Ocean–atmosphere coupled modelling of storm surges in the Bangladesh Coast

Nabir Mamnun [1,2] nabir.mamnun@gmail.com
Lucy Bricheno [3] luic@noc.ac.uk

[1] Nansen–Bangladesh International Centre for Coastal, Ocean and Climate Studies (NABIC),Dhaka, Bangladesh.
[2] Institute of Marine Sciences and Fisheries, University of Chittagong, Chittagong, Bangladesh.
[3] National Oceanography Centre (NOC), Liverpool, UK.

Introduction

Tropical cyclones are devastating hazards and have been major problem for the coastal population of Bangladesh. The massive destruction and loss of human life associated with a tropical cyclone can be attributed mainly to the sudden inundation and flooding of the coastal areas produced by storm surges. Any improvement in modelling and forecasting such surges has the potential to save lives and money. For decades, the numerical model-based storm surge prediction systems have been an important tool to reduce the loss of human lives and property damage caused by storms surge. In order to improve the accuracy in predicting storm surge and coastal inundation, recent model development efforts tended to include more modelling components, such as meteorology model and surface wave model in storm surge modeling.

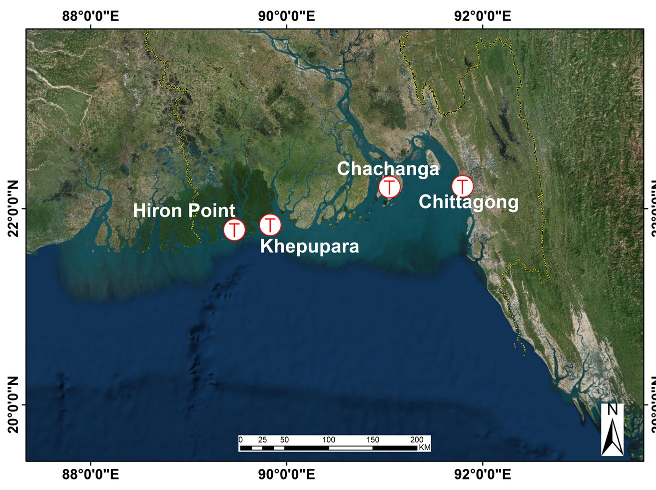

Figure: Location of tide gauges in the Bangladesh coast used for validation of POLCOMS

Numerical Modelling

Two well–established models have been used: the Advanced Research Weather Research and Forecasting model (WRF; Skamarock et al. 2008); and a 3D tide and surge model, Proudman Oceanographic Laboratory Coastal Ocean Modelling System (POLCOMS; Osuna and Wolf 2005). The outputs from the meteorological model were used to drive the ocean model.

b. Atmospheric Model – WRF

A 12 km resolution grid spacing (277 x 294 grid points) was defined . The initial and boundary conditions for the large-scale atmospheric fields were derived from the 1°x 1°NCEP global final analysis (FNL). WRF was run in a one configuration in a single domain re–initializing the model from global data daily to avoid excessive drift.

