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# Multi-Scale Hydro-meteorological Assessment of Extreme Flooding Events: The Case of Bangladesh's Eastern Deltaic Region

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## INTRODUCTION & AIM

The flash floods of August 2024 in the eastern and southeastern deltaic regions of Bangladesh severely impacted about 5.7 million individuals, claiming at least 23 lives and generating widespread destruction of infrastructure and agriculture. The occurrence was triggered by a combination of heavy rainfall, which was brought about by the interaction between cold air masses, a low-pressure system over the Bay of Bengal, and an intensified monsoon trough. Moreover, the coincidence of full moon and spring tides amplified the flood by holding back the outflow of floodwaters. In order to further investigate the water dynamics, the DELF3D model, which is a nested, wave-tide coupled model, is used in this study to simulate the water height changes in the Bay of Bengal (BoB) area [1]. The study also employs the HEC-HMS hydrological model, using discharge data from four stations to simulate the event with satisfactory accuracy, offering valuable insights into the hydrological dynamics. While the Dumboor Dam's water release during this period had minimal impact, the lack of early transboundary communication worsened the crisis. This study aims to quantify the contribution of tidal surges, rainfall, and geomorphological features to flood intensity. The results stress the pressing need for more integrated flood prediction systems with tidal-hydrological interactions, efficient early warning systems, and improved transboundary water communication to mitigate future flood vulnerability.

## METHOD

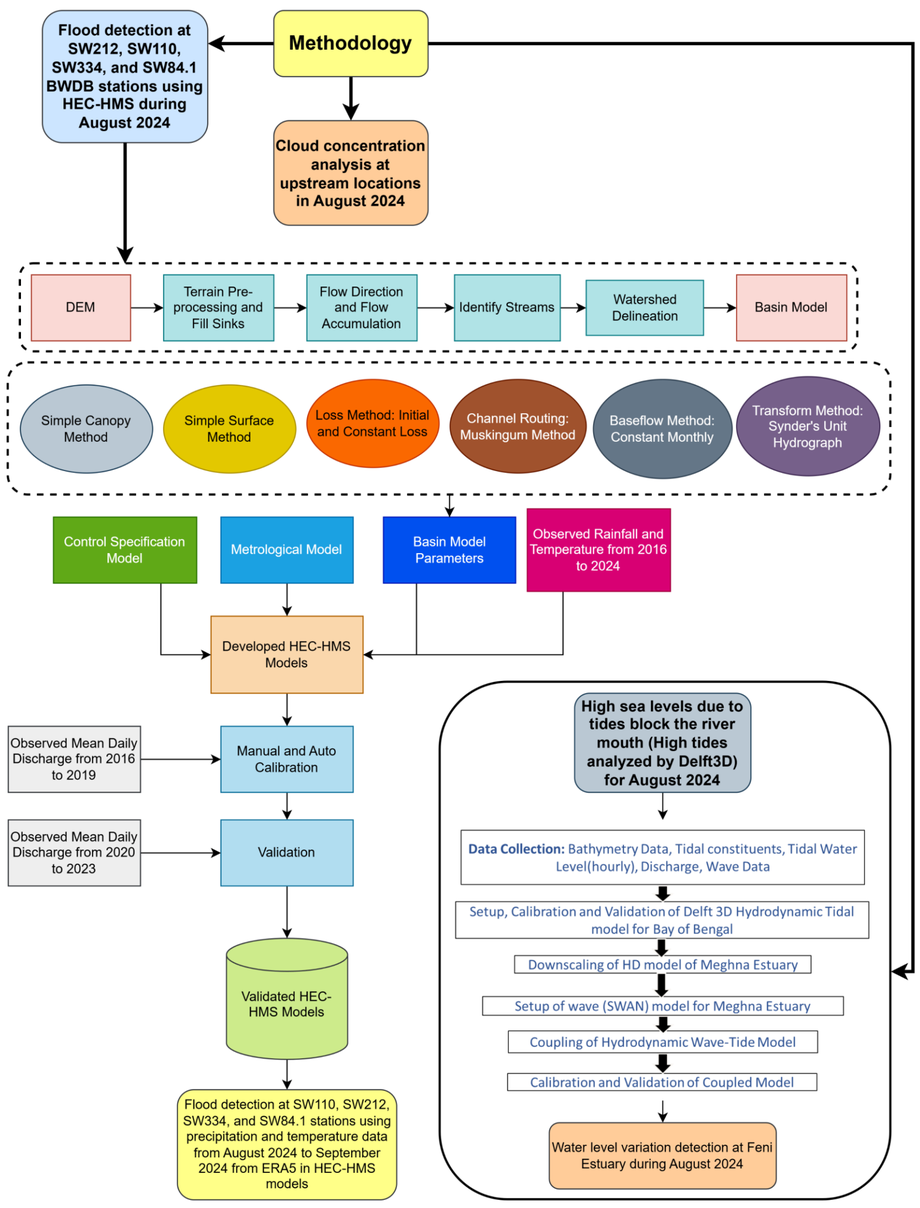
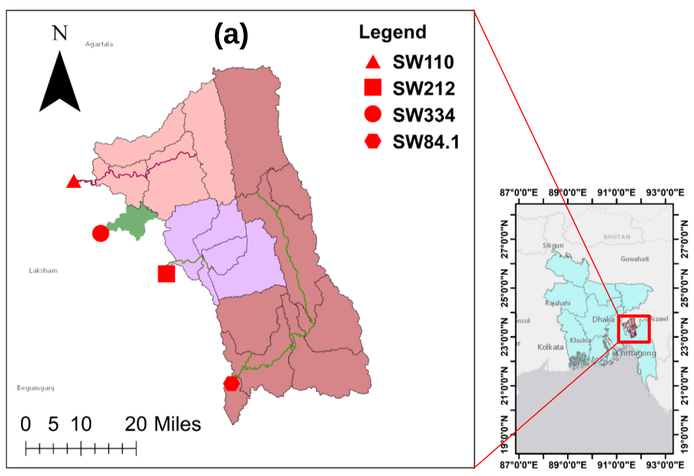



