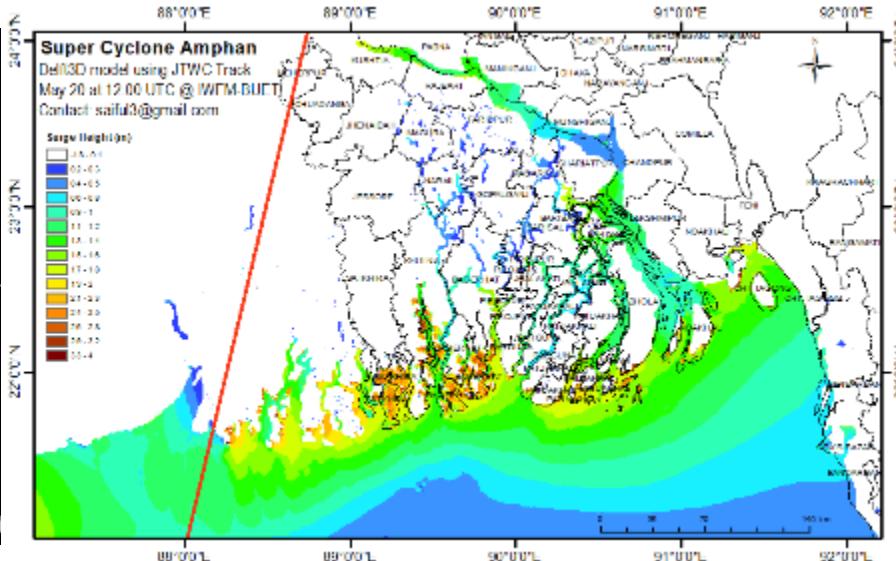
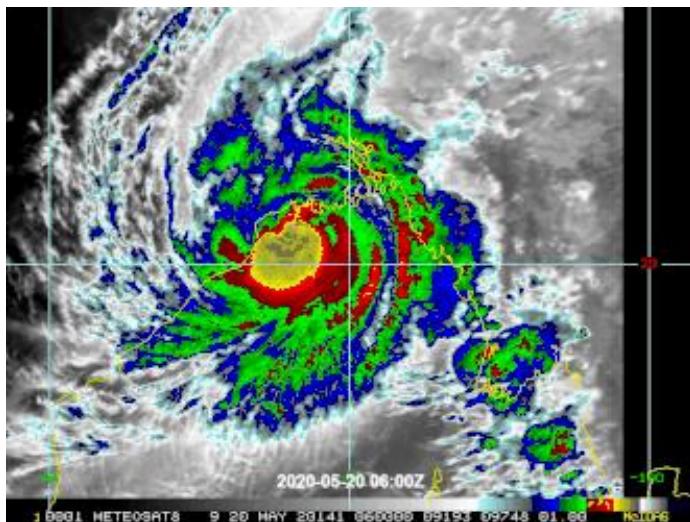


Webinar on “Risk Modelling for Improved Disaster Risk Governance in Bangladesh”

Oasis Platform for Cyclone and Storm Surge Risk Assessment for Bangladesh



Prof. A.K.M. Saiful Islam, Nahruma Mehzabeen, Dr. Mohan Kumar Das,
Faruque Abdullah and Maruf Billah

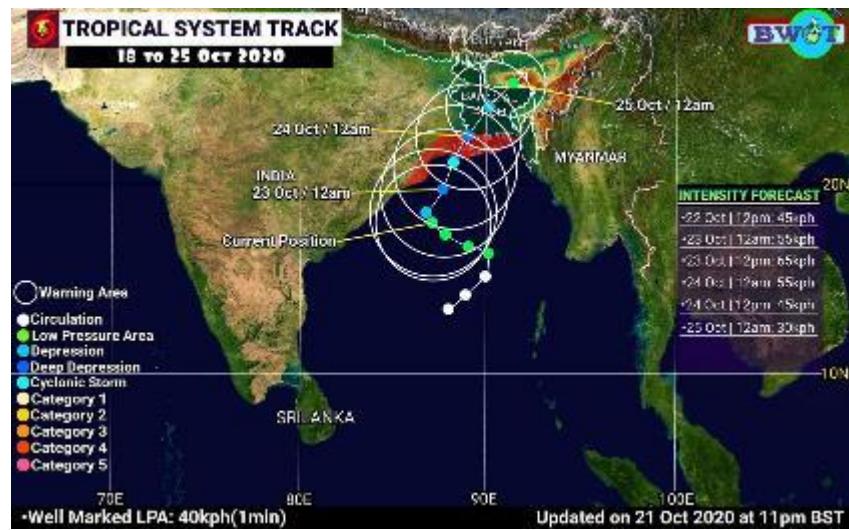


Institute of Water and Flood Management
Bangladesh University of Engineering and Technology (BUET)

Outline of the presentation

- Natural Disasters observed in recent time in Bangladesh under the warming world
- Comparing recent cyclones in the Bay of Bengal : Amphan (2020), Bulbul (2019), Fani (2019), Mora (2017), Roanu (2016), Aila (2009), Sidr (2007)
- Climate change Impact of tropical cyclones
- Importance of storm surge inundation modeling
- Risk assessment of cyclone using depth-damage relationship
- Oasis Loss Modeling Frame for assisting disaster risks management

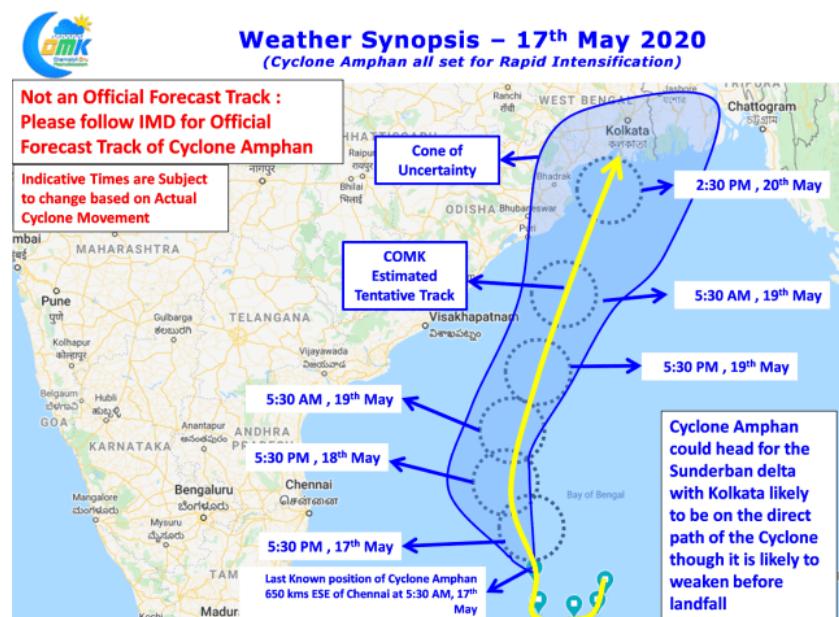
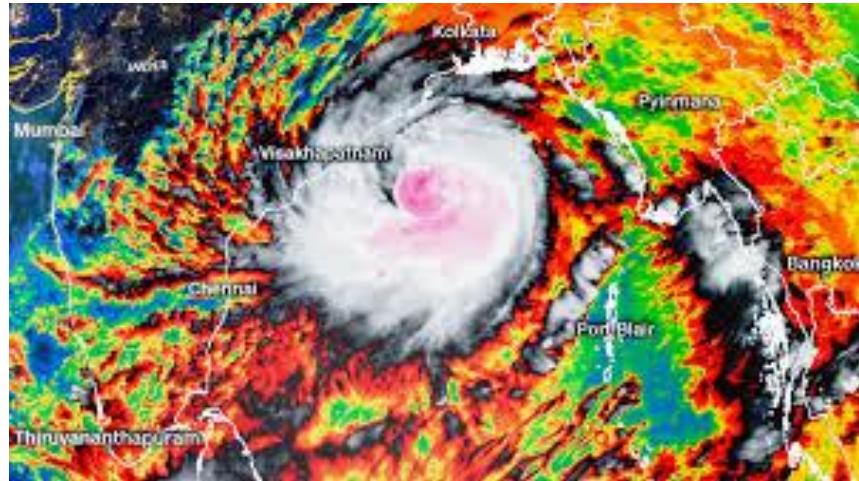
Today's Storms in the Bay of Bengal



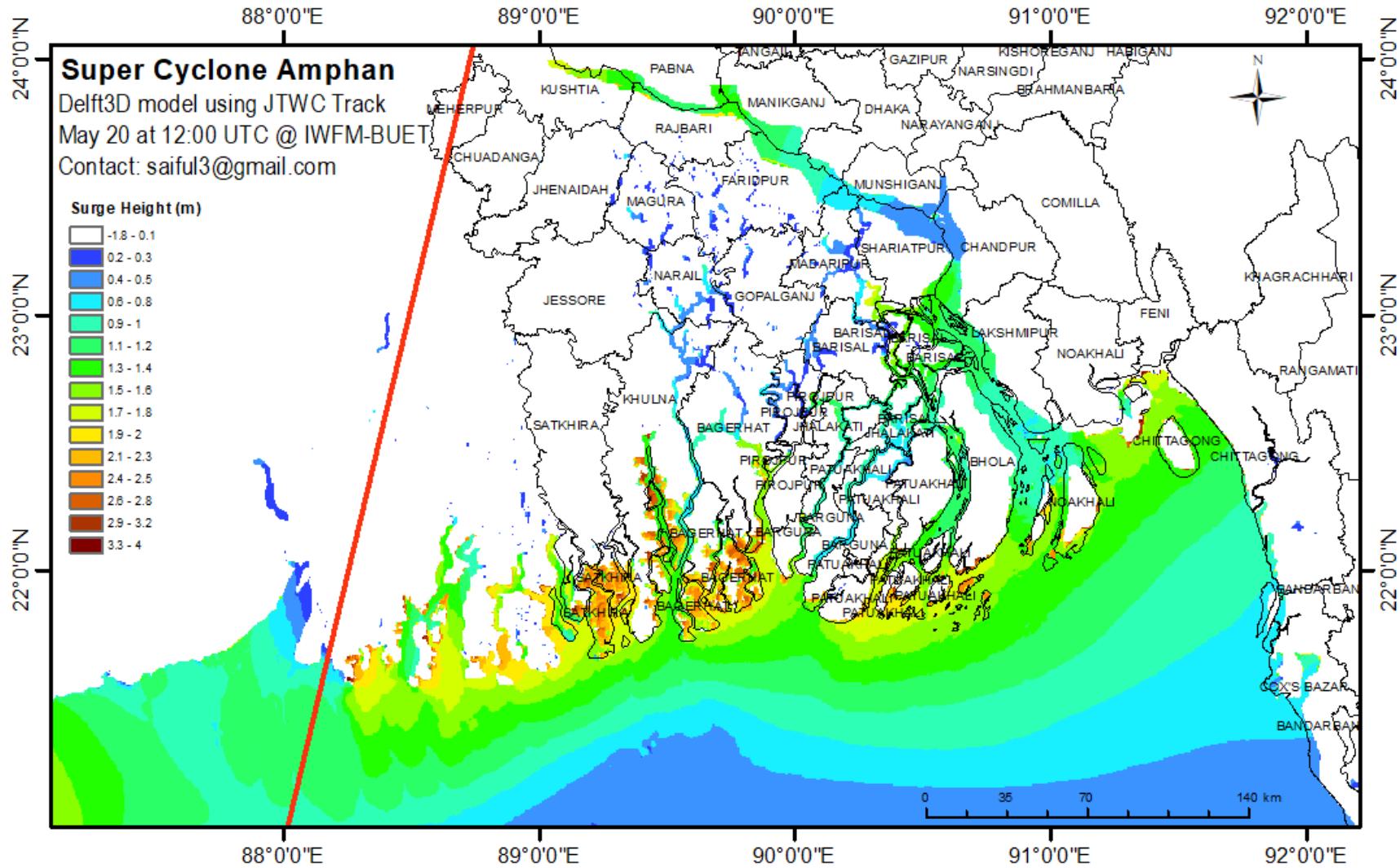
Favorable SST (29-30°C), Good moisture supply & partial MJO support that could aid the well marked low-pressure system to a deep depression in the Bay of Bengal with a wind speed of 40km/hr in a radius of 50km. Odisha, South Bengal, NE of India and Bangladesh could observe heavy rainfall.