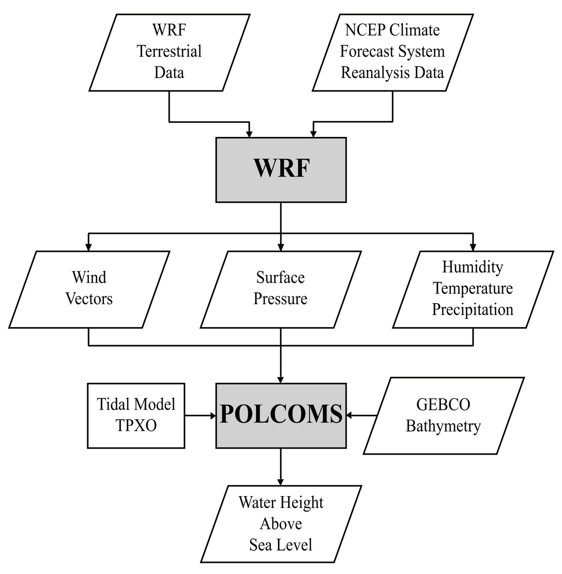

Figure: Model schematic diagram

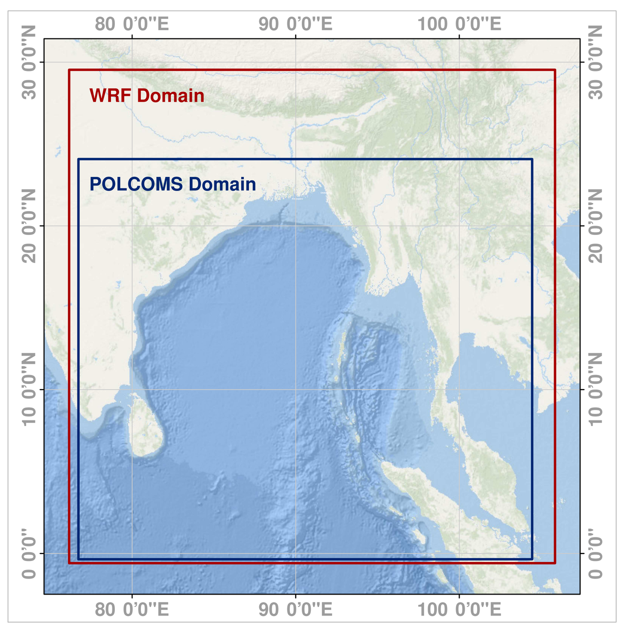

Figure: Model Domains

b. Ocean Model – POLCOMS

The model was set up over the region as described in Kay et a 2015). The spatial resolution was 0.1°in longitude and latitu (about 11 km) and the domain extended to 200 km offshore fro the shelf break. There were 40 vertical levels at each grid point, di tributed using an s-coordinate method. Bathymetric data definir the region were obtained from GEBCO data on a global 30 ar second grid. Minimum water depth in the model domain is 10 with no wetting and drying applied at the coast; hence the comple shape of the delta's coastline can only be represented approximatel Tidal forcing is built through forcing at the open ocean bounda with 8 harmonic components: Q1, O1, P1, K1, N2, M2, S2 and K

Table: The R^2 value, RMSE and Pbias for MSW comparing wi IMD and JTWC estimation for cyclone SIDR and AILA.

	R2		RMSE (KTs)		P-bias (%)	
	IMD	JTWC	IMD	JTWC	IMD	JTWC
SIDR	0.92	0.84	7.06	10.10	22.97	-6.47
AILA	0.89	0.76	5.53	8.15	-0.57	-0.41

Table: The R^2 value, RMSE and Pbias for MSLP comparing wi IMD and JTWC estimation for cyclone SIDR and AILA.

	R2		RMSE (hPa)		P-bias (%)	
	IMD	JTWC	IMD	JTWC	IMD	JTWC
SIDR	0.57	0.76	9.23	12.50	-1.84	1.11
AILA	0.89	0.76	5.53	8.15	0.576	3.656

WRF Model Results

Model simulated intensity and tracks of severe tropical cyclones SIDR and AILA are compared against Joint Typhoon Warning Center (JTWC) and India Meteorological Department (IMD) observations. Intensity of the cyclone is evaluated in terms of minimum central pressure (MCP) at sea level and maximum sustain wind (MSW).

