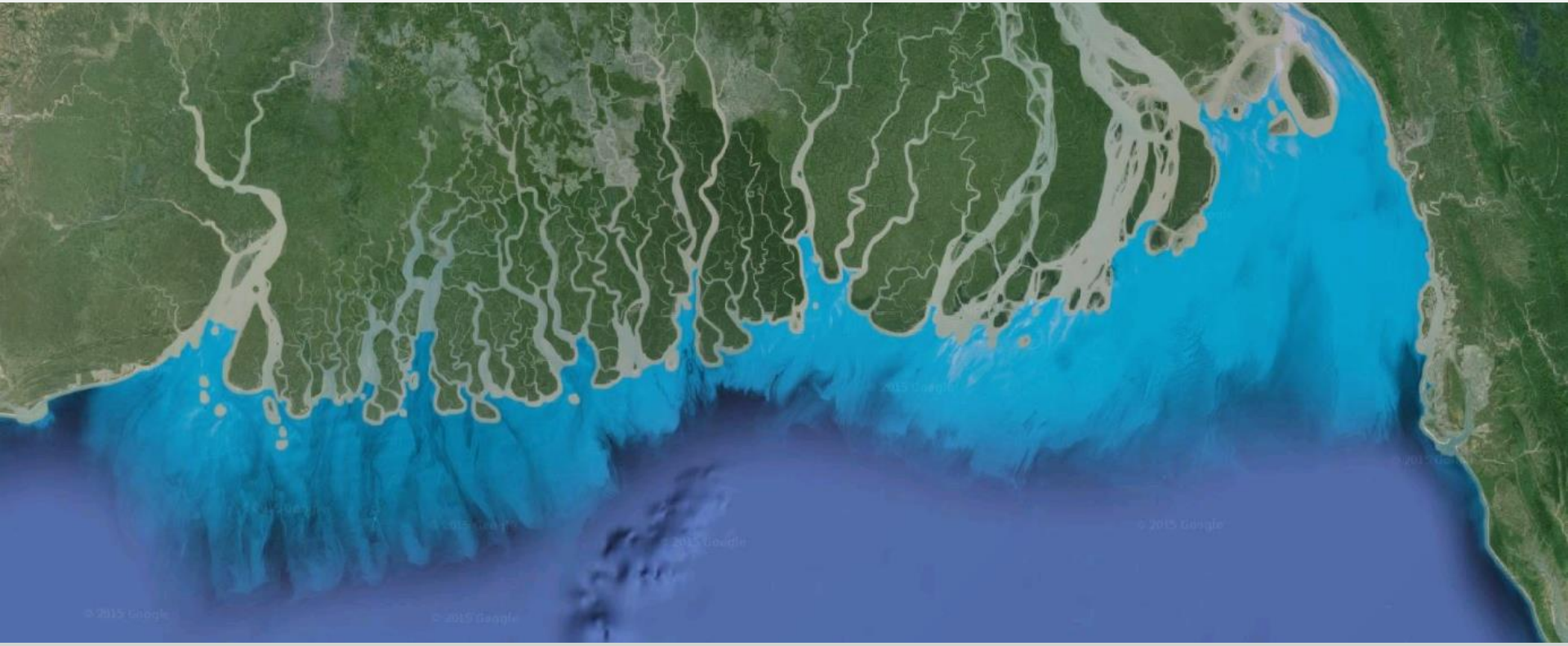
Storm surge modeling in the Bay of Bengal



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River flooding and house damages (BOB 1991 Cyclone)

Sunderban Mangrove forest (Sidr 2007 Cyclone)

Storm history at Bay of Bengal

List of major cyclones that made landfall to Bangladesh and associated coastal storm surges and casualties since 1960