Super Cyclone Amphan (16-21 May 2020)

- Formed: 16 May 2020
- Dissipated: 21 May 2020
- Wind Speed:
 - 3-minute sustained: 240 km/h
 - 1-minute sustained: 260 km/h
- Lowest pressure:
 - 920 hPa (mbar); 27.17 in Hg
- Fatalities: 128 total (26 in Bangladesh)
- Damage: > \$13.6 billion USD (1.5 billion for Bangladesh)
- Storm Surge: 3-4 meter



Model simulated storm surge of Cyclone Amphan on 20 May 2020 at 6:00 pm

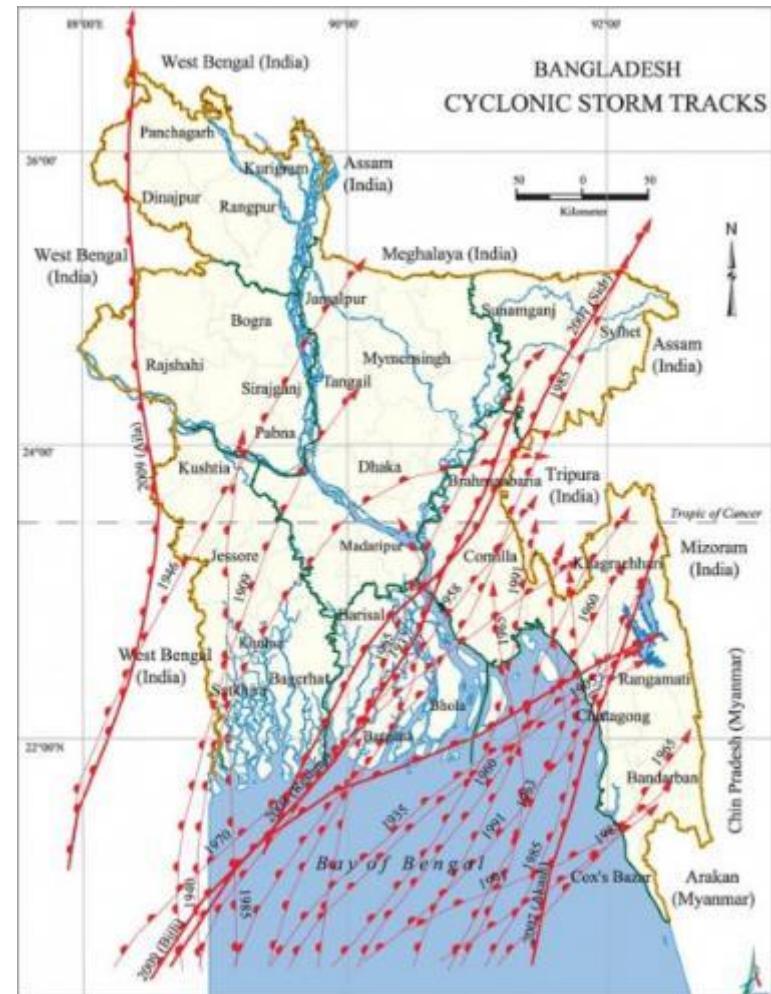


Recent Cyclones in the Bay of Bengal

Cyclone Amphan (2020) Date: 16-21 May 3-min wind: 240 km/hr 1-min wind: 260 km/hr Surge: 3-4 m Damage: USD 1.5 billion Fatalities: 26	Cyclone Bulbul (2019) Date: 5-11 November 3-min wind: 140 km/hr 1-min wind: 195 km/hr Surge: < 2 m Damage: USD 33 million Fatalities: 128	Cyclone Fani (2019) Date: 26 April -05 May 3-min wind: 215 km/hr 1-min wind: 250 km/hr Surge: < 2 m Damage: USD 63.6 million Fatalities: 17
Cyclone Mora (2017) Date: 28-31 May 3-min wind: 110 km/hr 1-min wind: 150 km/hr Surge: < 2 m Damage: USD 6 million Fatalities: 0	Cyclone Roanu (2016) Date: 16-21 May 3-min wind: 85 km/hr 1-min wind: 110 km/hr Surge: 2 m Damage: USD 31.8 million Fatalities: 30	Cyclone Aila (2009) Date: 17-27 May 3-min wind: 110km/hr 1-min wind: 120km/hr Surge: 3 m Damage: USD 1 billion Fatalities: 190
Cyclone Sidr (2007) Date: 11-15 November 3-min wind: 215 km/hr 1-min wind: 260 km/hr Surge: 5.5 m Damage: USD 2.31 billion Fatalities: 3,447	1991 Cyclone (1991) Date: 24-30 April 3-min wind: 235 km/hr 1-min wind: 260 km/hr Surge: 6.1 m Damage: USD 1.5 billion Fatalities: 138,000	Bhola Cyclone (1970) Date: 3-13 November 3-min wind: 185 km/hr 1-min wind: 240 km/hr Surge: 10.6 m Damage: USD 86.4 million Fatalities: 500,000

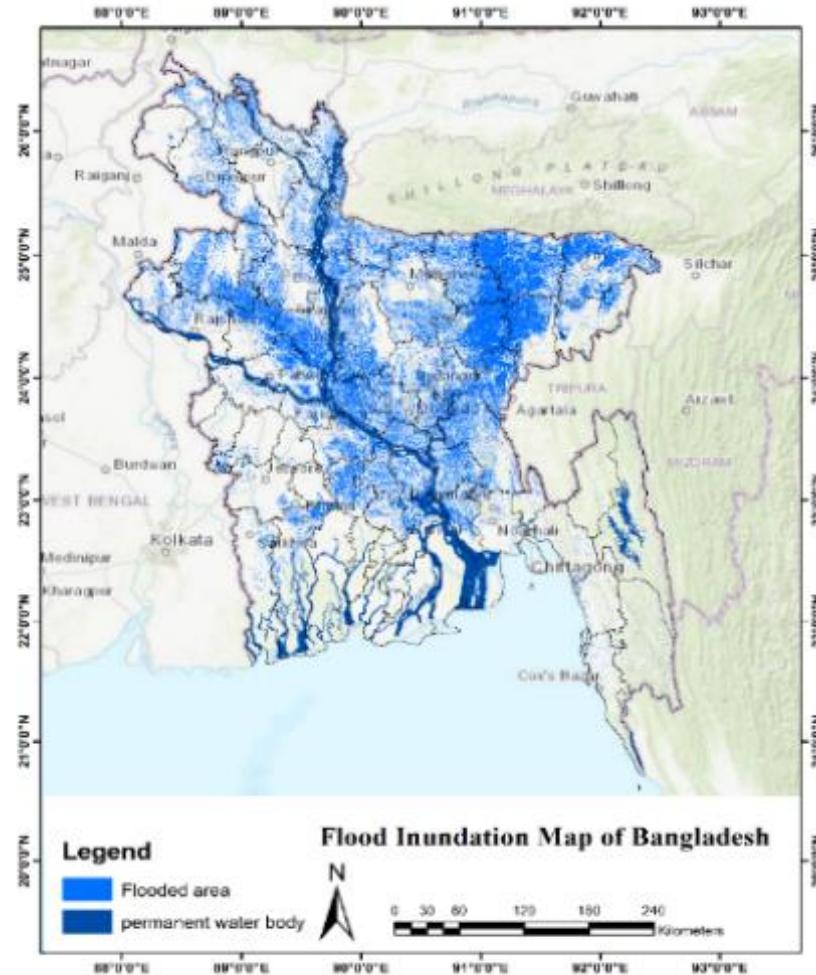
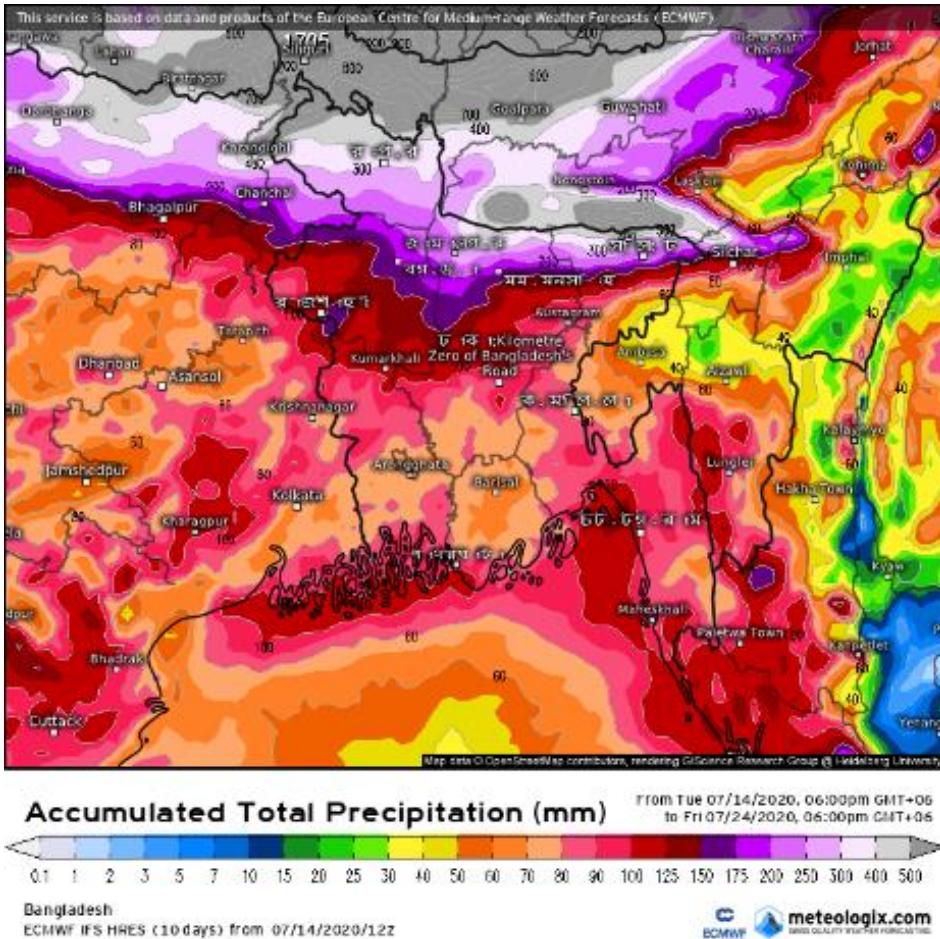
Cyclone and Storm Surge in Bangladesh: Why more cyclones in the Bay of Bengal?

- The ideal SST is around 25–27 degrees Celsius.
- Bay of Bengal is relatively warmer compared to Arabian Sea.
- Relatively lower vertical wind-shear.
- Additional influx of moisture from South China Sea.
- Terrain of the flat Coast which is not blocking ferocity of wind.
- Global mean ocean SST has increased at a rate of 0.11 [0.09 to 0.13] °C per decade which makes favorable conditions.



Natural Disasters in Bangladesh in 2020

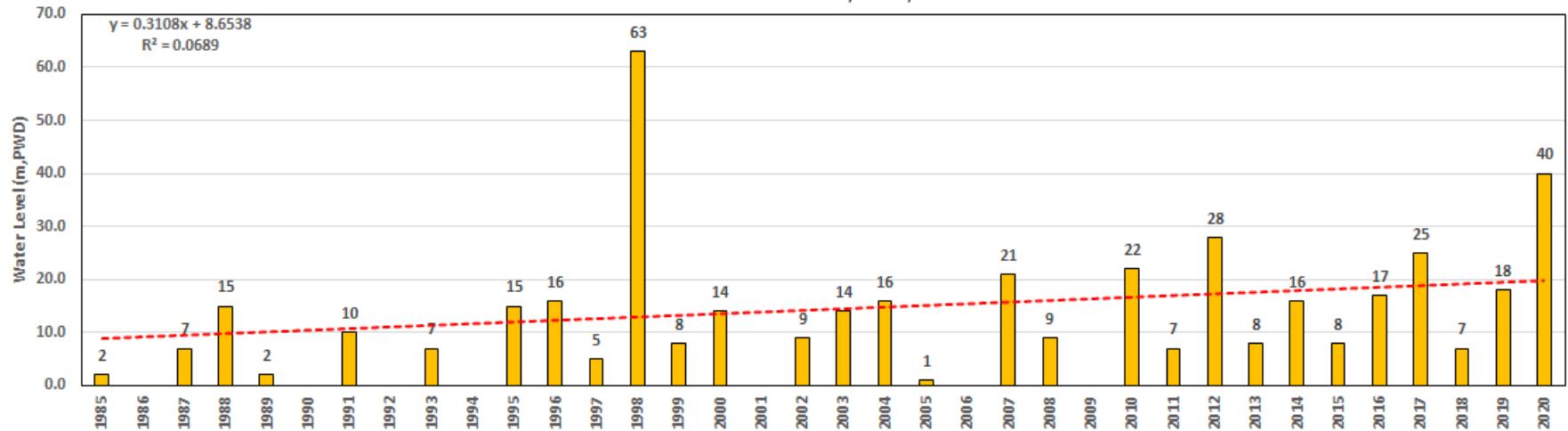
- Prolonged Monsoon Flood – 1/3 of the country was under water



Flood peak and duration are increasing

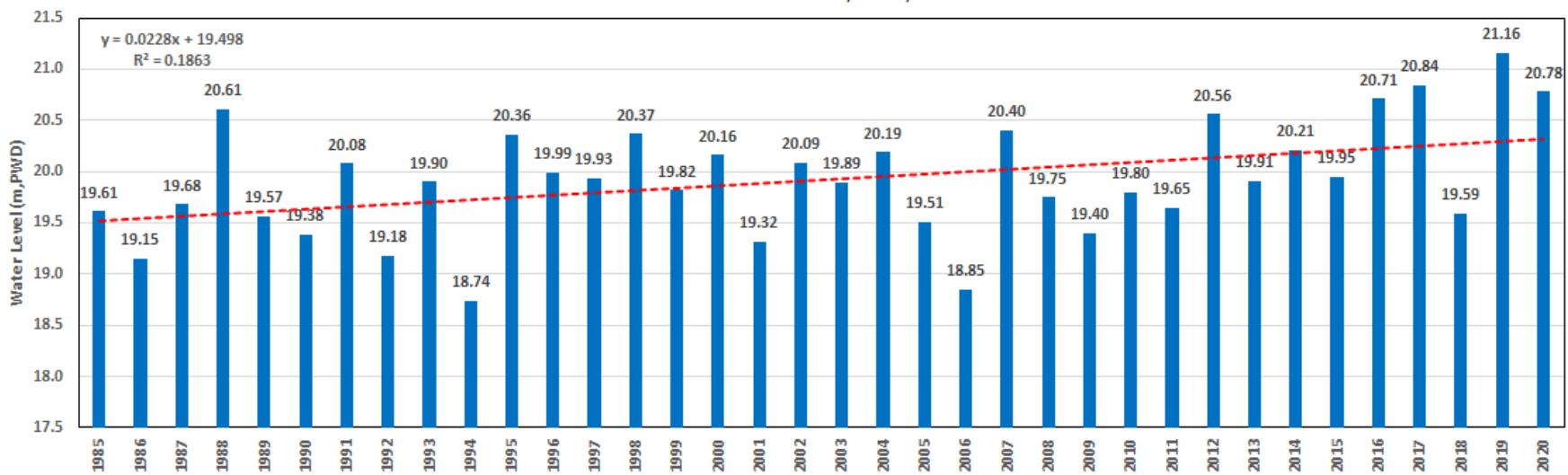
Total number of days above Danger Level at Bahadurabad in Brahmaputra River