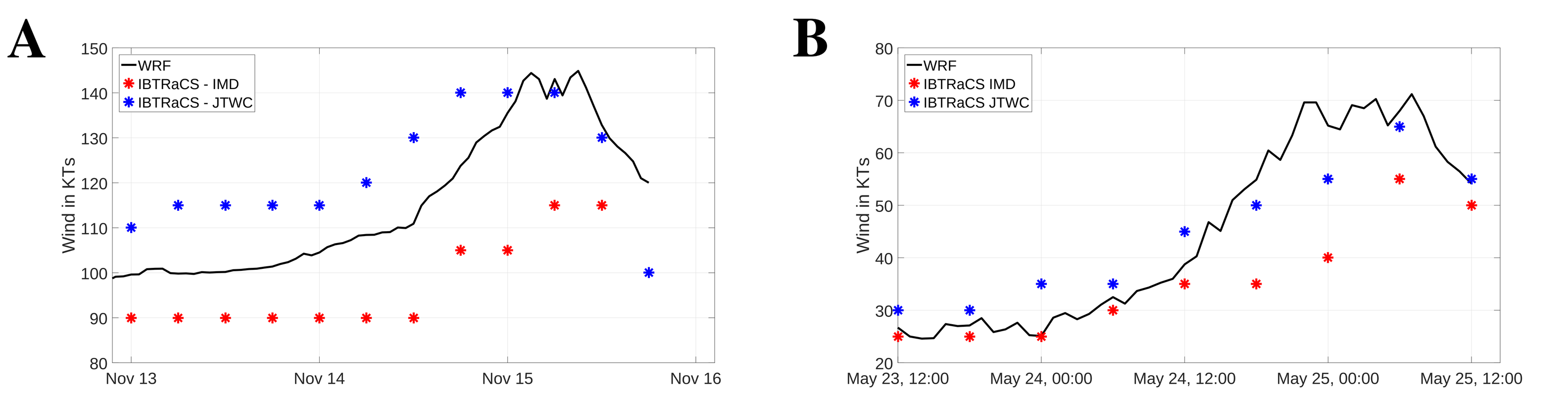

Figure: WRF simulated MSW compare to the estimation of JTWC and IMD; A) SIDR and B) AILA

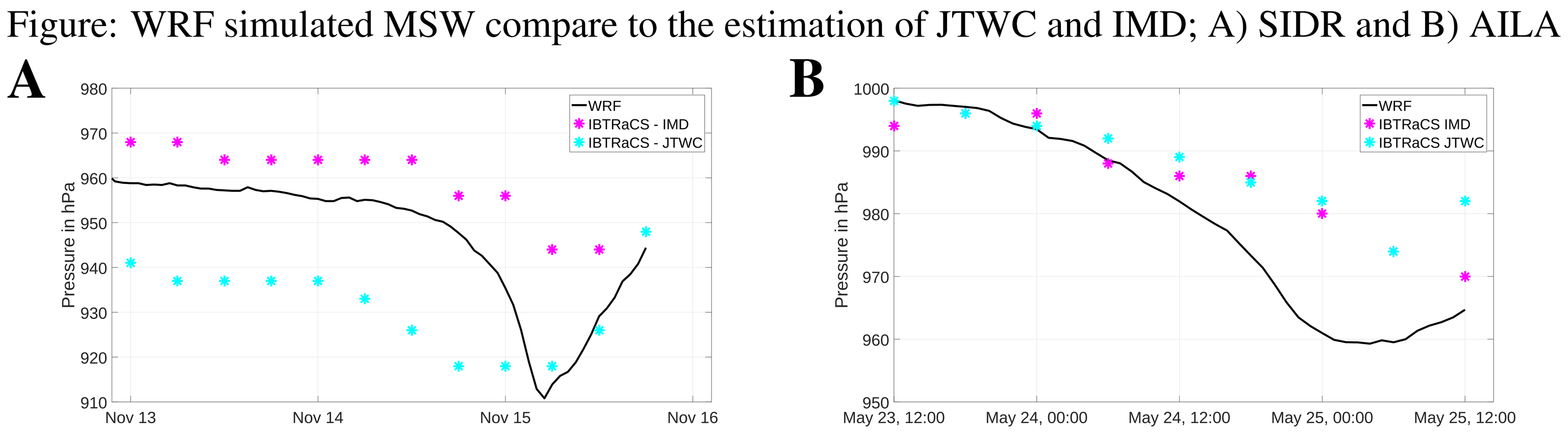

Figure: WRF simulated MSLP compare to the estimation of JTWC and IMD; A) SIDR and B) AILA