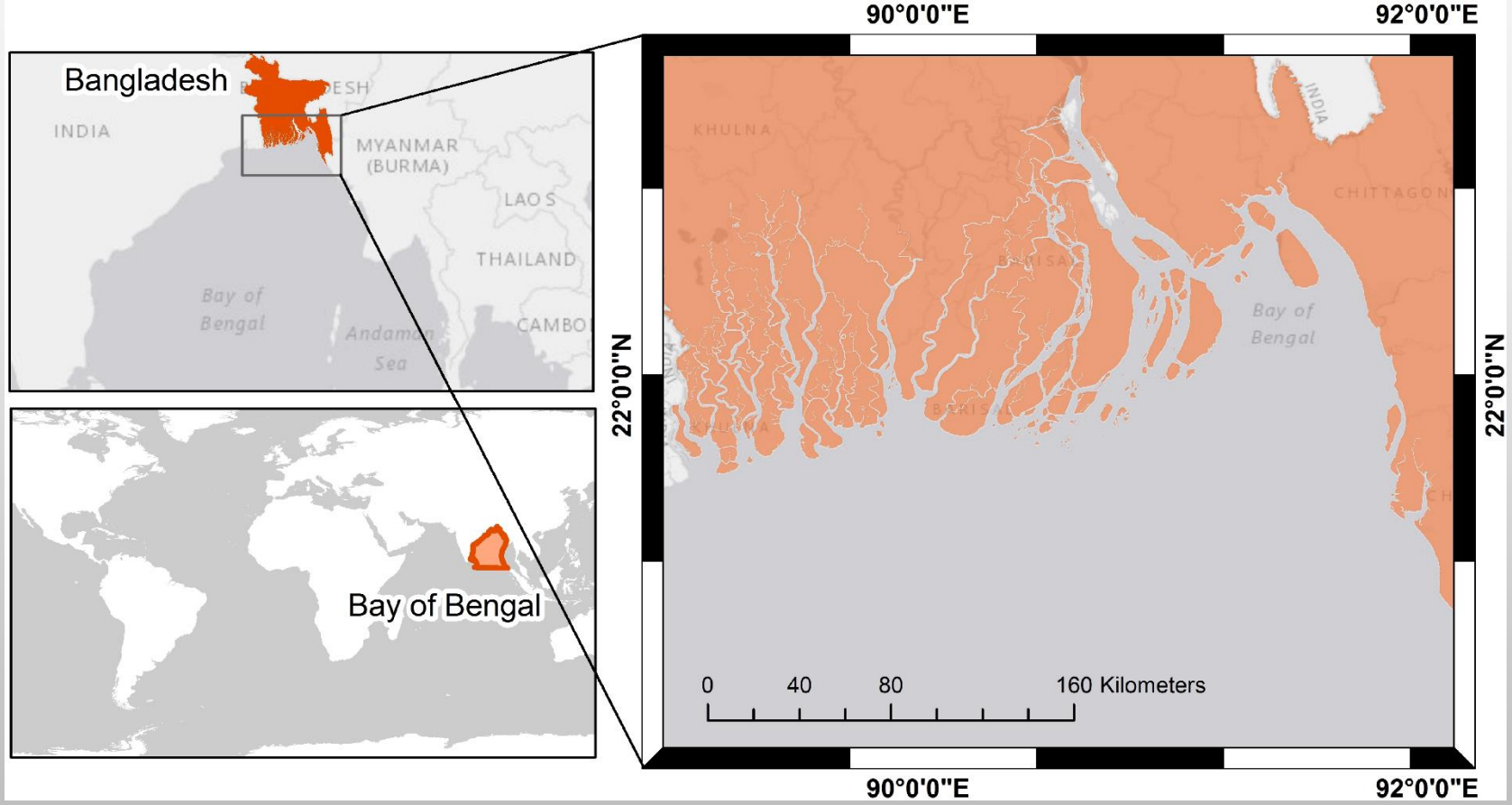
Landfall date	Location of landfall	Maximum wind speed (km/h)	Maximum surge height (m)	Death
30 Oct 1960	Chittagong-Cox's Bazar	208	6.1	5179
09 May 1961	Bhola, Noakhali	160	3.0	11 468
28 May 1963	North of Chittagong	203	3.7	11 520
11 May 1965	Barisal, Noakhali	162	4.0	19 279
15 Dec 1965	Cox's Bazar	210	3.7	873
23 Oct 1966	Noakhali, Chittagong	145	6.7	850
12 Nov 1970	Chittagong	222	10.6	300 000
25 May 1985	Chittagong	154	4.3	4264
29 Nov 1988	Khulna	160	4.4	1498
29 Apr 1991	Chittagong	225	6.1	138 000
02 May 1994	Cox's Bazar	215	3.3	188
19 May 1997	Chittagong, Feni	225	4.6	126
26 Sep 1997	Chittagong	150	3.0	155
16 May 1998	Chittagong, Cox's Bazar	165	2.5	12
15 Nov 2007	Barguna, Patuakhali	220–250	6.0	3500

[Source: IWM, 2005; Ali, 2000]

Objectives

- Validation of ADCIRC+SWAN model and the high resolution numerical mesh for Bay of Bengal
- Evaluate the role of mangroves in attenuating storm surges
- Identify vulnerable coastal zones based on storm categories and tracks

Study area



Bay of Bengal: Bangladesh coast

Methodology

ADCIRC V50.99

Two-dimensional, depth-integrated, barotropic time-dependent long wave circulation model. (Luettich & Westerink, 2000)

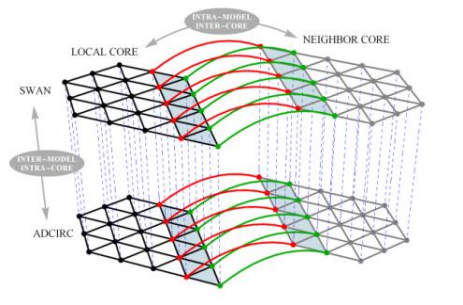
- Generates tide and storm surge elevations and velocities corresponding to each node over a very large domain

SWAN

Computes random, short-crested wind-generated waves in coastal regions and inland waters (Zijlema, 2010)

Coupled SWAN + ADCIRC model

ADCIRC passes wind velocities, water levels and currents through local cache or memory to SWAN (Dietrich et al., 2011)



Luettich R. & Westerink J. (2000) ADCIRC, A (parallel) advanced circulation model for oceanic,coastal and estuarine waters

Zijlema, M. (2010) Computation of wind-wave spectra in coastal waters with SWAN on unstructured grids.Coast. Eng. 57, 267–277

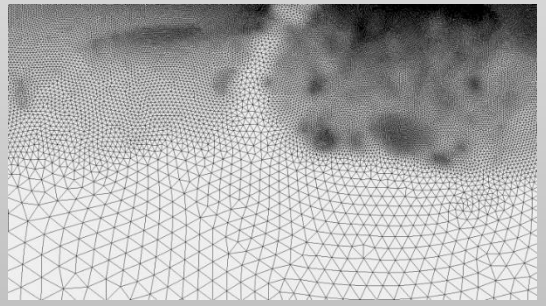
Dietrich, J.C., Zijlema, M., Westerink, J.J., Holthuijsen, L.H., Dawson, C.N., Luettich, R.A. Jr., Jensen, R.E., Smith, J.M., Stelling, G.S., Stone, G.W. (2011) Modeling hurricane waves and storm surge using integrally-coupled, scalable computations. Coast. Eng. 58, 45–65