Contact: Prof. A.K.M. Saiful Islam, IWMF, BUET

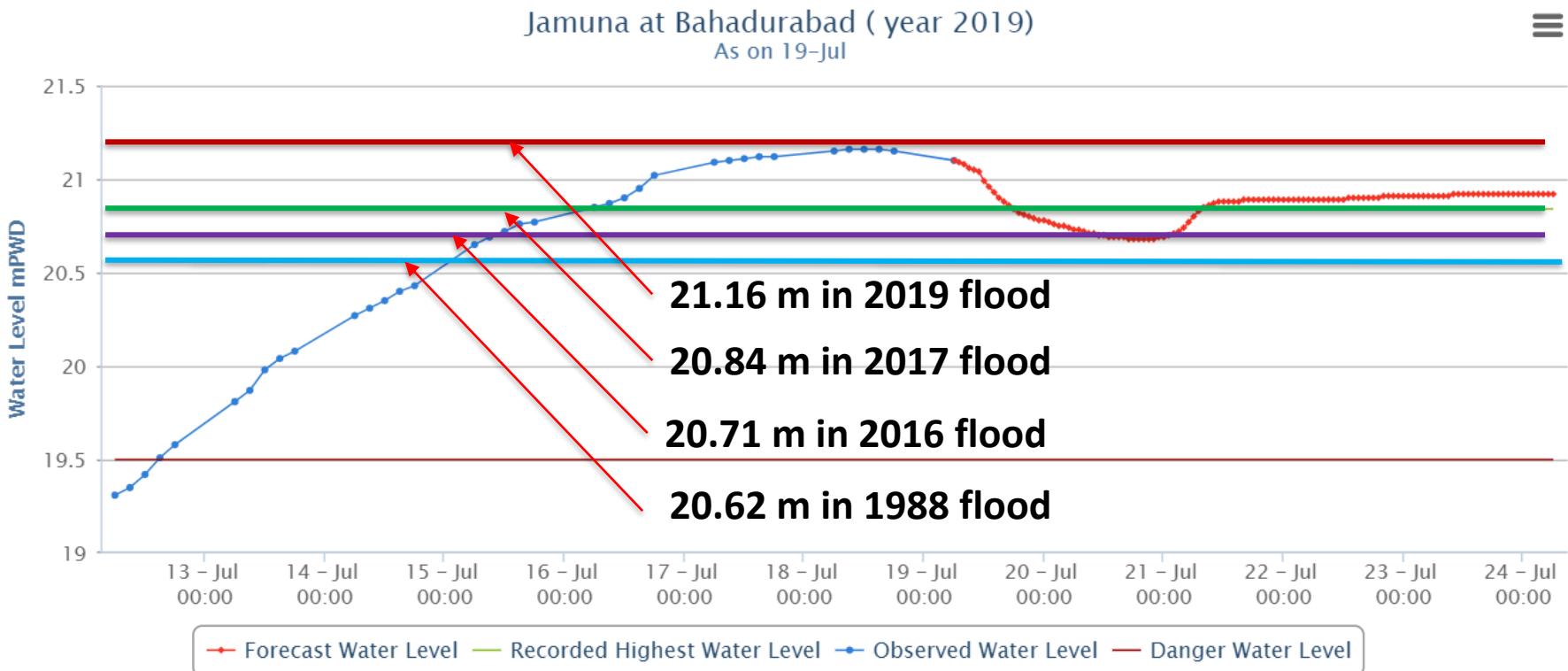


Annual Maximum Water Level at Bahadurabad in Brahmaputra River

Contact: Prof. A.K.M. Saiful Islam, IWMF, BUET



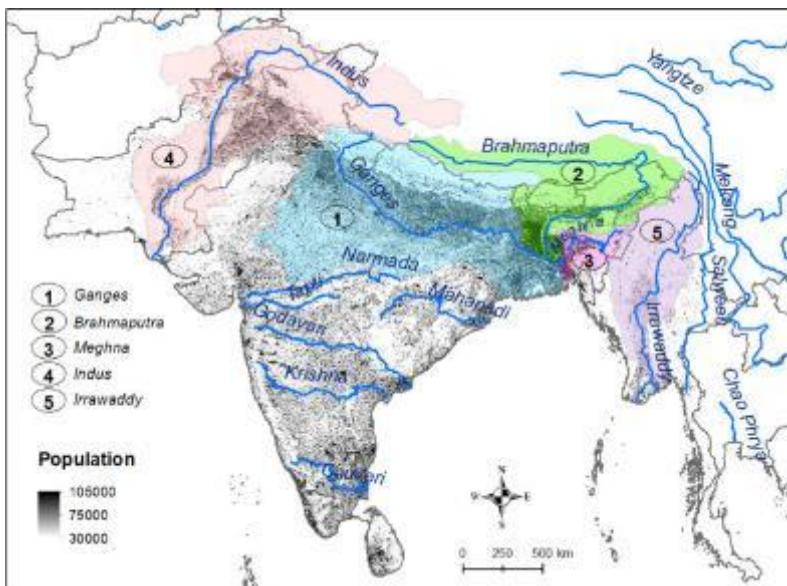
Flood peak is increasing at Bahadurabad Station on Brahmaputra- Jamuna River



River Name	Location	RHWL (mPWD)	Danger Level (mPWD)	18-07 06:00 AM	19-07 06:00 AM	20-07 06:00 AM	21-07 06:00 AM	22-07 06:00 AM	23-07 06:00 AM	24-07 06:00 AM
Jamuna	Bahadurabad	20.84	19.50	21.15	21.10	20.73	20.80	20.89	20.91	20.92

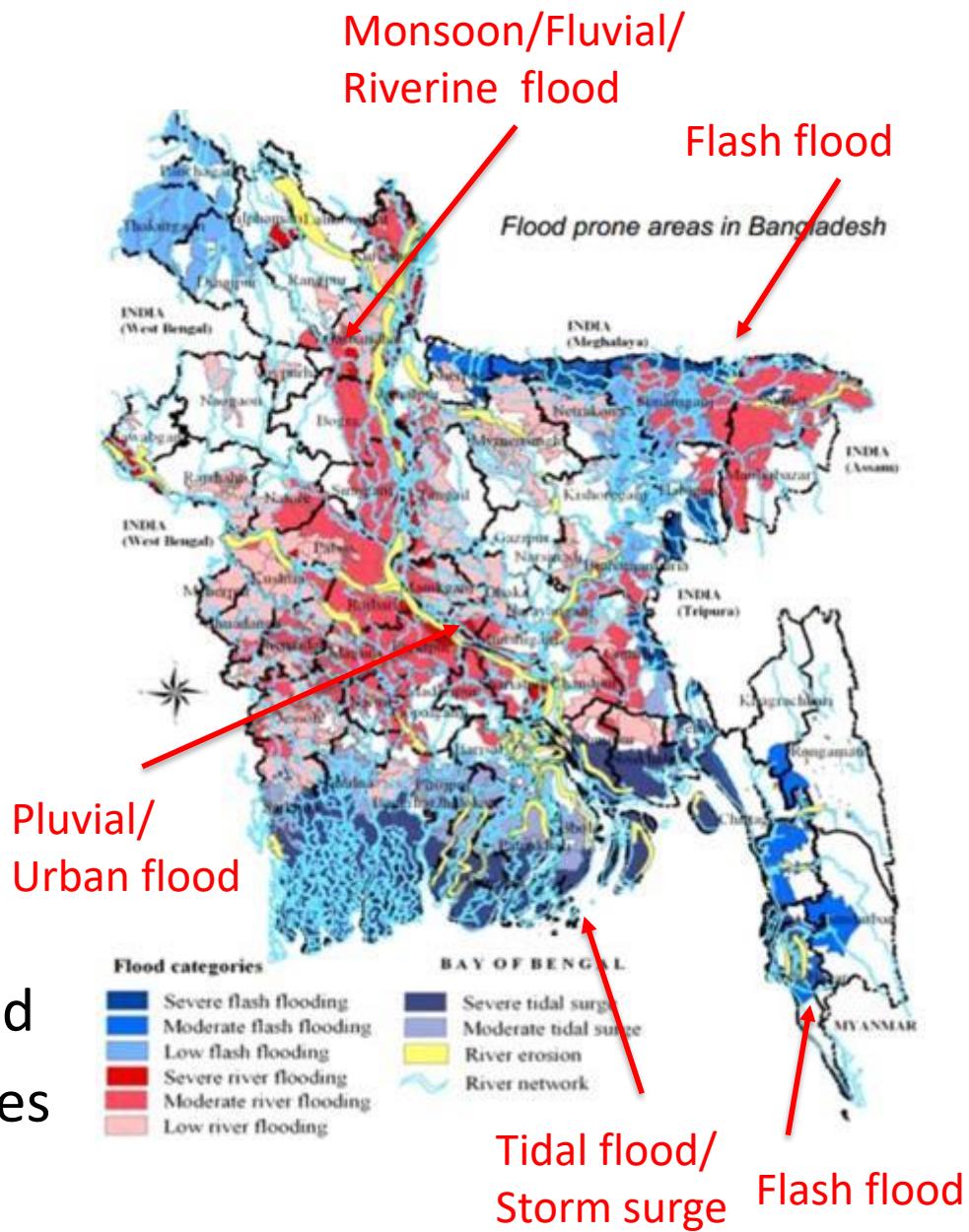
Flood hazards in Bangladesh

Ganges-Brahmaputra-Meghna (GBM) basins



Four flood types include-

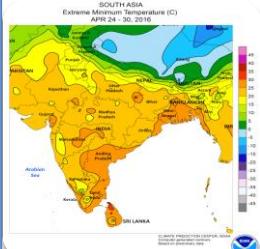
1. Flash floods in hilly areas
2. Riverine floods during monsoon season (Jun-Sep)
3. Rain-fed floods/Urban Flood
4. Tidal Flood and Storm Surges



