Research Proposal

on

Application of GPM IMERG Data for Near Real-time Flood Prediction in Bangladesh Using Statistical Validation and Hydrological Modeling Approach

Scholar Name

Sanjana Hasan

Scholar's Affiliation

Khulna University of Engineering & Technology

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Introduction: Bangladesh is particularly vulnerable to floods due to its flat terrain and seasonal variations. It frequently experiences extreme rainfall events that have caused extensive flooding [1]. Accurate flood forecasts are crucial for effective disaster mitigation [2]. Applications requiring extremes in rainfall, hydrological modeling, water resource management, and hydroclimatic research have great demand for accurate, reliable, high-resolution precipitation datasets [3]. In this respect, the latest version of the satellite precipitation estimates is the Integrated Multi-satellitE Retrievals for Global Precipitation Measurement (IMERG) version 06, which provides global rainfall and snowfall data starting from 2000 [4]. According to recent research, GPM IMERG Precipitation Products are effective for hydrological modeling and mapping flood inundation [5]. Subsequently, the IMERG-E product shows distinguished potential for near real-time rainfall forecasting [6]. Moreover, IMERG products accurately detected seasonal precipitation patterns and showed high accuracy over moderately elevated areas but struggled in coastal and mountainous regions [7]. Despite some progress in flood forecasting, the gap among the current practices, based on outdated techniques with limited real-time satellite data suitable for unique climatic conditions, is significant.

Research Questions: This study aims to evaluate the efficiency and accuracy of GPM IMERG satellite rainfall data for real-time flood prediction over Bangladesh. In this respect, the following research question has been addressed:

1. How well does GPM IMERG rainfall data capture extreme rainfall events compared to the ground-based rain gauge data across Bangladesh?
2. Given the complications in land-use patterns, how effective will GPM IMERG data be in supporting near-real-time flood prediction in Bangladesh?
3. What are the modifications to enhance GPM IMERG data performance concerning flood modeling over Bangladesh?

Literature Review: The precipitation-based analysis is essential to understand the flood risk, especially the IMERG products, which perform better than other satellite data in hydrological modeling. However, there might still be potential routes to increase the accuracy of flood prediction using the development of satellite-based precipitation products and the usage of multi-methods in hydrological modeling over data-scarce regions like Bangladesh.

Hydrologic variables such as discharge provide an exact prediction of flood magnitude in complex basins like Brahmaputra, contrary to precipitation-based analysis, though useful to understand flood risks. Further development must occur for a more thorough understanding and forecasting [1]. On the other hand, the IMERG precipitation products outperform GSMaP and TRMM in hydrological modeling, mainly high flows in the Brahmaputra Basin; meanwhile, improvements of satellite products in data-scarce regions for accurate flood modeling are needed [5]. Following that, the strength of IMERG in capturing total rainfall and extreme events in Bangladesh makes it suitable for flood forecasting. Its tendency to overestimate top-percentile events suggests that bias correction could improve its accuracy for real-time flood monitoring [8]. In addition, IMERG precipitation estimates produce a performance superior to those of other satellite products over Bangladesh. On the other hand, it shows an overestimation propensity for rainfall amounts, especially during the monsoon season. Including rain gauge data improves the accuracy, though high biases remain, especially at extreme events; hence, further adjustment is required to enhance GPM IMERG Precipitation Product performance [9].

It also includes the proposed method using real-time GPM IMERG precipitation data, coupled with advanced predictive algorithms to overcome deficiencies in current flood prediction models [10], hence providing more accurate and dynamic forecasts for Bangladesh.

Proposed Methodology: The method is a quantitative approach.

1. **Data Collection & Preprocessing:** GPM IMERG Early rainfall data will be collected from January 2000 to December 2024. It must cover high-intensity rainfall events over Bangladesh. Rain gauge data will serve as the reference for these studies. These data are then processed temporally and spatially synchronized with the IMERG dataset.
2. **Statistical Accuracy Assessment:** The accuracy of the IMERG data will be evaluated by applying the following - Correlation Co-efficient (CC) for agreement strength between IMERG and ground data, Root Mean Square Error (RMSE), and Bias to quantify average error and systematic deviation. POD and FAR will be applied to assess the ability of IMERG to capture rainfall events critical for flood predictions. Apart from that, high-intensity rainfall events will also be studied to visualize the performance of GPM IMERG under extreme conditions.
3. **Hydrological Modeling and Flood Simulation:** The HEC-HMC model will be applied for the flood event simulation. Historical flood data, along with rain gauge measurements, will be utilized for model calibration. Subsequently, the model will be executed with the IMERG-E rainfall to enable the study to assess the reliability of IMERG data for real-time flood prediction. The results of the simulated flood from the model will be compared with the observed flood events to evaluate the reliability and accuracy of the IMERG data for real-time flood prediction over Bangladesh.
4. **Temporal and Spatial Discrepancy Analysis:** Timing offsets between the IMERG and Ground on rainfall onset, peak intensity, and duration will be analyzed to show some timing lags in the IMERG data that may impact real-time flood prediction. The rainfall estimation by IMERG will be mapped and analyzed using GIS tools. Spatial accuracy will be calculated to detect how well IMERG captures rainfall variability over land-use types.
5. **Performance Evaluation and Recommendations:** The overall performance of the IMERG for flood forecasting in Bangladesh will be examined through statistical and hydrological analyses, more precisely based on accuracy, timing, and spatial alignment. Any necessary calibrations will be identified to enhance IMERG's accuracy for real-time flood prediction, such as adjustments for timing, spatial resolution, or integration with soil moisture data. Recommendations will aim to improve the application of IMERG for flood preparedness and early warning systems in Bangladesh.

Expected Outcome: Results are expected to provide a comprehensive evaluation of GPM IMERG accuracy in Bangladesh and a model that develops and calibrates real-time flood forecast with the application of IMERG-E, along with recommendations on possible improvements that could be useful in enhancing the effectiveness of such a procedure.

Potential Limitation: The model may not capture the complicated urban environment with insufficient gauge data, hence affecting the accuracy of flood predictions.

Conclusion: The GPM IMERG data will be used to enhance Bangladesh's real-time flood forecasting; the study offers a key instrument for flood control and early warning systems.

Project Practicalities: The project will take 10 months. The first 3 months will be used to collect data and preprocess; subsequent data analysis will take the next 6 months. The last month will be reserved for writing the final report.

Post-program Plan: After further collaboration with researchers for guidance and refinement, the results will be published as a journal paper.

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