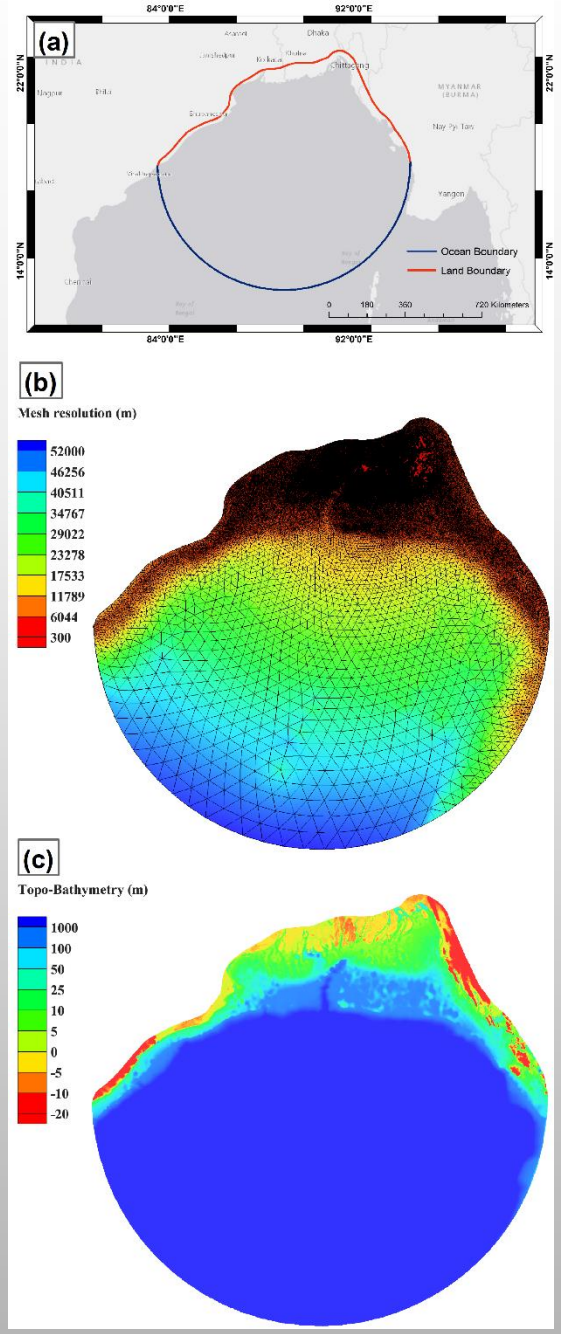
Mesh Development

General Bathymetric Chart of the Oceans (GEBCO)

- British Oceanographic Data Centre
- Shuttle Radar Topography Mission (SRTM) 900m global DEM data