Natural Disasters in Bangladesh during 2016-2019

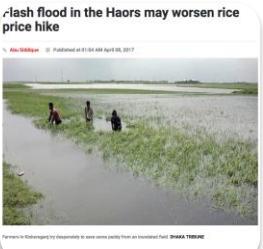
2016

6-30 April 2016



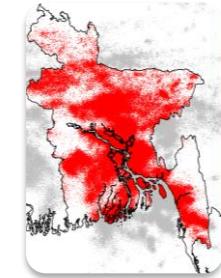
Heatwave

17-21 April 2016



Flash Flood

12-13 May 2016



Lightening

17-23 May 2016



Cyclone Roanu

August 2016



Floods

57 People Killed

30% Crop damaged

57 people killed

24 People Killed

3.7M affected

2017

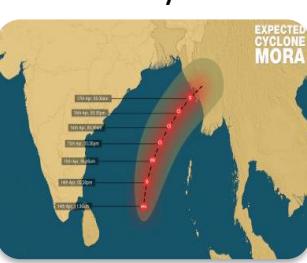
1-10 April 2017



Flash Flood

90% Crop damaged

28-31 May 2017



Cyclone Mora

135 people died

13 June 2017



Landslide

168 people died

20 June 2017



Lightening

22 people died

August 2017



Floods

3.9 M affected

2018

29 April -11 May 2018



Lightning

67 People Killed

September 2018



Blast Diseases in Rice

2019

20 April -12 May 2019



Heatwave

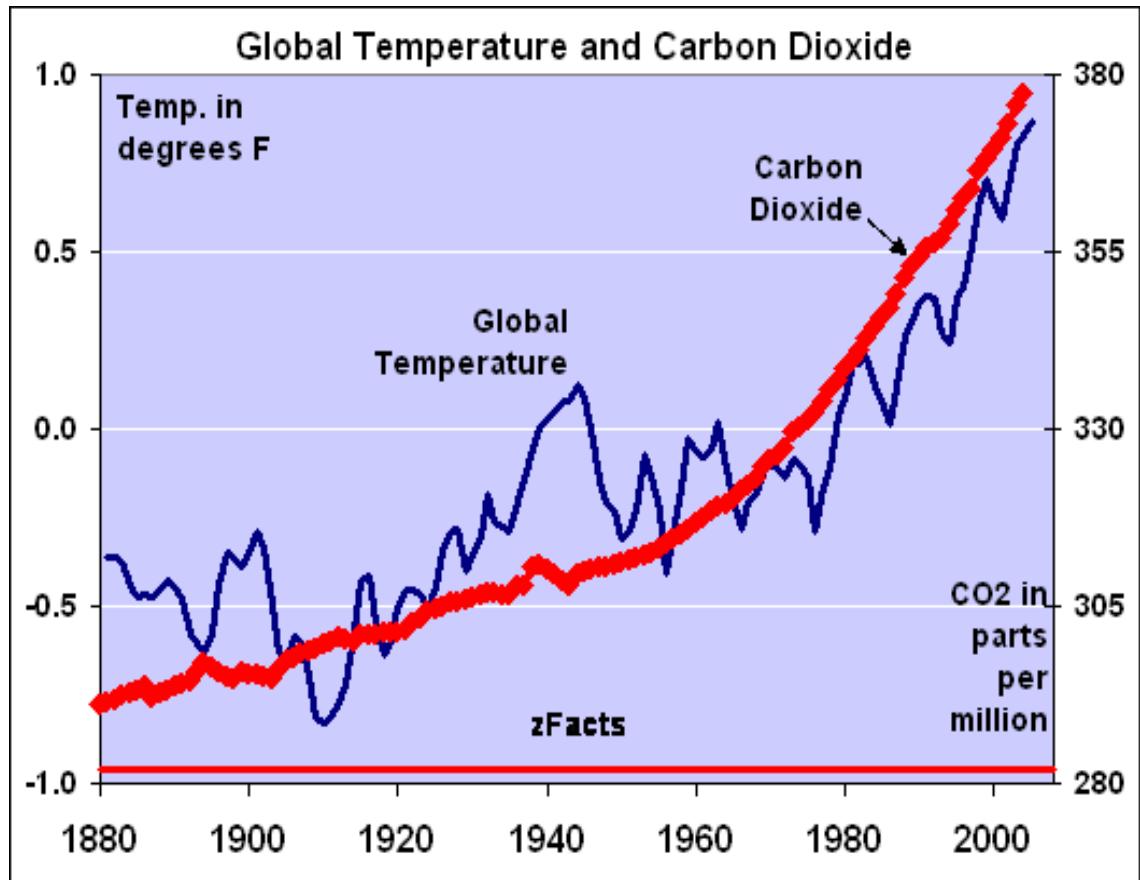
3-4 May 2019



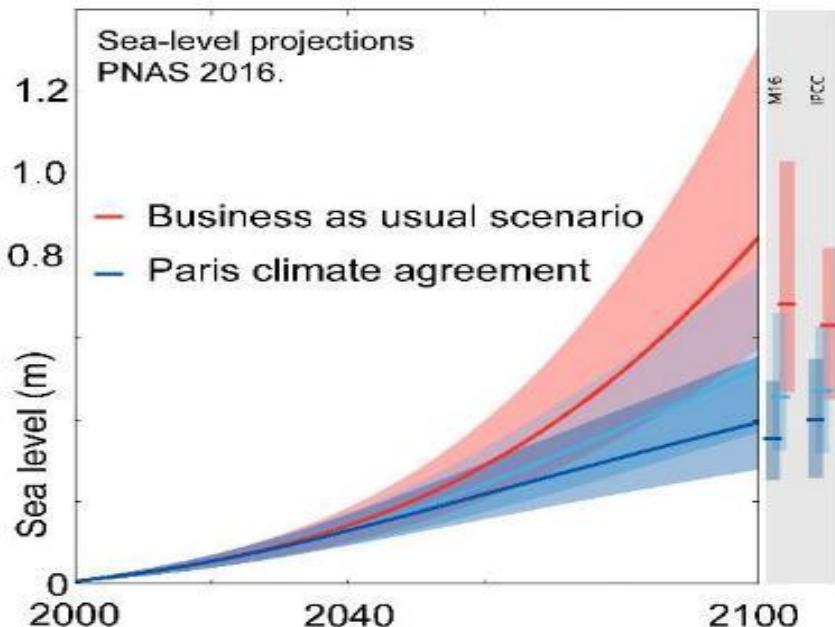
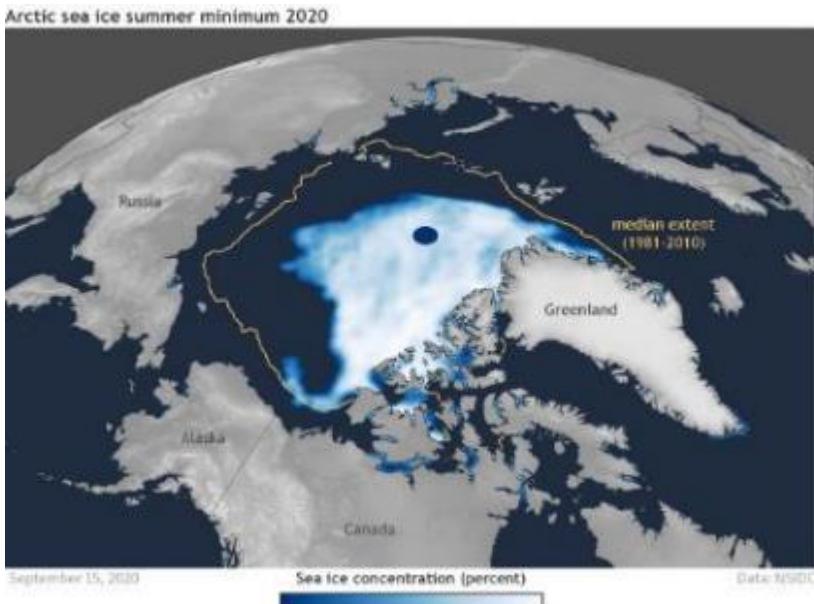
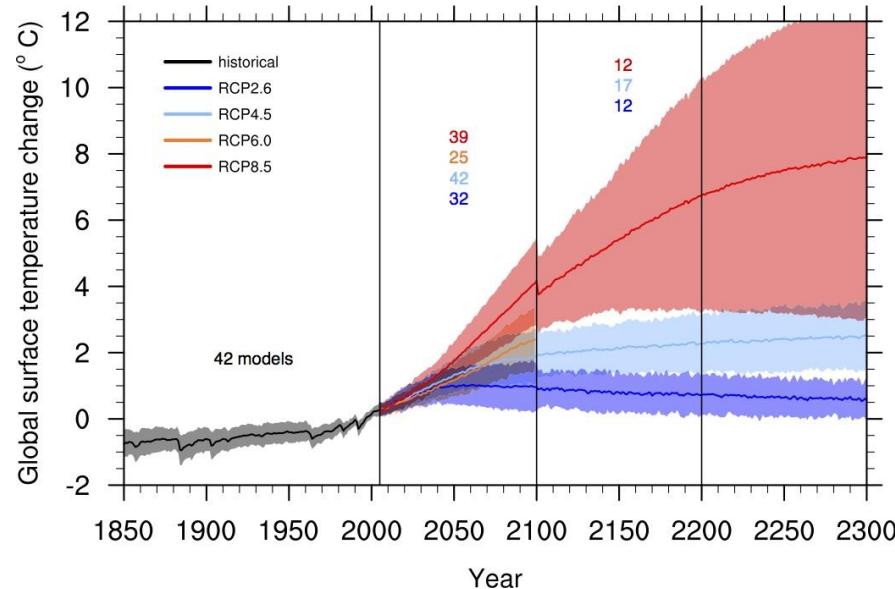
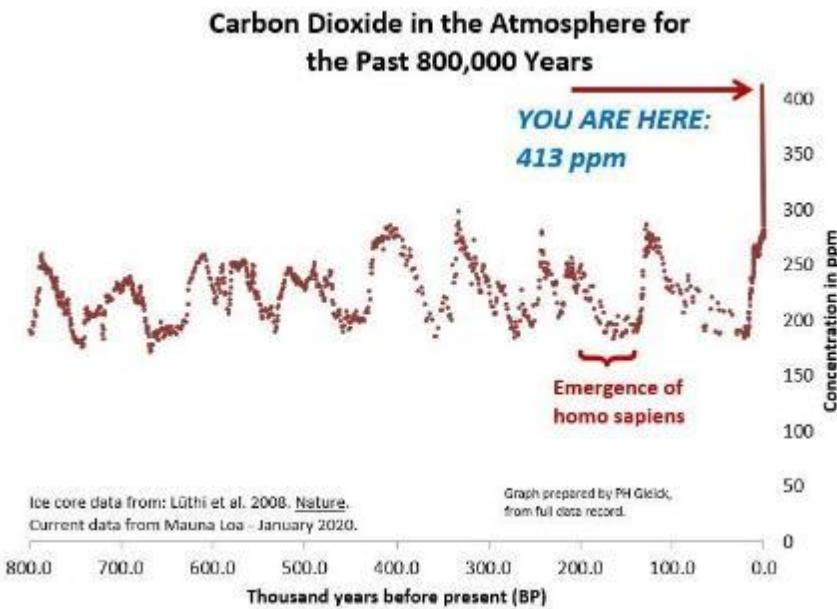
Cyclone Fani

14 People Killed

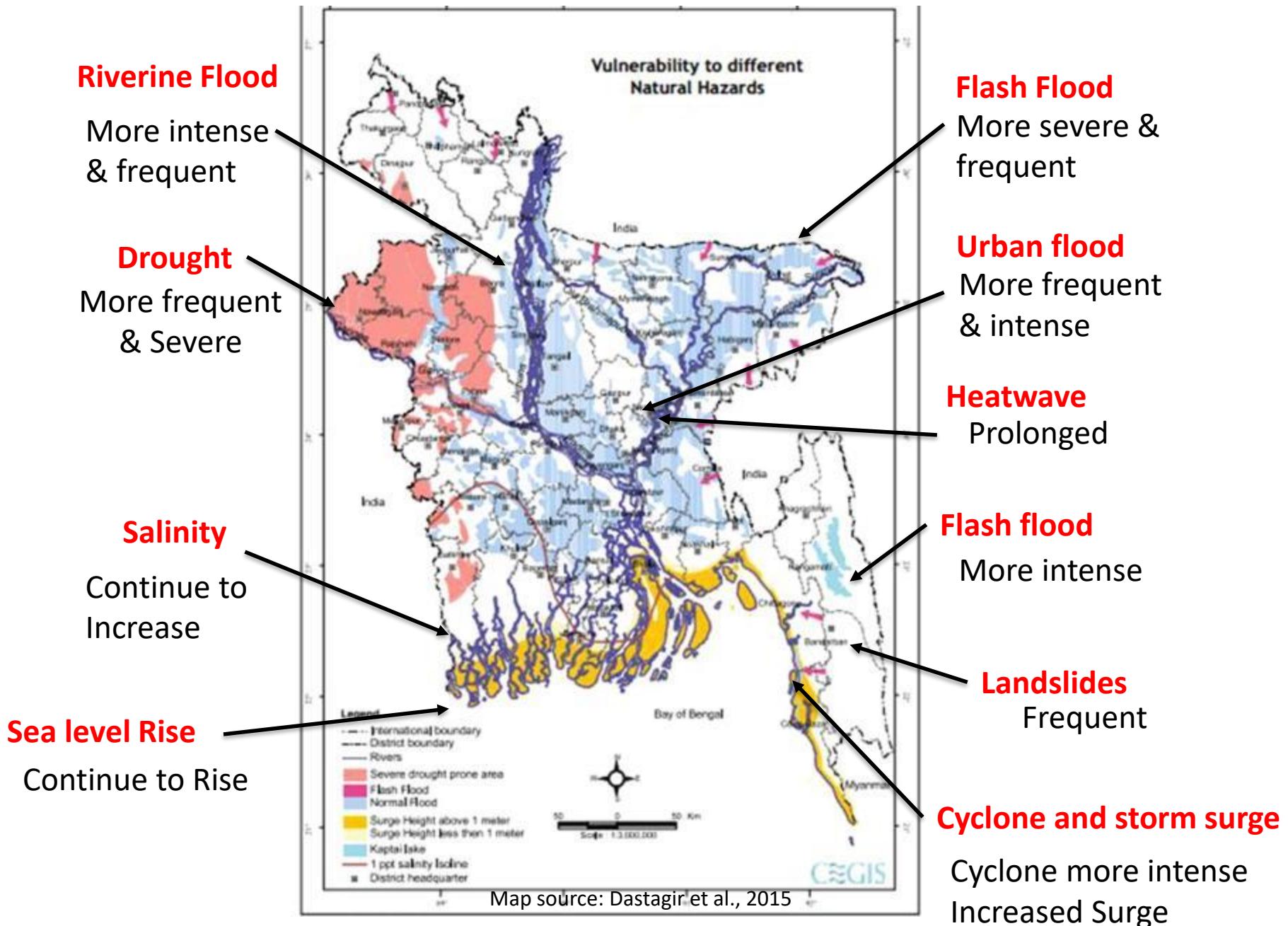
Global Rise of CO₂ emissions and Temperature after Industrializations



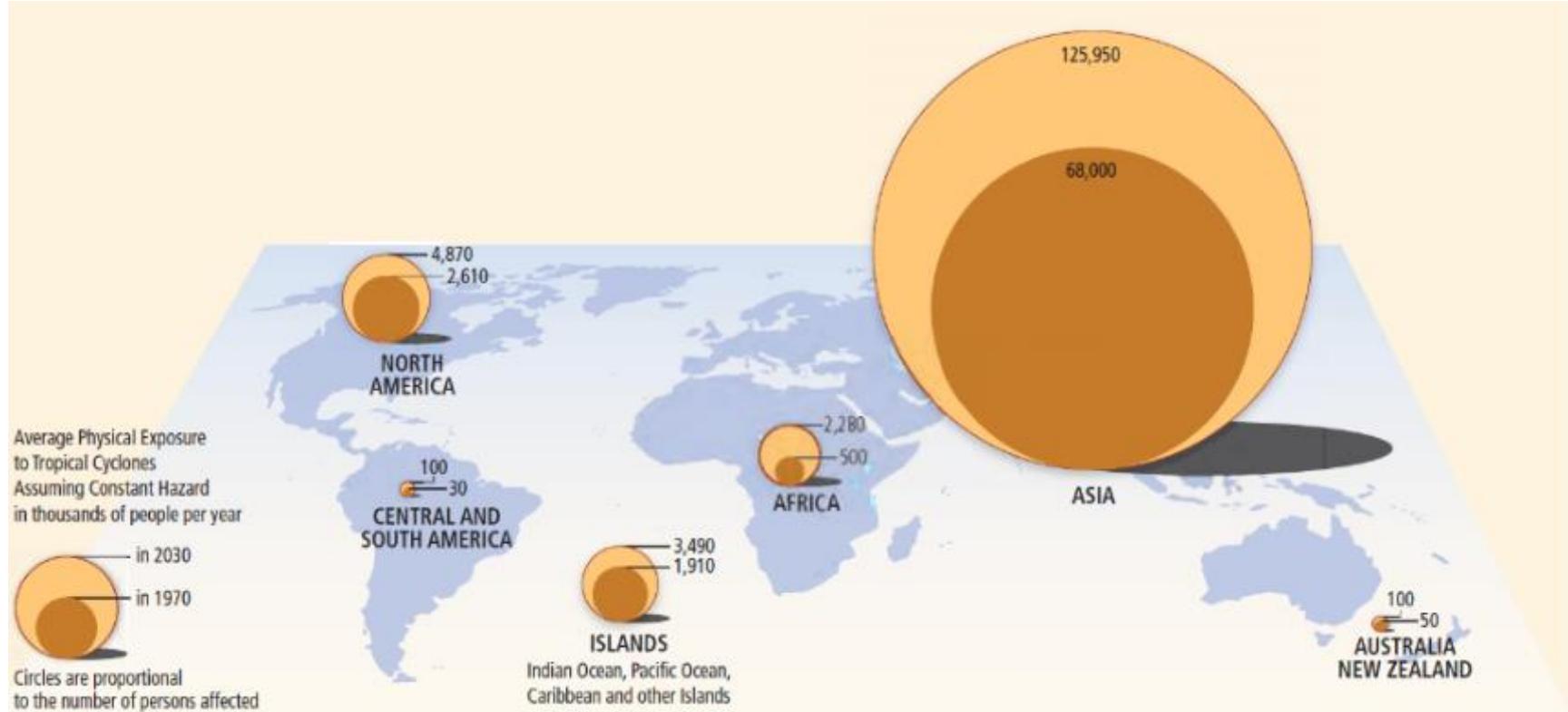
Humans are changing the climate (8,00,000 years of CO₂)