**Figure 1.** Methodological flowchart.

## STUDY AREA



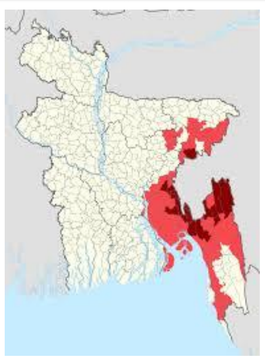




**Figure 2. (a)** Study area (Locations of four outlets used for developing the HEC-HMS model: SW112, SW212, SW334, and SW84.1 stations), **(b)** Flood-affected areas, worst-affected areas in dark red.

## RESULTS & DISCUSSION

**Table 1.** HEC-HMS model performance: Calibration and validation results for selected stations.

| Stations | SW110 | | SW212 | | SW334 | | SW84.1 | |
|---|---|---|---|---|---|---|---|---|
| Phase | Calibration | Validation | Calibration | Validation | Calibration | Validation | Calibration | Validation |
| Peak Discharge ($m^3/s$) | | | | | | | | |
| Computed | 124.1 | 152.1 | 124.1 | 166.7 | 7.8 | 8.3 | 120.9 | 155.2 |
| Observed | 190.5 | 180.5 | 232.5 | 134.2 | 20.2 | 17.6 | 227.9 | 144.1 |
| Volume (mm) | | | | | | | | |
| Computed | 1650.98 | 1774.67 | 1150.98 | 1151.12 | 705.49 | 1705.40 | 681.36 | 356.13 |
| Observed | 1796.05 | 1815.69 | 1271.37 | 1206.09 | 909.55 | 1675.35 | 472.08 | 244.37 |
| Performance Metrics | | | | | | | | |
| RMSE Std Dev | 0.59 | 0.64 | 0.76 | 0.81 | 0.84 | 0.88 | 0.77 | 0.90 |
| Nash-Sutcliffe | 0.754 | 0.746 | 0.714 | 0.684 | 0.663 | 0.652 | 0.689 | 0.676 |
| Percent Bias | -0.79% | -2.30% | -9.47% | -4.56% | -8.40% | -7.60% | -0.84% | 1.46% |