High resolution numerical mesh with 200,000 nodes, 400,000 elements





Spatial attributes

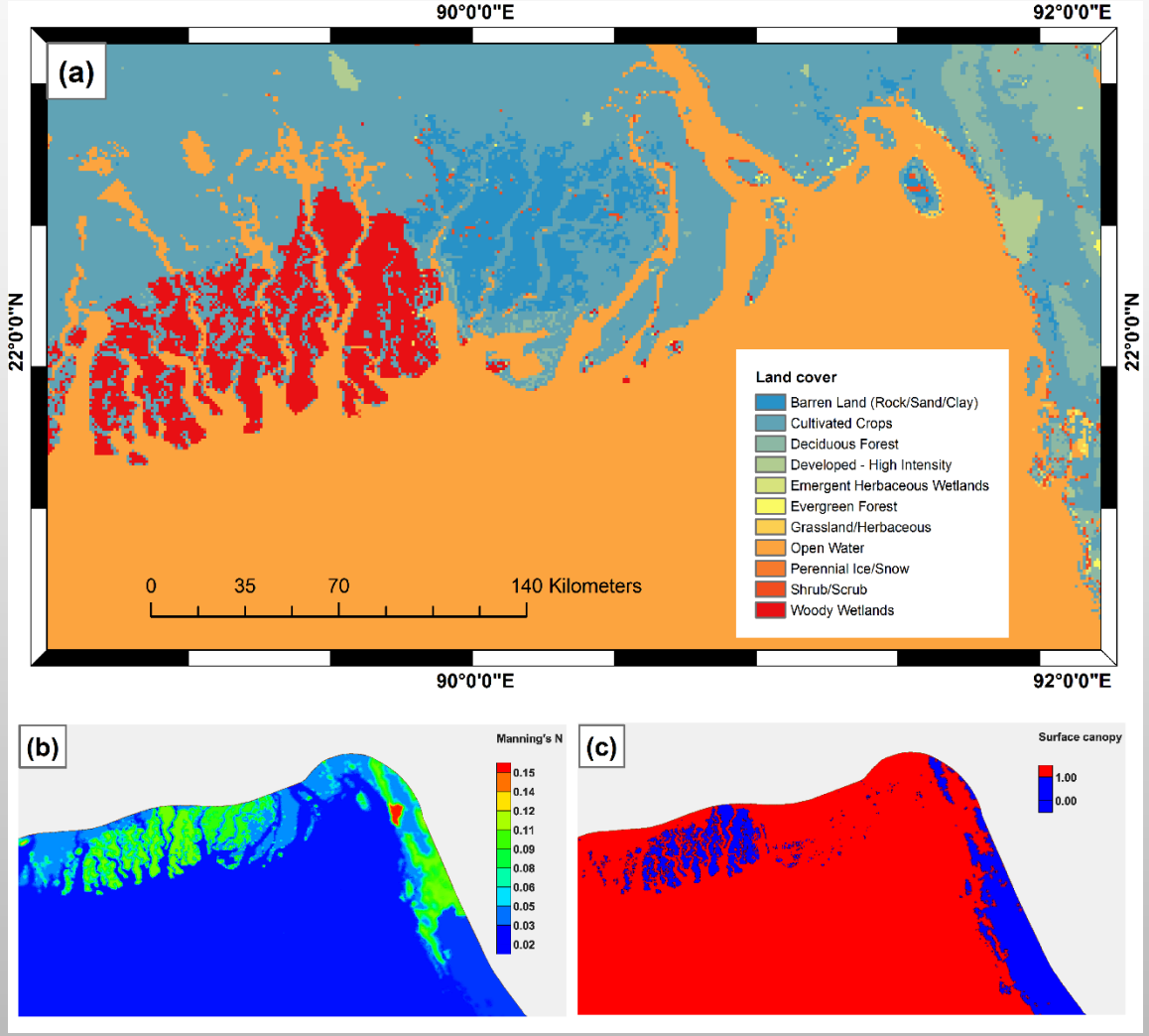
Global Land Cover 2000

Generalized Wave-Continuity Equation (GWCE) weighting factor

Manning's n at sea floor

Surface canopy coefficient

Surface directional effective roughness length



To run ADCIRC + SWAN model

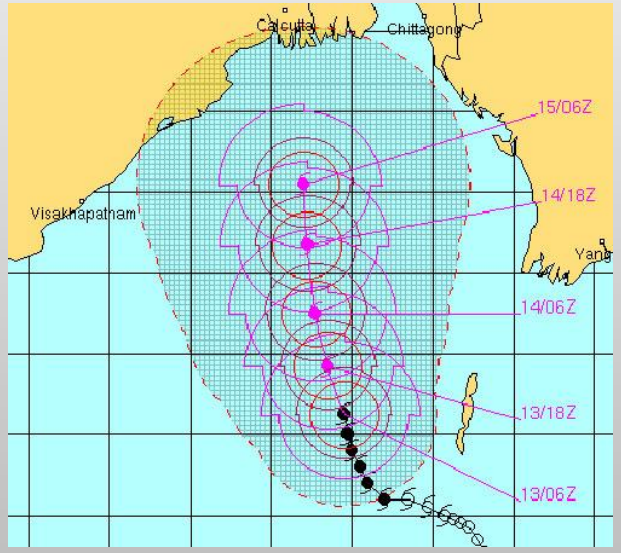
- **Tidal constituents**

  LeProvost Tidal Database (http://aquaveo.com/downloads)

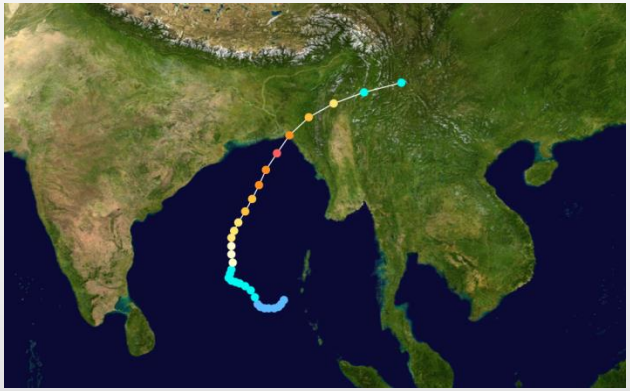
- **Meteorological Forcing Input**
  - Joint Typhoon Warning Centre

  (http://www.usno.navy.mil/JTWC/)

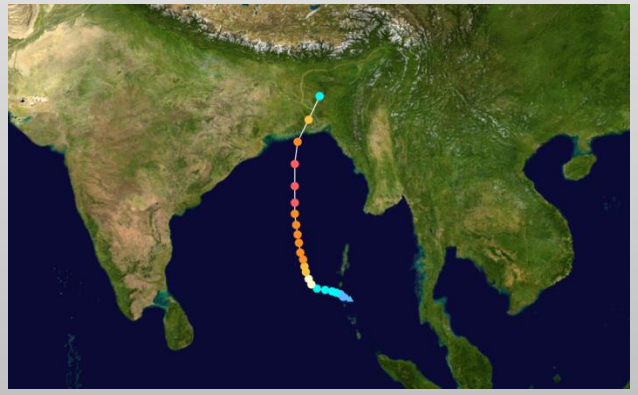
  - Bangladesh Meteorological Department
    - Hurricane Track
    - Central Pressure (Cp)
    - Radius of storm (Rp)
    - Forward Speed (Vf)



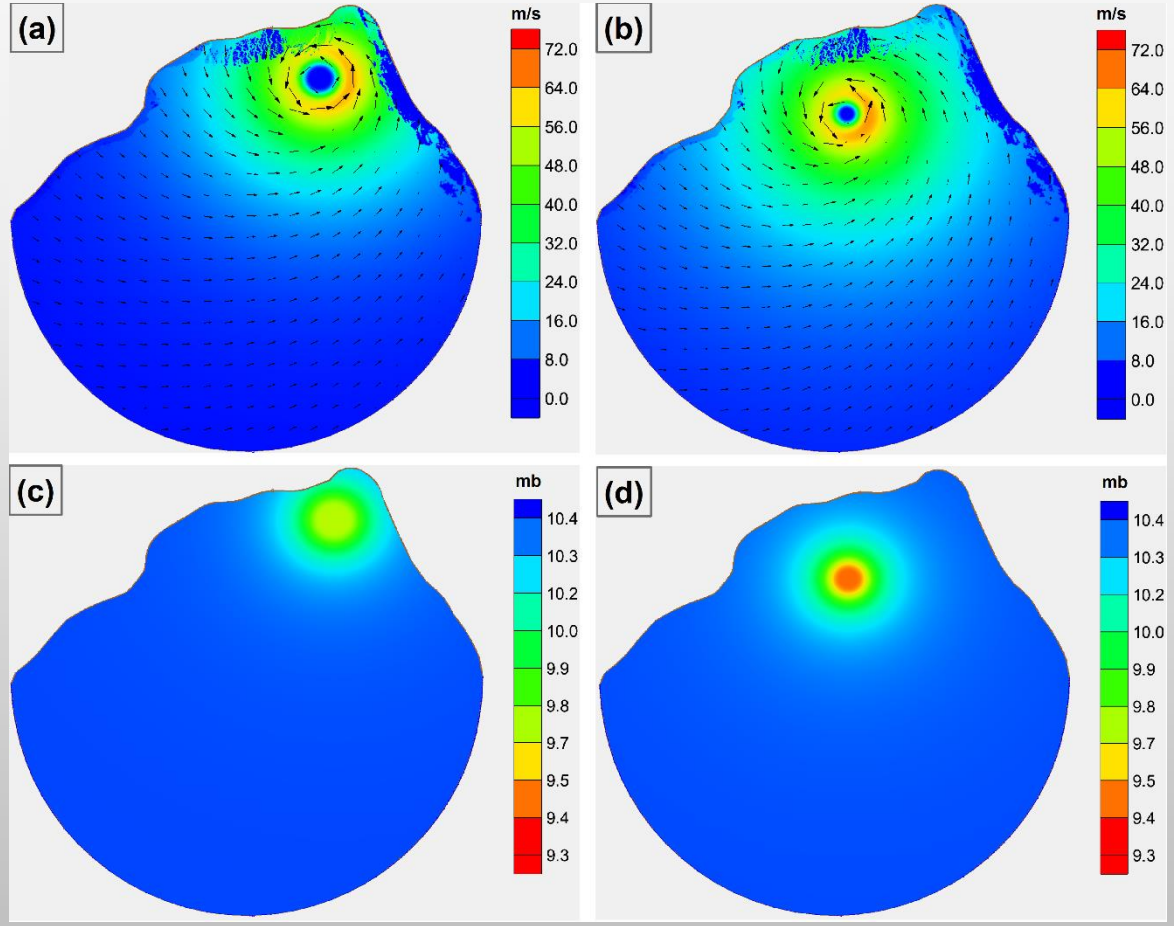
Storms



BOB 1991 (wikipedia.org)