Hazards Expected to Change under Global Warming



Average physical exposure to tropical cyclones assuming constant hazard (SREX, 2017)



Oasis Platform for Climate and Catastrophe Risk Assessment – Asia Project

- **High resolution (~4km) storm modeling** for both historical and future cyclones over the Bay of Bengal (**Met office**).
- **Storm surge Inundation Modeling** for historic and future considering global warming (**BUET**).
- **Determine damage from storm surge inundation** using depth damage functions prepared for historic cyclones (**BUET**)
- **Changes of floods and rainfall extremes** in the coastal region of Bangladesh (**PIK**).
- Coastal vulnerability Assessment for floods, storm surges using community surveys and **transforming risks to stakeholders** (**IUCN**).
- **Capacity building training on climate data analysis, processing for impact modeling** (**PIK**)

Catalogues of recently occurring major Tropical Cyclones in Bay of Bengal considering in this study

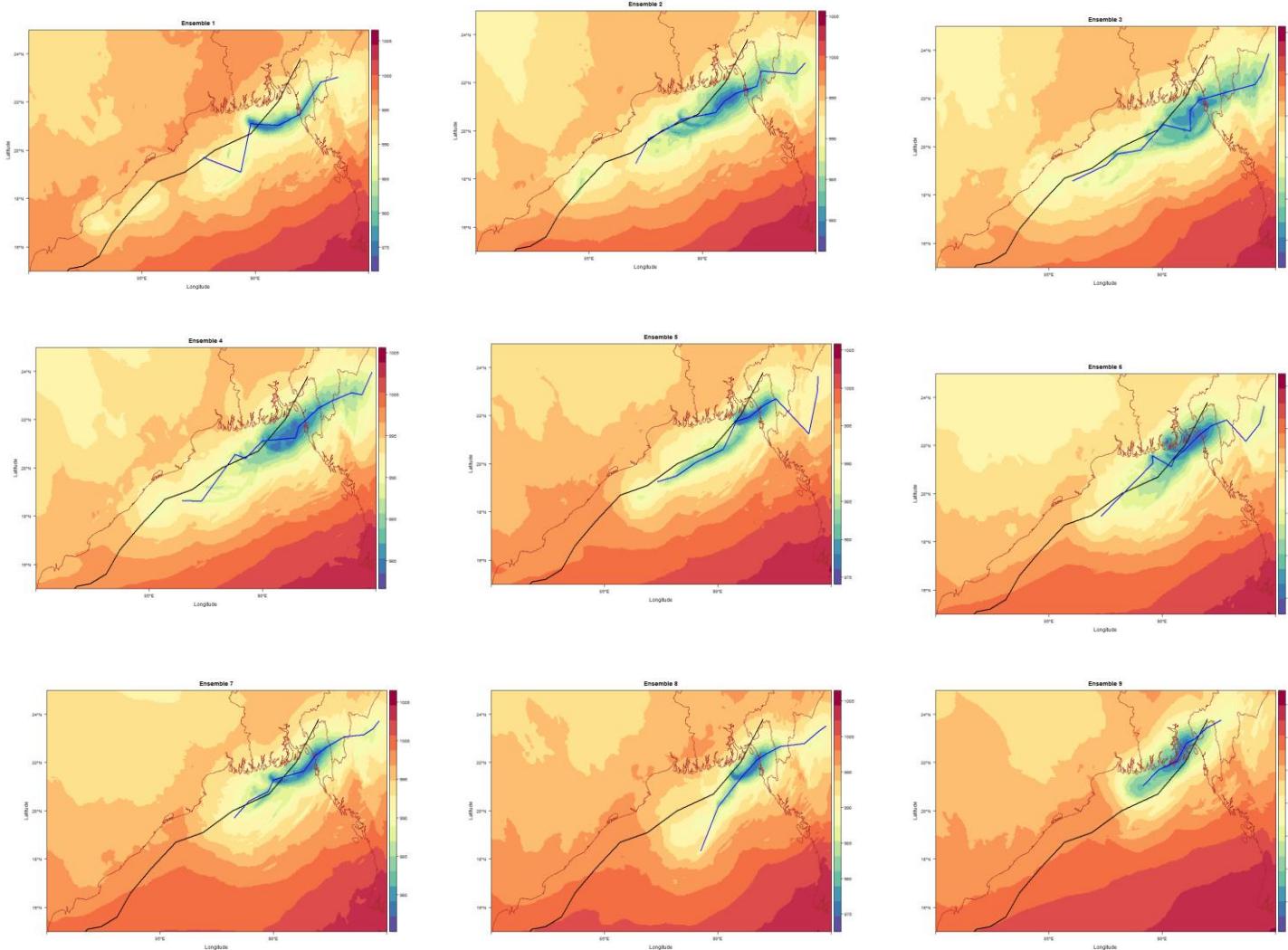
Serial	Name of the Cyclone	Year	Landfall
1	BOB01	1991	30 April, 00:00 UTC
2	BOB07	1995	25 November, 09:00 UTC
3	TC01B	1997	19 May, 15:00 UTC
4	Akash	2007	14 May, 18:00 UTC
5	Sidr	2007	15 November, 18:00 UTC
6	Rashmi	2008	26 October, 21:00 UTC
7	Aila	2009	26 May, 08:00 UTC
8	Viyaru	2013	16 May, 09:00 UTC
9	Roanu	2016	21 May, 12:00 UTC
10	Mora	2017	30 May, 03:00 UTC
11	Fani	2019	04 May, 06:00 UTC
12	Bulbul	2019	11 November, 12:30 UTC

Pre-processing of Historical catalogue of tropical cyclones

- Storm tracking. storm tracking is what identifies when and where the storms occur in a dataset that doesn't have a historical equivalent to get this info from.
- Recalibration (post-processing - to describe the need to post-process the model data in the event that it doesn't provide 10-m wind gusts
- Downscaling, or similar process to add fine/small-scale detail typically found in gusts.

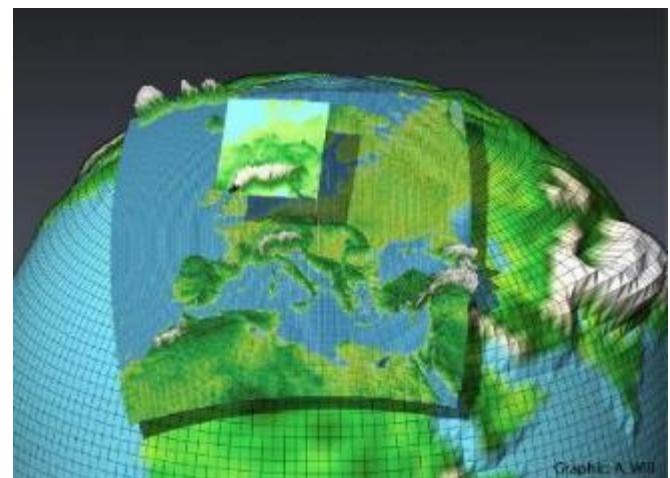
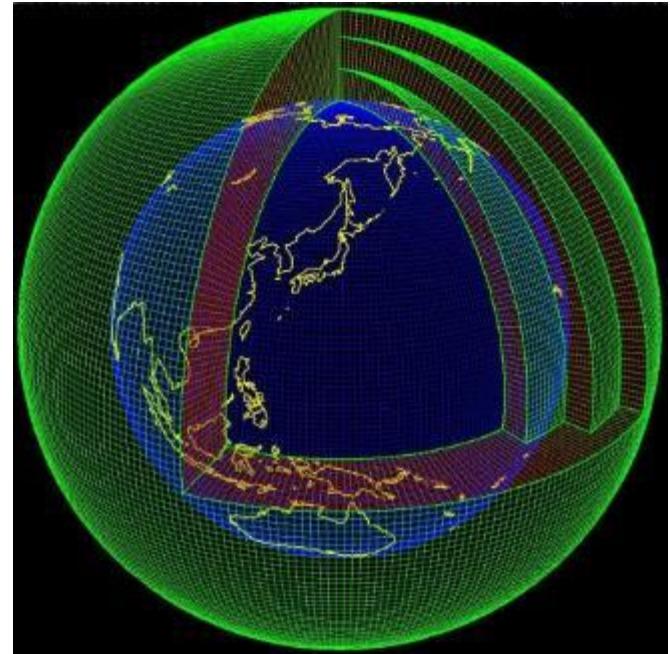
Name	Date	Location
Bhola	3 rd – 13 th Nov 1970	
BOB 01	24 th – 30 th Apr 1991	
Sidr	11 th – 16 th Nov 2007	
Aila	26 th – 27 th May 2009	
Mohasen	10 th – 17 th May 2013	
Roanu	17 th – 23 rd May 2016	
Mora	28 th – 31 st May 2017	

Simulation of cyclone Roanu with possible 9-ensemble members



Cyclone simulation using Weather modeling (WRF) at BUET

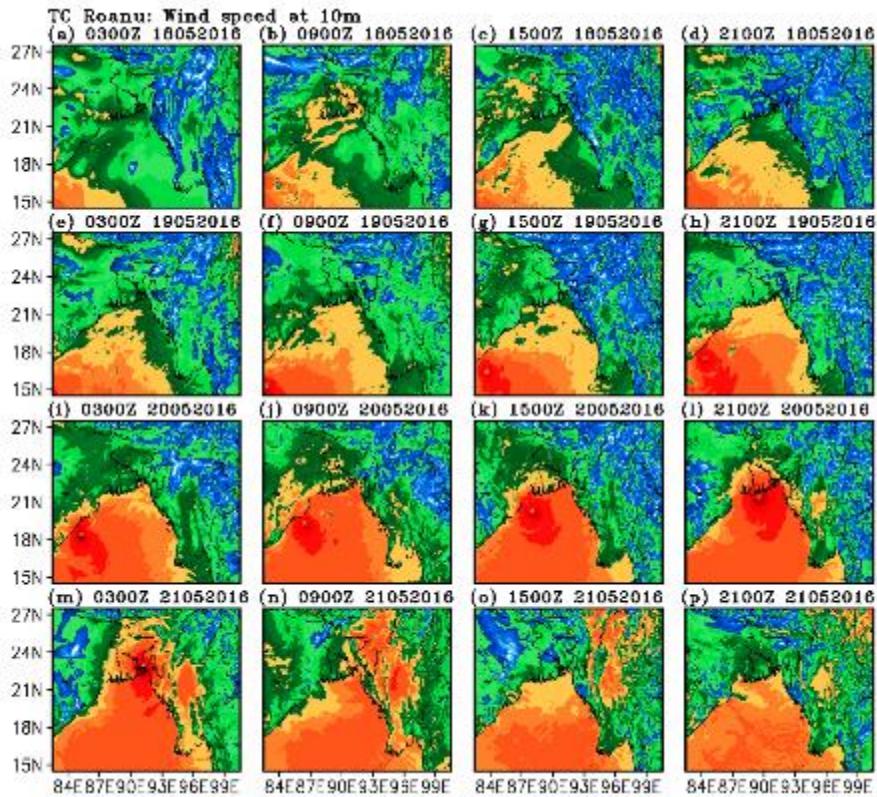
- The WRF model has been used for simulation of the MCSs associated with squalls in this study.
- The WRF model is a new generation mesoscale NWP system designed to serve both operational forecasting and atmospheric research needs (NCAR 2009).
- It features multiple dynamical cores, a 3DVAR data assimilation system, and a software architecture allowing for computational parallelism and system extensibility.
- WRF is suitable for a broad spectrum of applications across scales ranging from meters to thousands of kilometers.
- Applications of WRF include research and operational NWP, data assimilation and parameterized physics research, downscaling climate simulations, driving air quality models, atmosphere-ocean coupling, and idealized simulations (i.e., boundary layer eddies, convection, baroclinic waves).