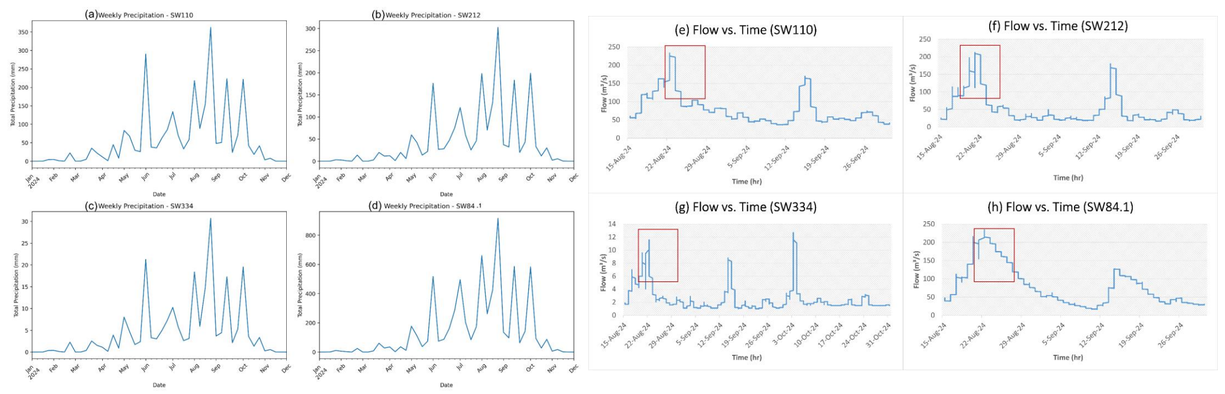



**Figure 1.** Weekly precipitation time series for (a) SW110, (b) SW212, (c) SW334, and (d) SW84.1 stations; and flow hydrographs for (e) SW110, (f) SW212, (g) SW334, and (h) SW84.1 stations. Red boxes in panels (e) to (h) indicate detected flood events.

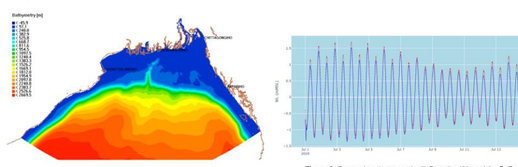


**Figure 2.** Location of Calibration and Validation BoB Hydrodynamic Model.



**Figure 3.** Comparison between the IHO station WL and the BoB model WL during the wet season for calibration at SHORTT ISLAND.

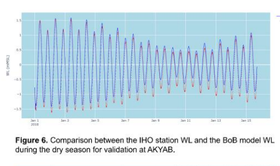


**Figure 6.** Comparison between the IHO station WL and the BoB model WL during the dry season for validation at AKYAB.

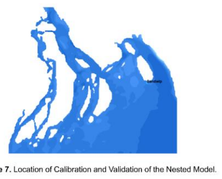


**Figure 7.** Location of Calibration and Validation of the Nested Model.

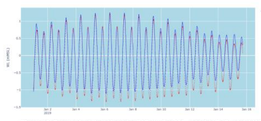


**Figure 4.** Comparison between the IHO station WL and the BoB model WL during the dry season for calibration at SHORTTIS LAND.

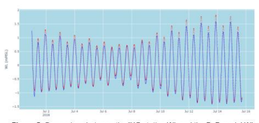


**Figure 5.** Comparison between the IHO station WL and the BoB model WL during the wet season for validation at SHORTTIS LAND.

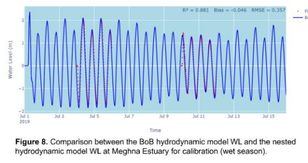


**Figure 8.** Comparison between the BoB hydrodynamic model WL and the nested hydrodynamic model WL at Meghna Estuary for calibration (wet season).