Sidr 2007 (wikipedia.org)



storm wind speed and central pressure
BOB 1991 (a,c) & Sidr 2007 (b,d)

Water level data collection

- University of Hawaii Sea Level Center

(http://uhslc.soest.hawaii.edu/data/download/rq#uh136a)

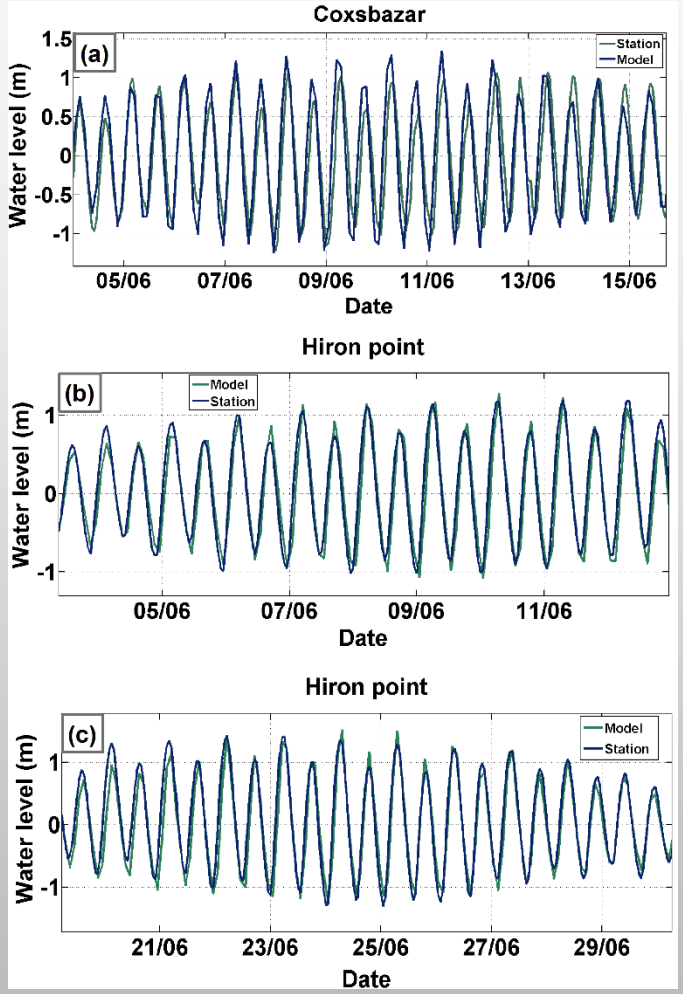
Contributor: Dept. of Hydrography, Bangladesh

- Cox'sbazar (1983 – 2006)
- Charchanga (1980 –2000)
- Chittagong (2007 – 2012)
- Hiron Point (1977 – 2003)
- Teknaf (1983 – 1988)
- Khepupara (1987 –2000)
- Khal (1983 – 1992)