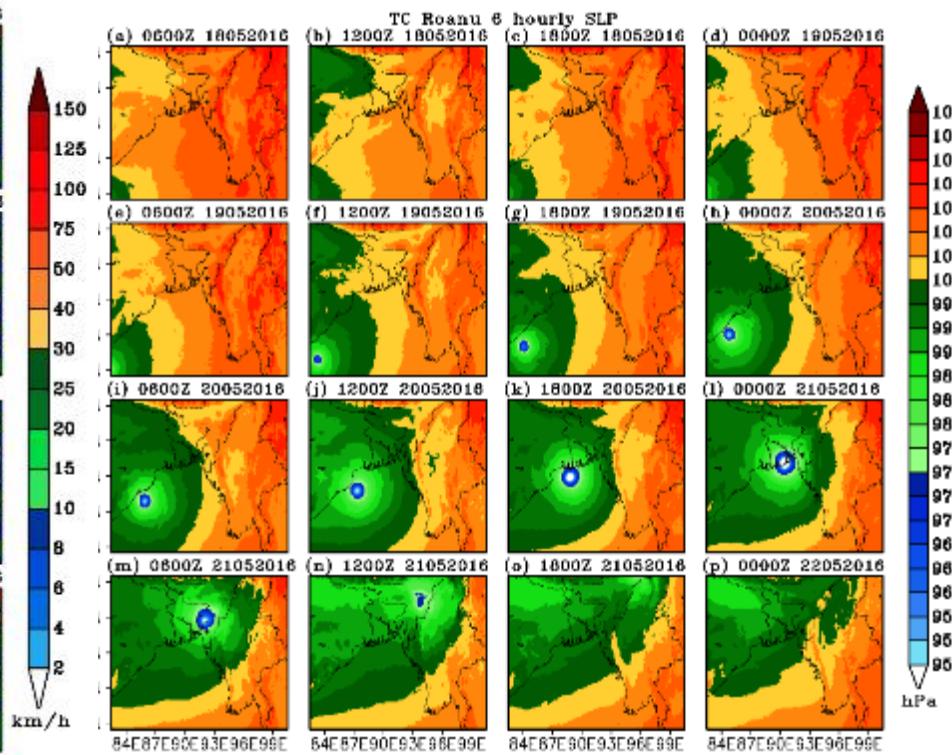
Graphic: A. Will

Wind Speed at 10m and Mean Sea Level Pressure for Cyclone Roanu simulated by WRF Model for Cyclone Roanu @IWFM, BUET

Wind Speed at 10m (km/hr)

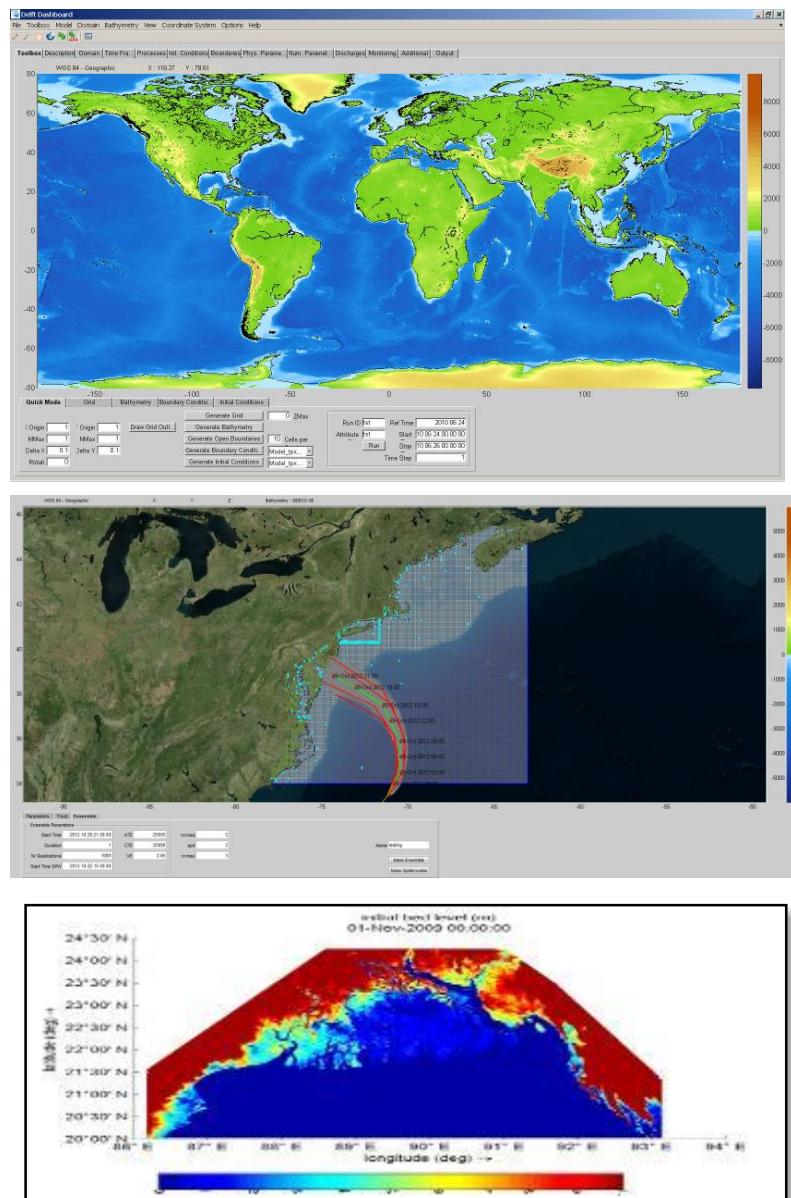


Mean Sea Level Pressure (hPa)

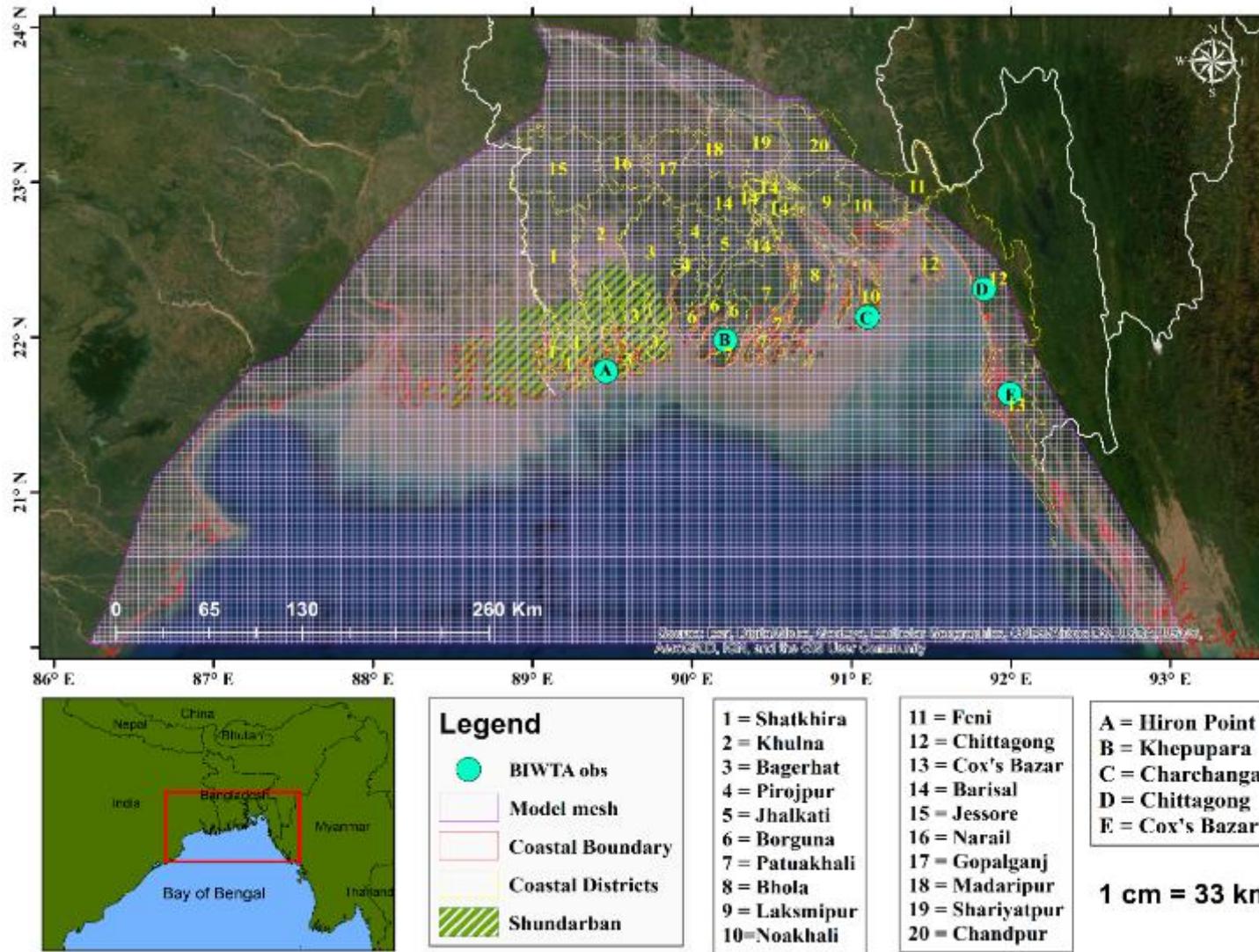


Coastal modeling using Delft3D

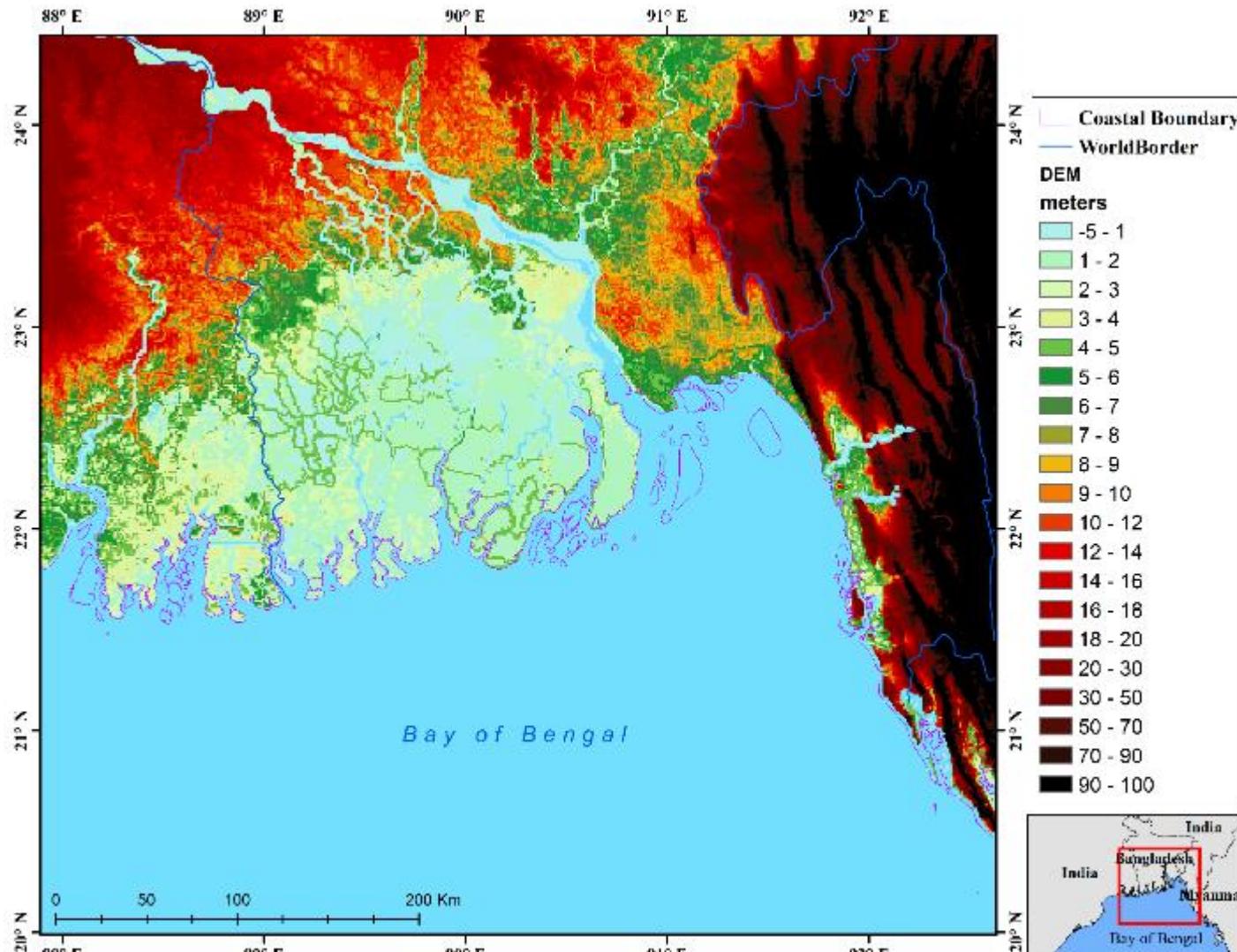
- DELFT3D- FLOW is a multi-dimensional (2D or 3D) hydrodynamic (and transport) simulation program which calculates unsteady flow and transport phenomena that result from tidal and meteorological forcing on a rectilinear or a curvilinear, boundary fitted grid.
- Using Delft3D-dash board model can be setup, simulate, calibrate and validate over a region of interest. Using the Advanced Cyclone Toolbox and possible cyclone tracks, boundary conditions can be generated to derive the Delft3D model for study inundation patterns.