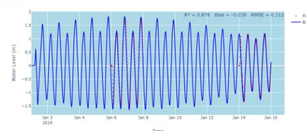


**Figure 9.** Comparison between the BoB hydrodynamic model WL and the nested hydrodynamic model WL at Meghna Estuary for calibration (dry season).

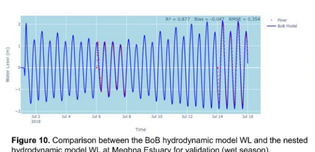


**Figure 10.** Comparison between the BoB hydrodynamic model WL and the nested hydrodynamic model WL at Meghna Estuary for validation (wet season).

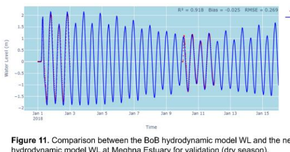


**Figure 11.** Comparison between the BoB hydrodynamic model WL and the nested hydrodynamic model WL at Meghna Estuary for validation (dry season).

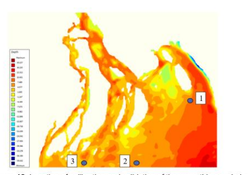


**Figure 12.** Location of calibration and validation of the wave-tide coupled model.

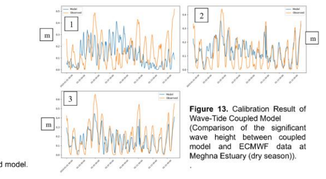


**Figure 13.** Calibration Result of Wave-Tide Coupled Model (Comparison of the significant wave height between coupled model and ECMWF data at Meghna Estuary (dry season)).

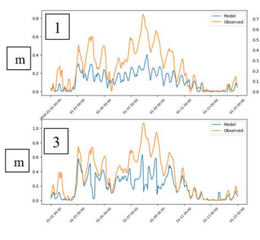


**Figure 14.** Validation Result of Wave-Tide Coupled Model (Comparison of the significant wave height between the coupled model and ECMWF data at Meghna Estuary (dry season)).

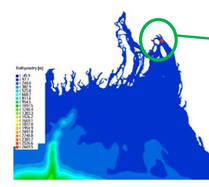


**Figure 15.** Location to observe water level measurements in the Feni Estuary.


**Figure 16.** Data Source: Delft3d Model Run (2024-08-20 to 2024-08-24).

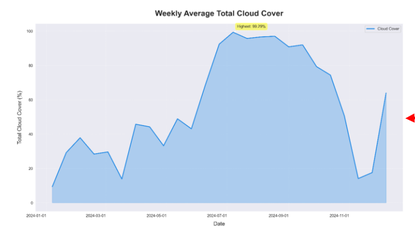



**Figure 17.** Weekly average total cloud cover over the study area during 2024. The highest cloud cover (99.29%) was observed in August.

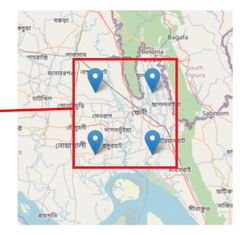


**Figure 18.** Study area map showing the region (red boundary) for cloud cover concentration analysis.

## CONCLUSION & FUTURE WORK

Future work should focus on enhancing the integration of tidal and hydrological models to improve flood forecasting accuracy, particularly in deltaic regions like Bangladesh. There is a need for real-time monitoring systems that combine meteorological, hydrological, and tidal data to provide more timely and localized early warnings. Additionally, strengthening transboundary water management and communication mechanisms with neighbouring countries is crucial to mitigating the impacts of such cross-border disasters. Future studies could also explore the impact of climate change on the frequency and intensity of similar events in the region.

## REFERENCES

**[1]** Md. Shahriar; Dr. Md. Ataur Rahman DEVELOPMENT OF WAVE-TIDE HYDRODYNAMIC MODEL USING DELFT 3D FOR BAY OF BENGAL AND SIMULATION OF NEARSHORE HYDRODYNAMIC AT MEGHNA ESTUARY. **2025**, doi:10.5281/ZENODO.17403666.