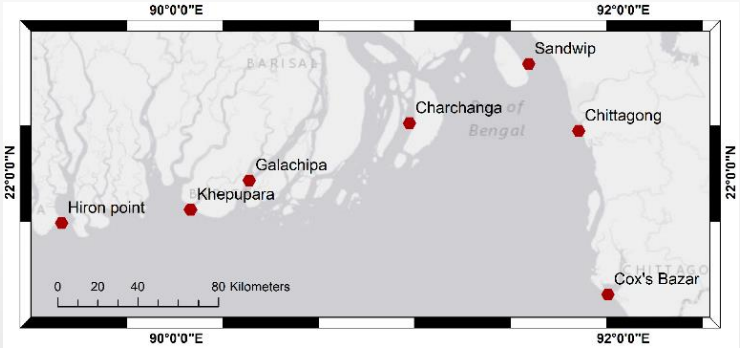
- Previous studies

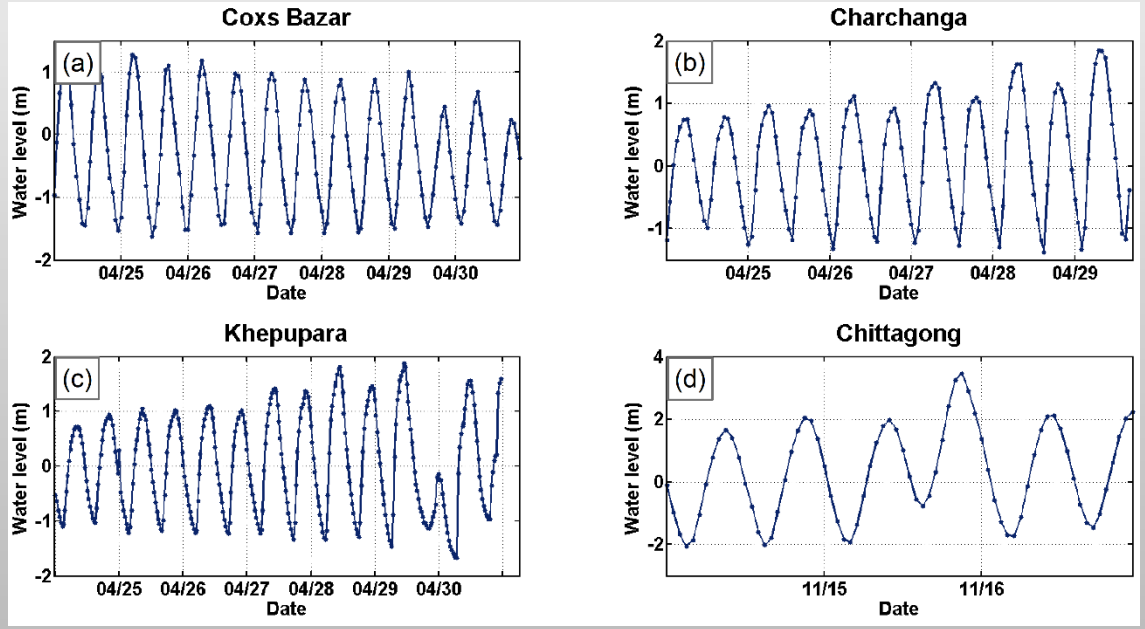
- Dube, S. K. & Murty, T. S. (2009) “Storm surge modelling for the Bay of Bengal and Arabian Sea”, Nat Hazards (2009) 51:3–27
- AS-SALEK, J. A. (1998) “Coastal Trapping and Funneling Effects on Storm Surges in the Meghna Estuary in Relation to Cyclones Hitting Noakhali–Cox’s Bazar Coast of Bangladesh”, J. Phys. Oceanogr., 28, 227–249, American Meteorological Society
- Investigation Report on the Storm Surge Disaster by Cyclone SIDR in 2007, Bangladesh, Japan Society of Civil Engineering
- Lewis, M. & Bates, P. (2013) “A storm surge inundation model of the northern Bay of Bengal using publicly available data”, Q. J. R. Meteorol. Soc.139: 358–369, January 2013 B

Preliminary results



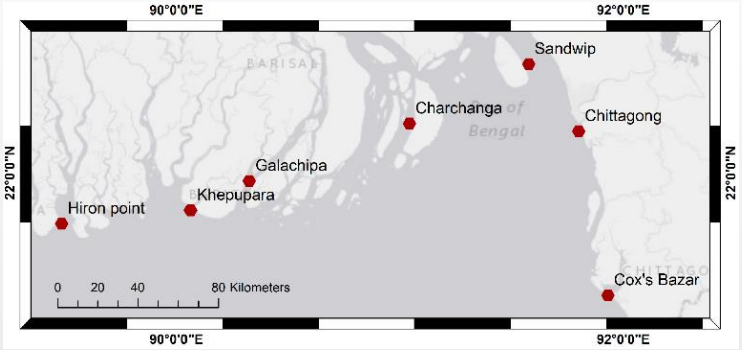
Tidal validation for the year of 1990

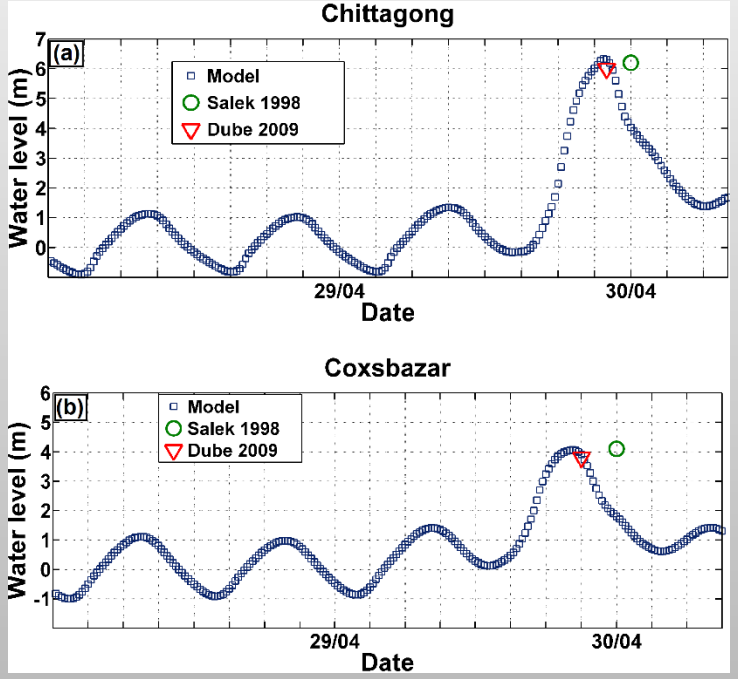




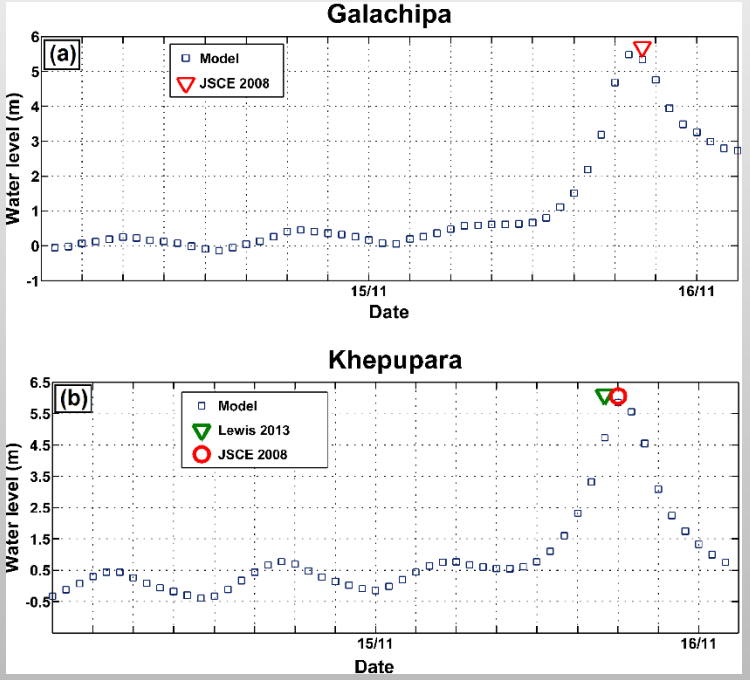
Water level data from available stations during BOB 1991 (a,b,c) and Sidr 2007 cyclone (d)