Delfft3d Modeling Domain, Grid and BIWTA & BWDB Observation Stations



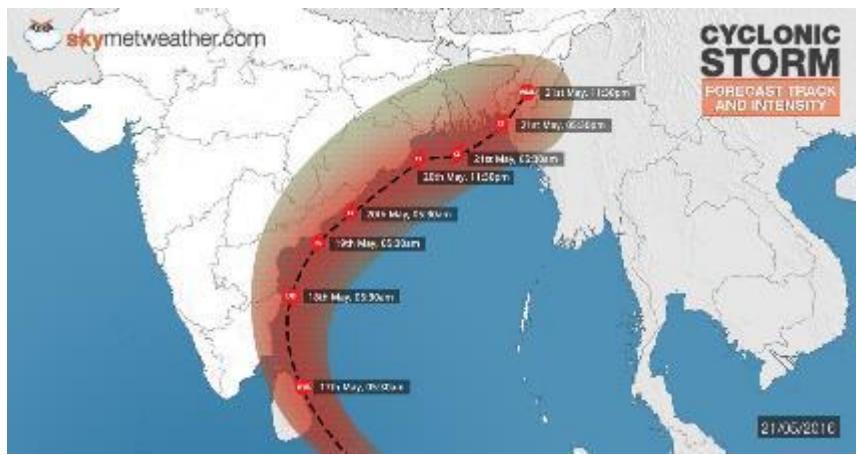
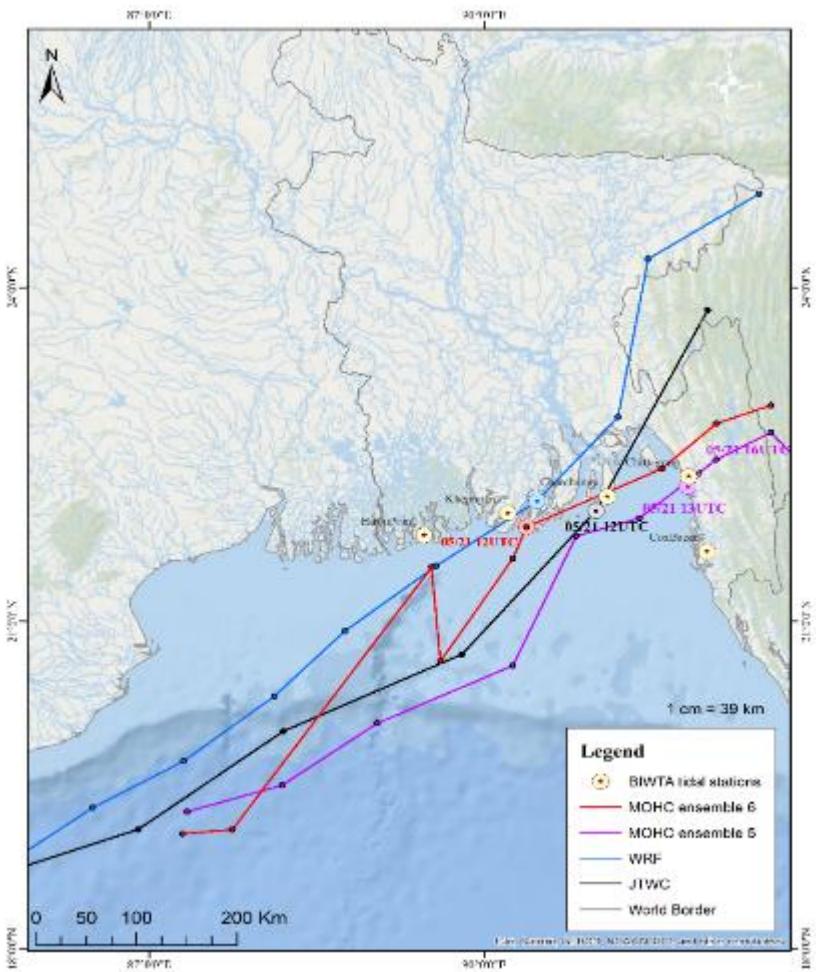
Topography of the Coast and Bathymetry of the Bay of Bengal



Bathymetry data has been collected from GEBCO data sets and also survey from BWDB, Bangladesh Navy and IWMF of BUET.

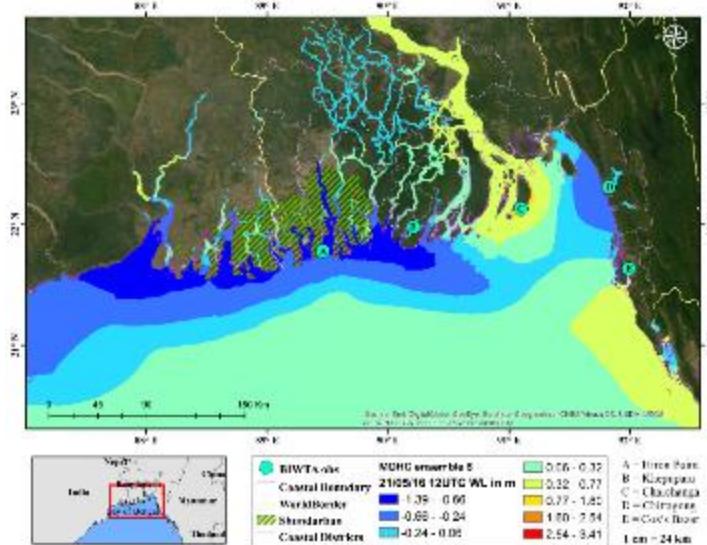
Comparison of Tracks of Cyclone Roanu

Track of JTWC, WRF, MOHC-5, MOHC-6

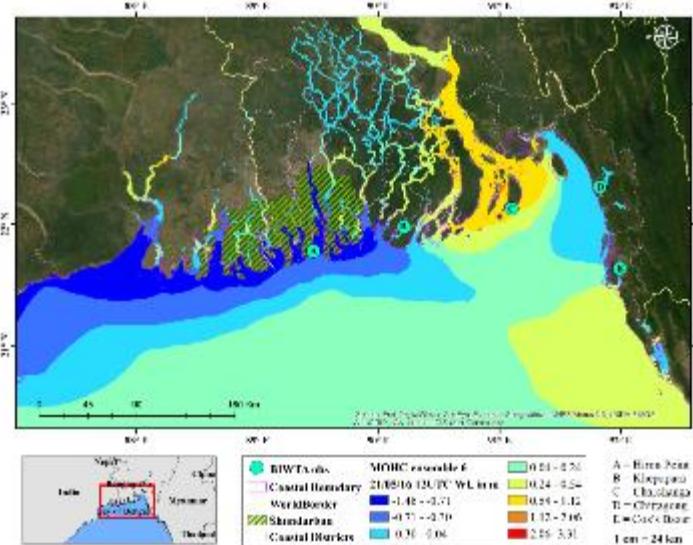


Comparison of flood inundation

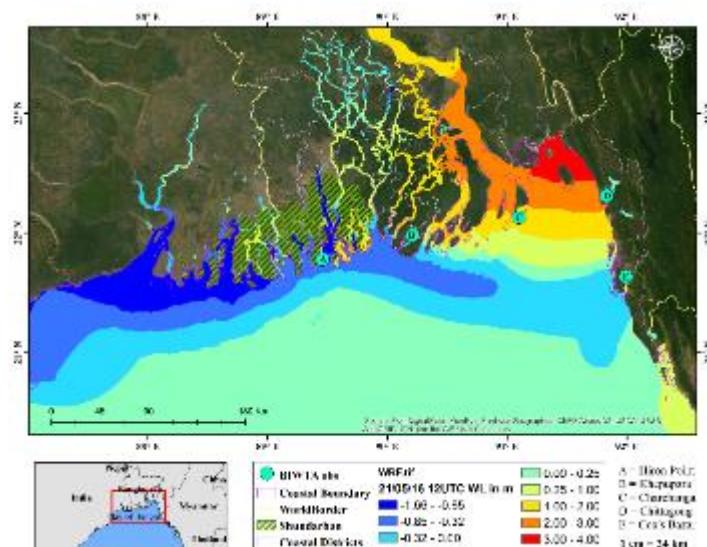
MOHC-5



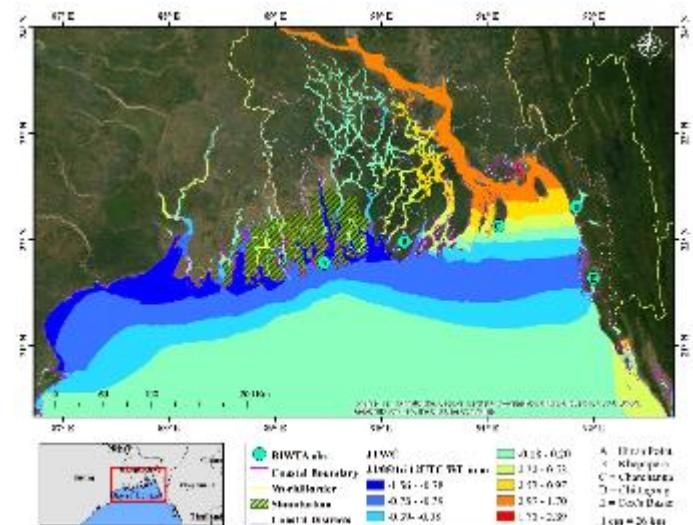
MOHC-6



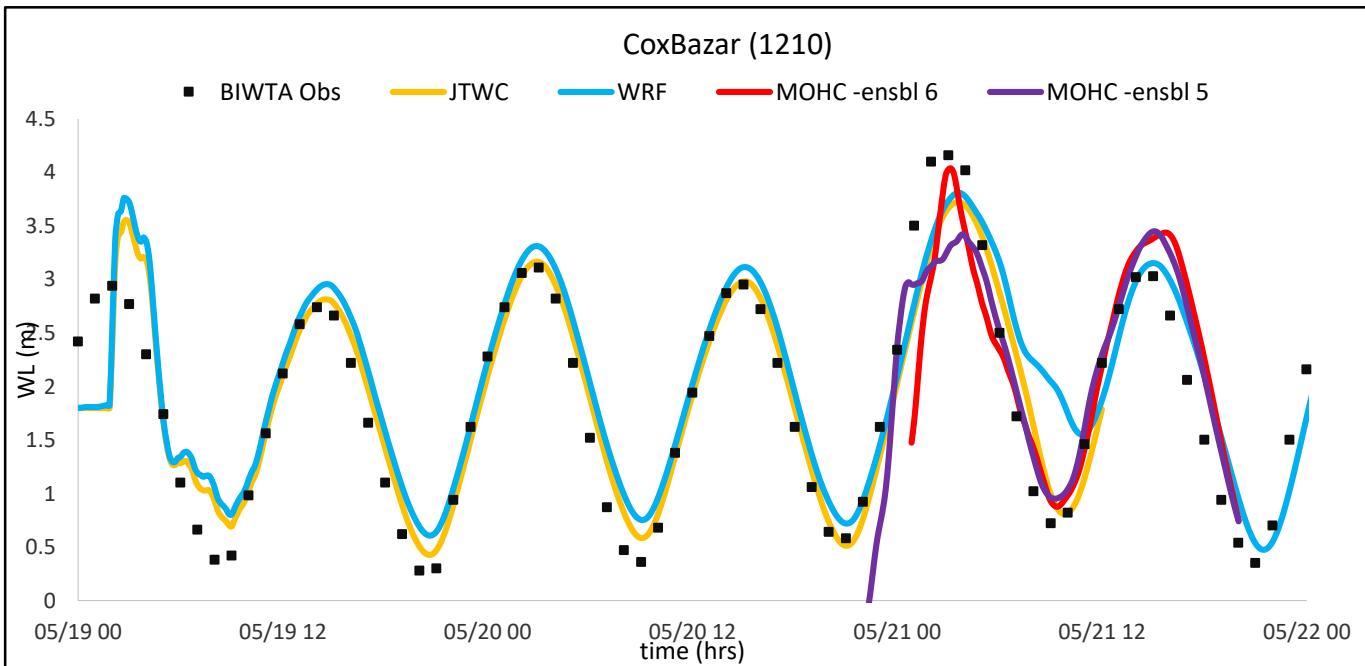
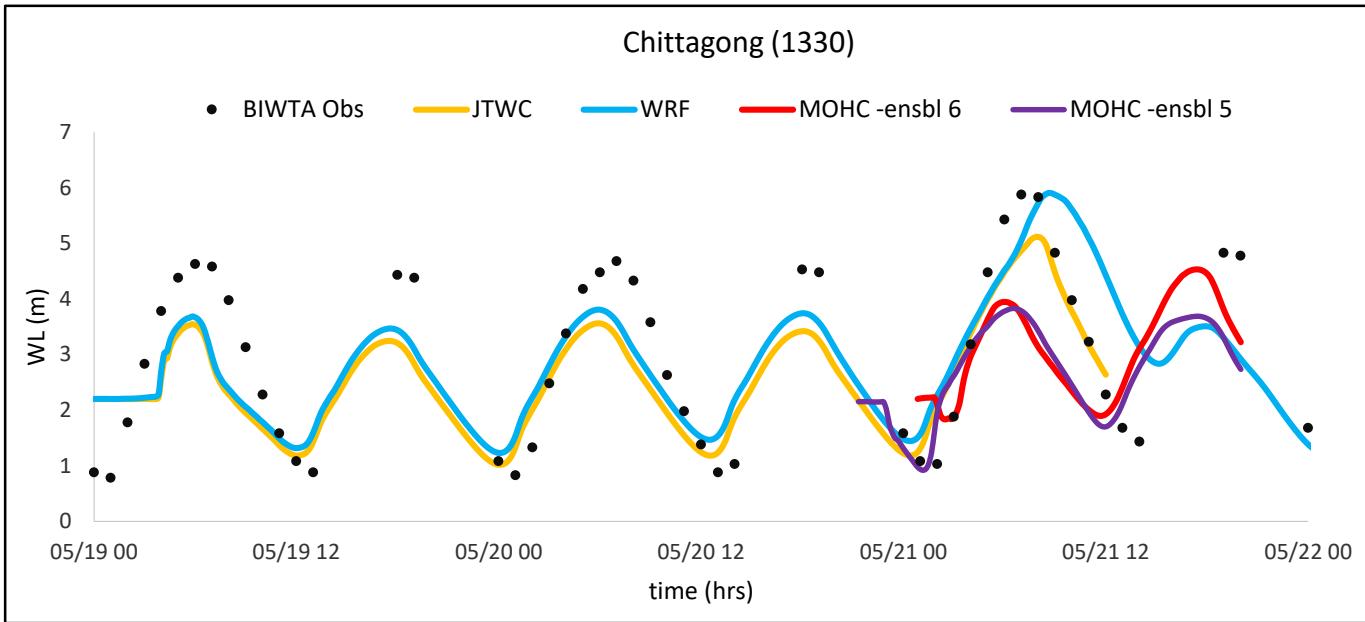
WRF



