, in which the map units is a function of coefficient of variation (CV, %) is used (Nanda *et al.*, 2017).

- The Wavelet-based Non-linear Auto-Regressive with eXogenous inputs (WNARX) error updating model develeoped by Nanda *et al.* (2019) is shown below:



Where, ε = streamflow prediction error

t = time of forecast

d = effective lag time for exogenous inputs

ζ = effective lag time for endogenous inputs

α = lead time

RESULTS

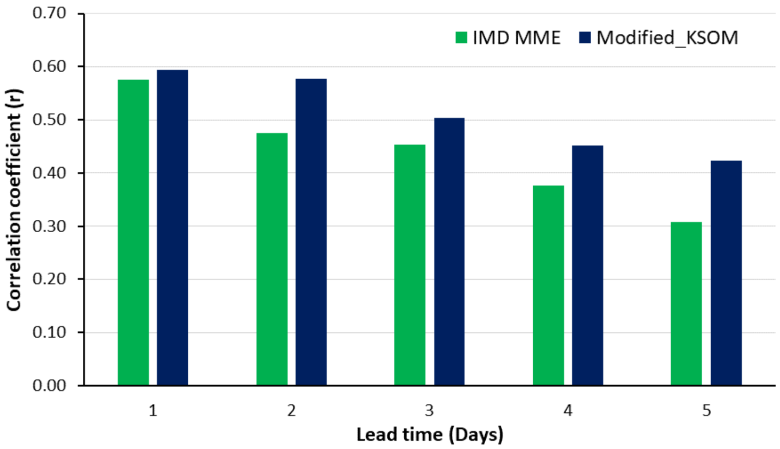


Fig. Correlation coefficient of IMD MME and the bias-corrected rainfall forecasts with observed rainfall.

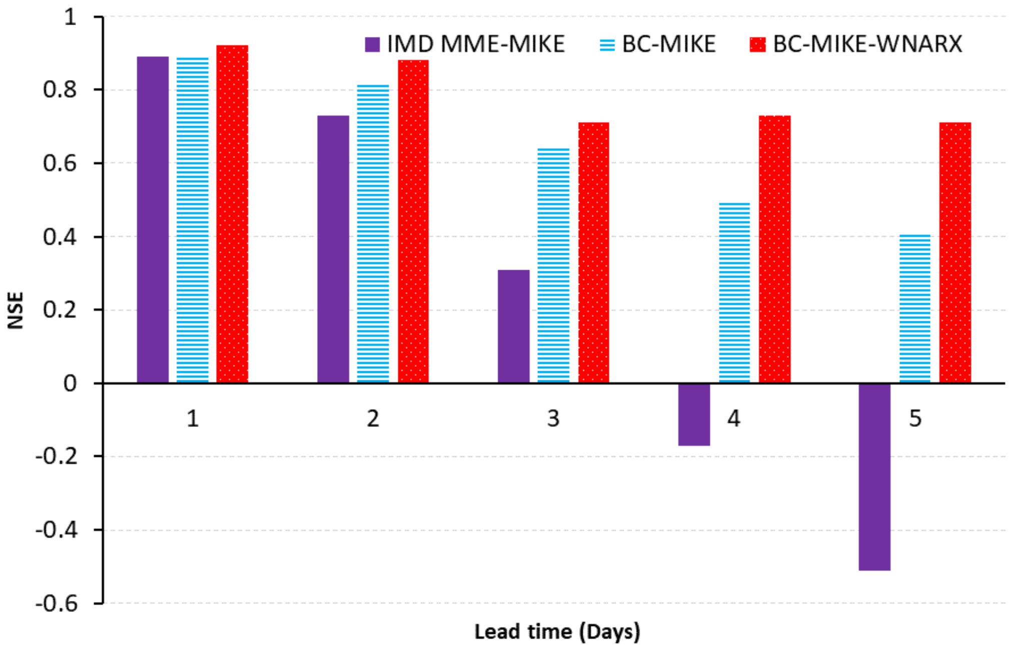


Fig. NSE of streamflow prediction by (a) MIKE11 NAM-HD model using IMD MME rainfall data (IMD MME-MIKE), (b) MIKE11 NAM-HD model using bias-corrected IMD MME rainfall data (BC-MIKE), and (c) MIKE11 NAM-HD model using bias-corrected IMD MME rainfall data and error updating using WNARX error model (BC-MIKE-WNARX).

CONCLUSIONS

Following are the conclusions from this study:

- The IMD MME rainfall forecasts improves to certain extent after bias correction (r = 0.59-0.42).
- Use of bias corrected rainfall forecasts as input forcing to the MIKE11 NAM-HD model provides better streamflow forecasts at all the lead times (NSE = 0.89 to 0.41) compared to the use of raw IMD MME rainfall forecasts (NSE = 0.89 to -0.51).
- Error updating with the recently developed robust WNARX error model further improves the streamflow forecast quality to an acceptable range (NSE = 0.92-0.71) up to 5-days lead time.

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ABSTRACT

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