Storm surge validation





WL comparison during BOB 1991 cyclone



WL comparison during Sidr 2007 cyclone

Storm surge flooding scenario

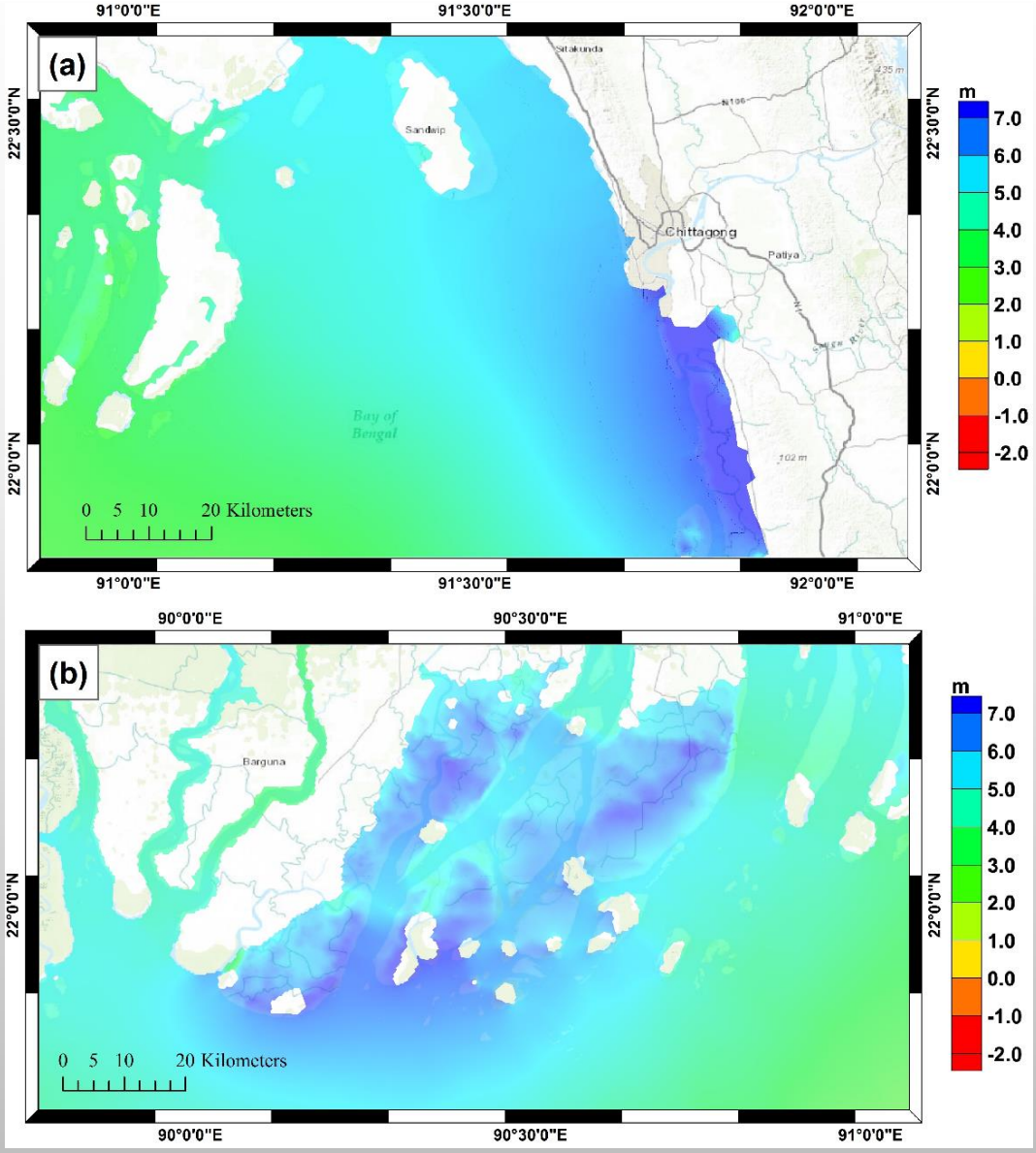


Fig. a,b Maximum water level (m) during BOB 1991 and Sidr 2007 cyclone respectively