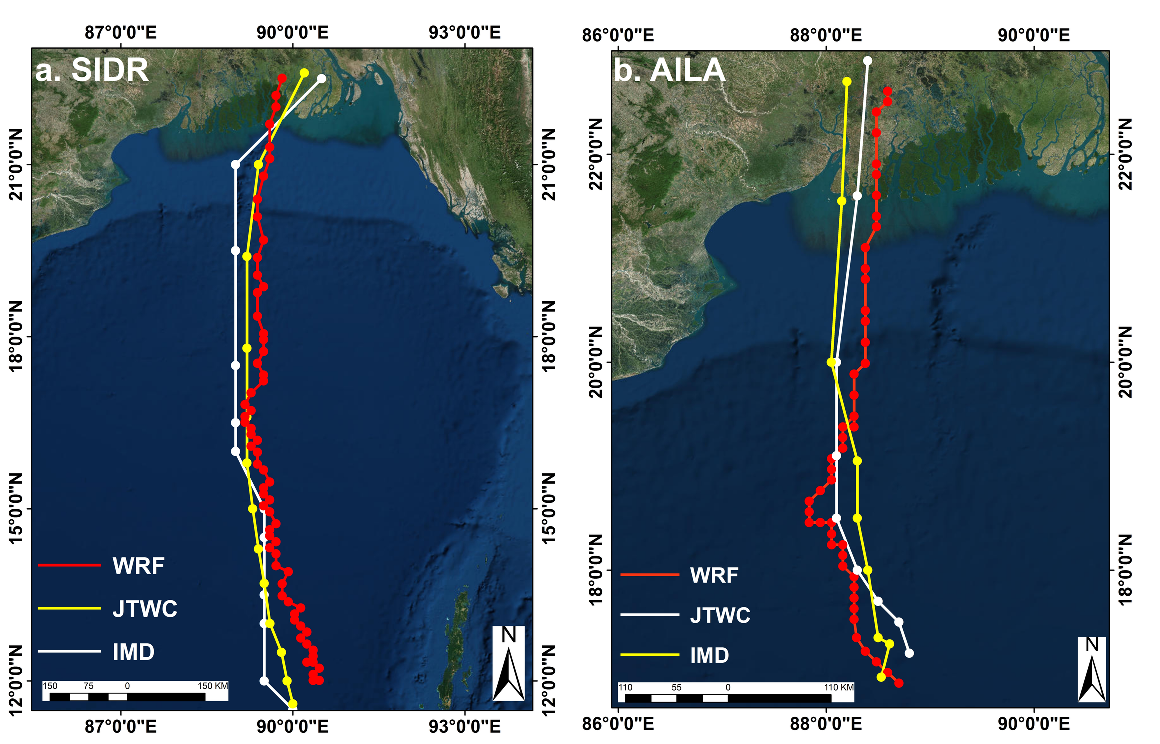

Figure: WRF simulated tracks of cyclone SIDR and AILA compare to observed tracks of JTWC and IMD. WRF data are hourly interval, and the JTWC & IMD data are in 6 hourly interval. The model simulated track of SIDR showed a track displacement error of about 45 km with JTWC, and about 62 km with IMD during landfall. The model simulated track of AILA showed a maximum track displacement error of about 28 km with JTWC and about 42 km with IMD.

Conclusions

The ability of a 'state-of-the-art' WRF-POLCOMS modelling system was investigated to simulate water levels in the Bay of Bengal with particular focus on Bangladesh Coast. The effectiveness of the model was verified through the obtained computational outputs against BIWTA tide gauge data. The model is found to reproduce surge elevation with a relatively good accuracy, although errors still exist.

Skill is also gained through forcing the ocean model with higher-resolution wind and pressure fields. By forcing the ocean model with hourly meteorology, response times in the model system can also be observed.

POLCOMS Results

The POLCOMS model outputs have been validated against tide gauge data provided by Bangladesh Inland Water Transport Authority (BIWTA) of four stations at Hiron Point, Khepupara, Charchanga and Chittagong. The order of magnitude of the maximum water level is fairly well reproduced by POLCOMS.

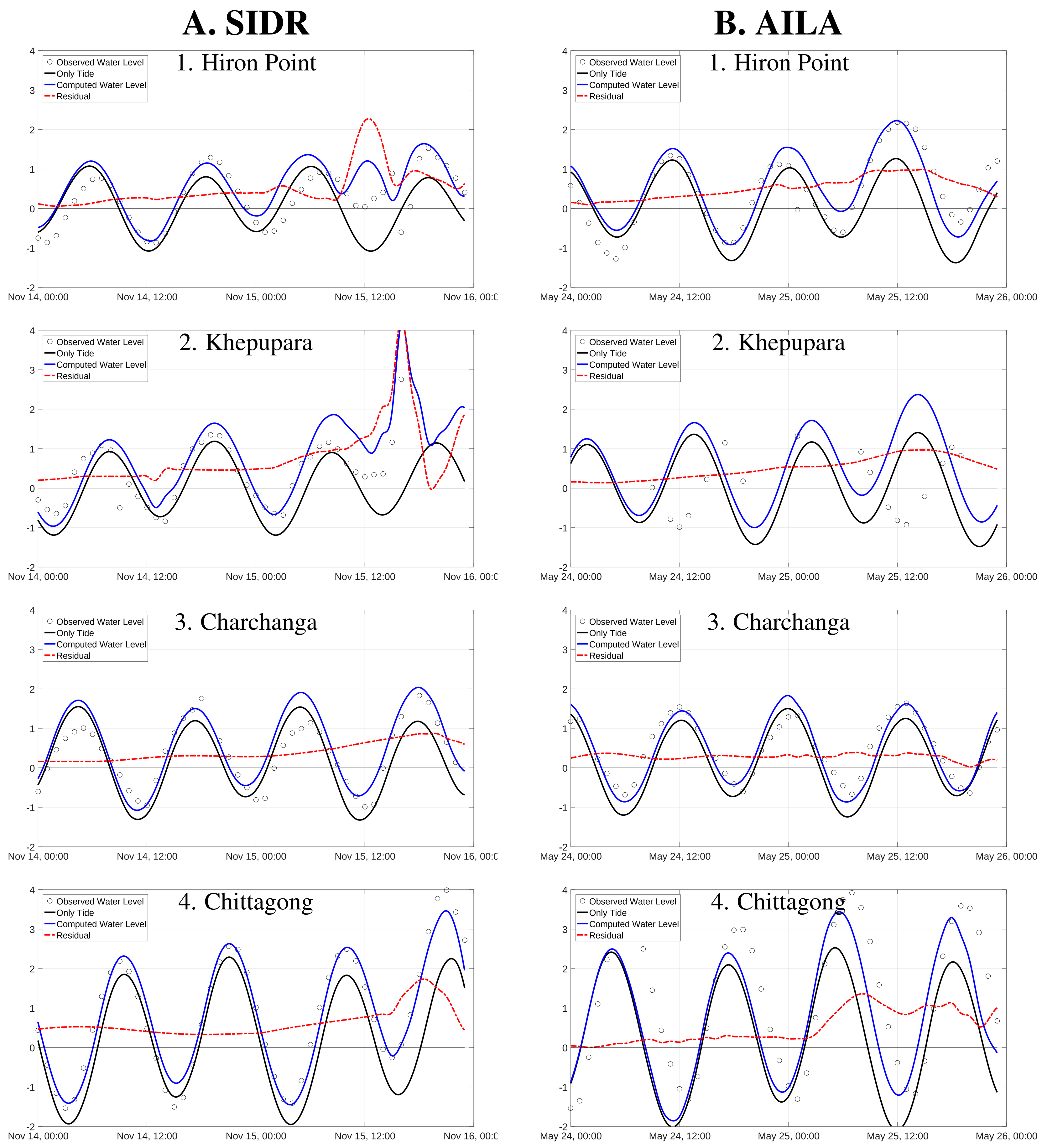

Figure: Computed water level and observed data referred to M.S.L. from the sea level center at four tide gauge stations during cyclone SIDR (A) and AILA (B). Water level for tide only run and model surge residuals are also plotted. The hourly tide only and computed water level data were linearly interpolated using spline method.

Table: R^2 value, RMSE, and Pbias of water level (tide plus surge elevation) compare to BIWTA observation at the four locations during the cyclone SIDR and AILA.

Tide Gauge Station	SIDR			AILA		
	R^2	RMSE (m)	Pbias (%)	R^2	RMSE (m)	Pbias (%)
Hiron Point	0.66	0.42	34.32	0.62	0.58	47.61
Khepupara	0.66	0.45	29.90	–	–	–
Charchanga	0.84	0.32	24.11	0.87	0.26	– 20.39
Chittagong	0.97	0.28	19.35	0.99	0.21	– 18.39

References

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