Significant wave height scenario

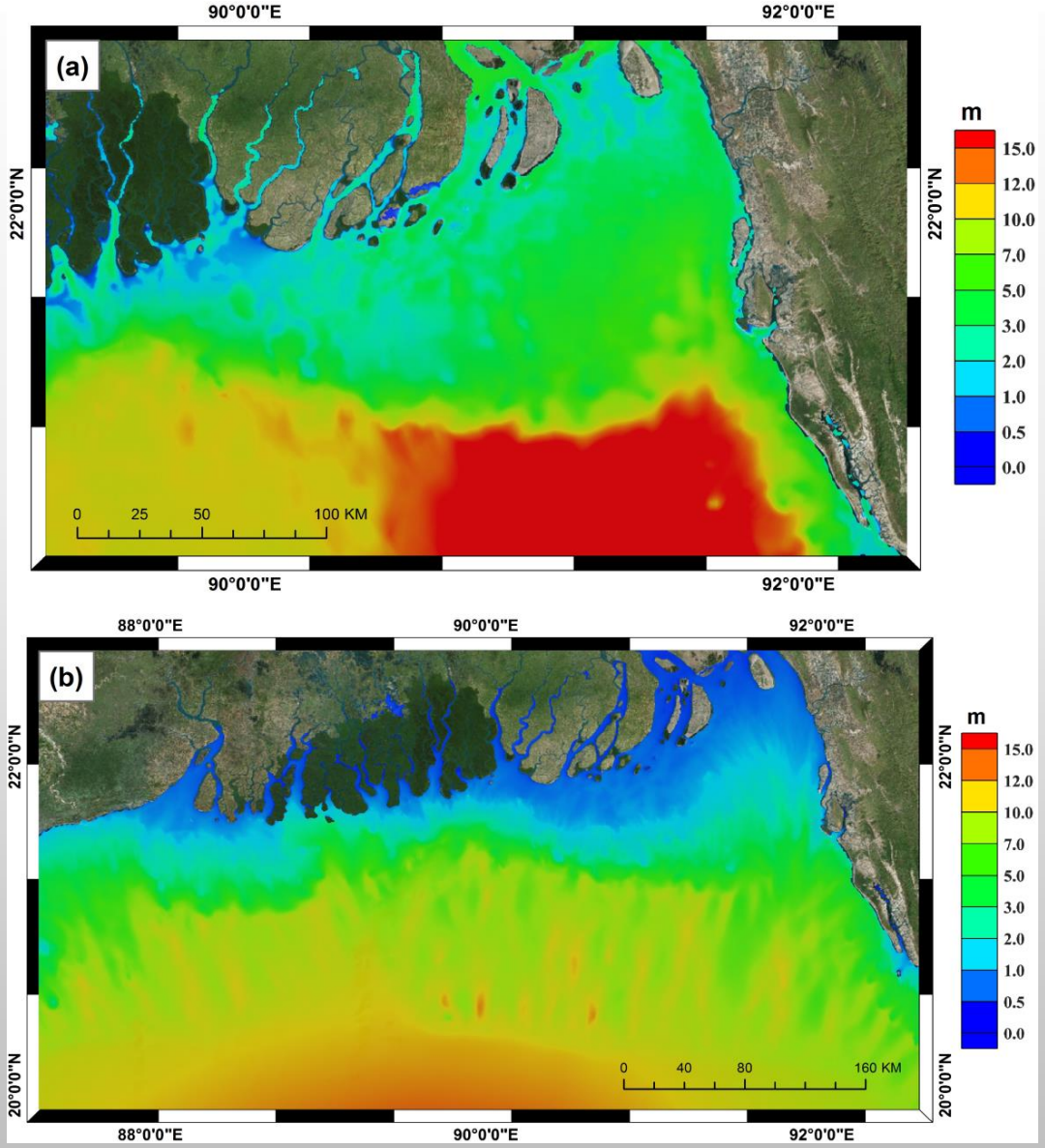


Fig. a,b Significant wave height (m) during BOB 1991 and Sidr 2007 cyclone respectively

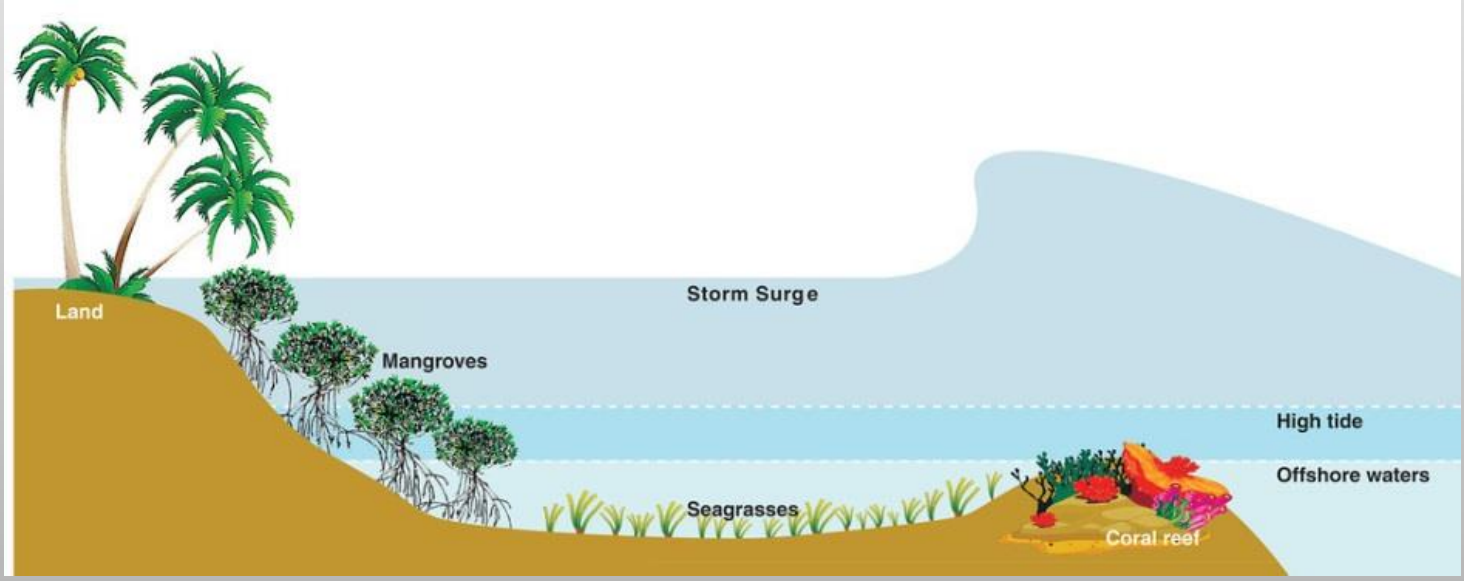
Summary

- An unstructured numerical mesh with high resolution (~ 300 m) on the shallow water region and coarser in deep waters (~ 52 km) has been developed
- Bottom friction and roughness coefficients were generated from available global land cover dataset
- The coupled SWAN+ADCIRC model was applied with two different storms (BOB 1991 and Sidr 2007)
- Computed and observed data showed good agreement, where the correlation coefficients found to vary between 0.91 to 0.98 and RMSE of approximately 0.3 m to 0.6 m for both cyclones
- This research work would contribute largely in the operational forecasting system and decision making strategies for severely affected areas with cyclone induced flooding of Bangladesh

Ongoing work

Mangrove analysis

Importance of mangroves in storm surge attenuation and their roles in coastal defense to reduce risk to people and infrastructures from storm surges



Questions?

Acknowledgements

XSEDE
Extreme Science and Engineering Discovery Environment

TACC
TEXAS ADVANCED COMPUTING CENTER