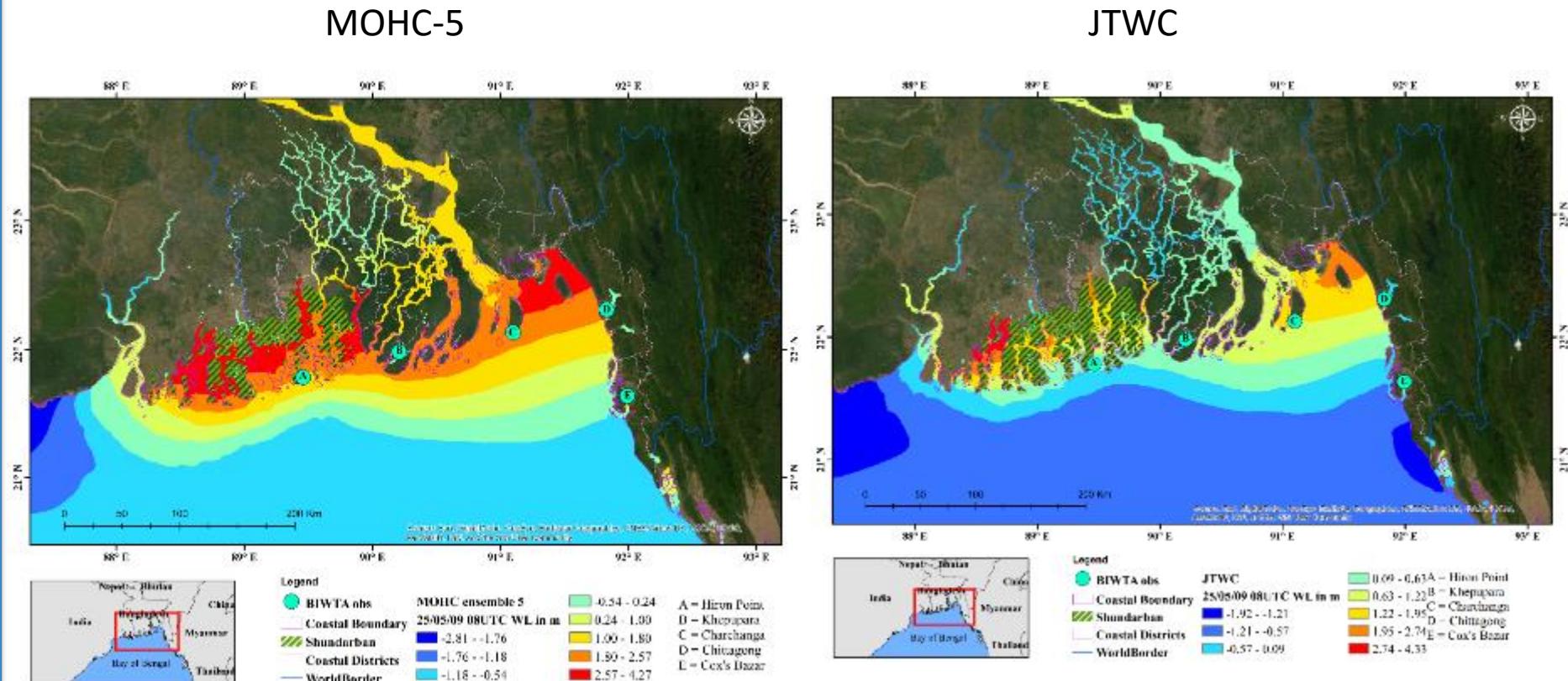
JTWC



Comparison of Time series plots for cyclone Roanu

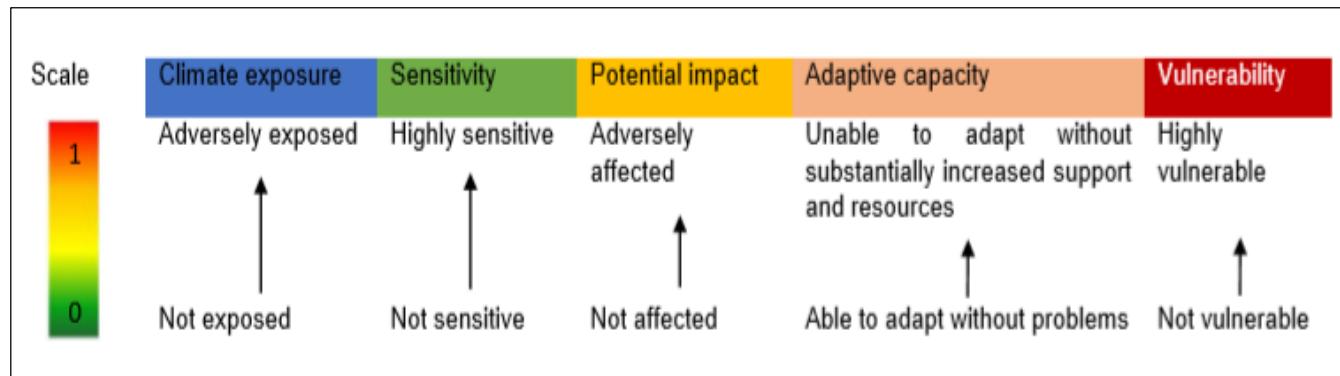


Comparison of storm surge inundation of cyclone Aila using boundary data from MOHC and JTWC



Selection of Damage Classes for depth-damage function development

Residential	Transport	Agriculture	Normalized data value with the corresponding vulnerability component (source: Report on Nationwide Climate Vulnerability in Bangladesh, 2018)
<ul style="list-style-type: none">Mud houseWooden tinSemi pucca tin	<ul style="list-style-type: none">Mud roadBrick roadDouble brick road	<ul style="list-style-type: none">RiceVegetables	



$$X_{nv} = \frac{X_{ov} - X_{min}}{X_{max} - X_{min}}$$

Xnv is the normalized value within the range of 0 to 1

Xov is the original value of a data point to be normalized;

Xmin is the minimum value of all data points corresponding to the worst situation; and

Xmax is the maximum value of all data points corresponding to the optimal situation.

Developing depth to damage functions for cyclone Roanu – Field visit to Bashkhali, Chittagong

Cyclone Shelter



Coastal Embankment



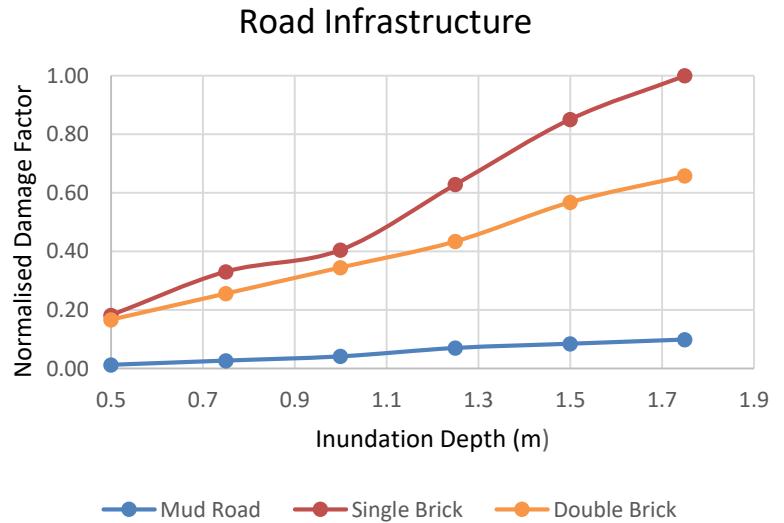
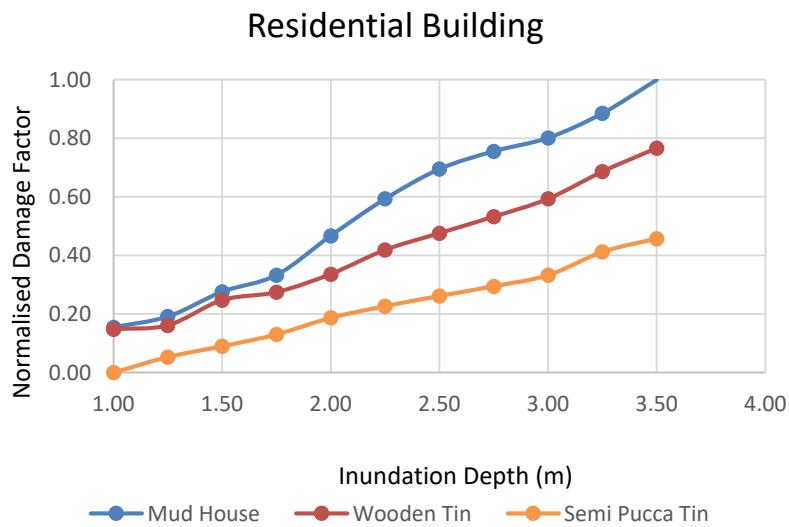
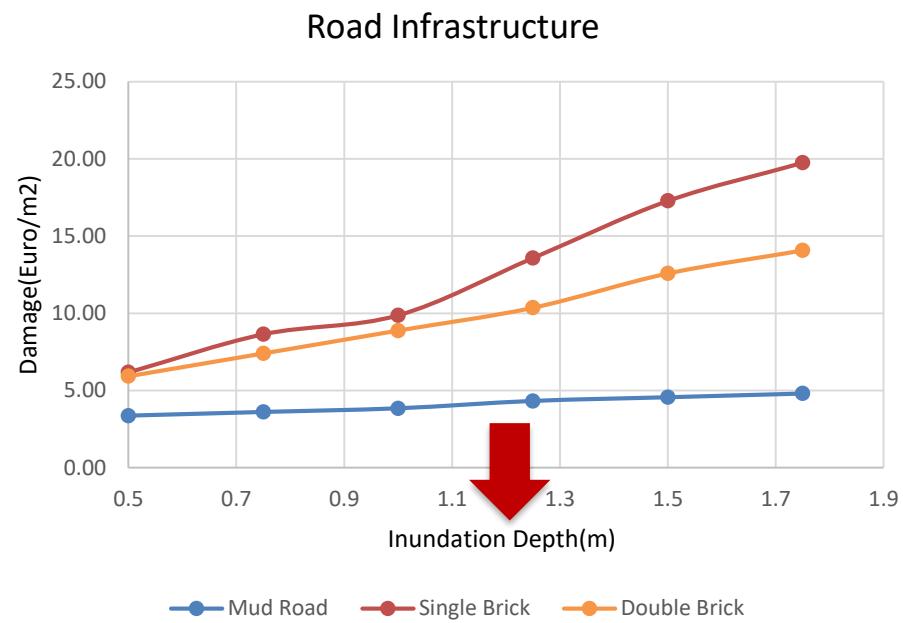
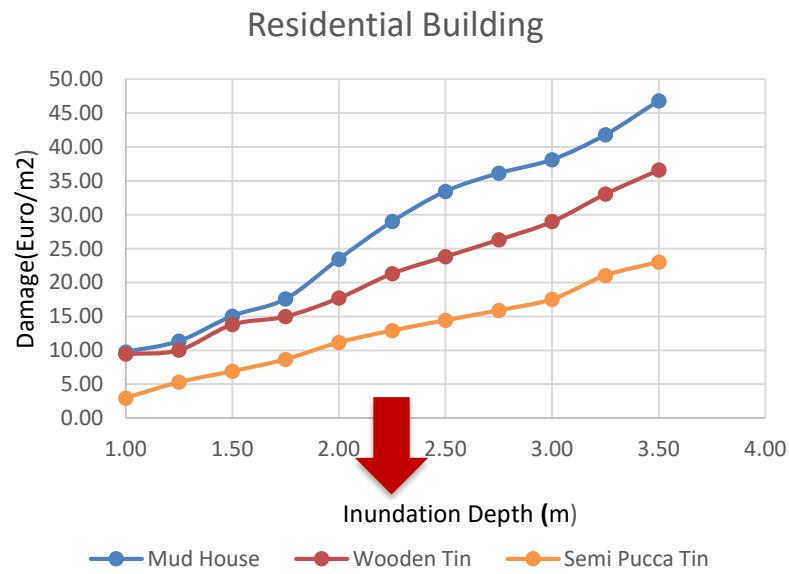
Mud House



Interview - Questionnaire



Normalized Damage curves for Residential Buildings and Road infrastructures



“Oasis Hub” Environmental Data, Tool & Services

<https://oasishub.co/>

The screenshot displays the homepage of the Oasis Hub website. At the top, there is a purple header bar with the "OASIS HUB" logo on the left, followed by the text "The Global Window to Free and Commercial Environmental and Risk Data, Tools and Services". On the right side of the header are links for "Feedback", "Create Organization", a shopping cart icon, and a menu icon.

The main content area features a large banner image of a coastal landscape with waves and rocks. Below the banner is a row of twelve circular icons representing different environmental hazards and services:

- Map
- Cyclone
- Earthquake
- Environment
- Flood
- Landslide
- Tsunami
- Volcano
- Water
- Weather
- DF
- Cat Risk Catalogue

Below these icons are four rectangular cards, each showing a preview of a specific dataset or tool:

- OasisLMF-compliant Future Danube Catastrophe Model: Fluvial and pluvial flooding. It includes an image of the Hungarian Parliament building and a German flag.
- Fluvial flood data for German Danube Basin with future climate scenarios - GFZ. It includes an image of a classical building under floodwater.
- Europe - Middle Danube, Oder and Wisla Historical Flood Database - Hydro-GIS Ltd. It includes an image of the European Union flag.
- United Kingdom Historical Rainfall Digital Maps from 1866 to 1968 - Hydro-GIS. It includes an image of a coastal arch and a cliffside.

Below these cards is another purple header bar with the text "Tools & Services" on the left and a "View all" dropdown menu on the right.

The bottom section contains four more preview cards:

- Geoflood Europe (SmartFLOOD Europe)
- Geoflood Global (SmartFLOOD Global)
- Imperial College London - Tropical Cyclone Landfall Event Generator
- ARIA - E3PViz (ARIA TECHNOLOGIES)

Each card shows a preview image and the name of the tool or service.

Transferring Results into the Oasis Hub



Bangladesh - Storm Surge Inundation for Historical Tropical Cyclones in the Bay of Bengal - IWFM, BUET PRIVATE

Storm surge simulation using open source-based Delft3D model for historical tropical cyclones in the Bay of Bengal. Delft3D is simulated over a rectangular curvilinear grid spacing 0.006° (~ 666 m). The mesh used for this model covers 20.71°N to 23.97°N and on an average 87°E to 92°E . The open boundary conditions in the Bay of Bengal are time series water level. These data have been generated from TPXO 7.2 global inverse tidal model. Open boundaries have been defined at three upstream points of GBM delta, namely, at Hardinge Bridge for the Ganges river, at Bahadurabad for the Brahmaputra river and at Bhairab Bazar Railway Crossing for the Meghna river. The boundary conditions of these three points are water discharge measured by the Bangladesh Water Development Board. Daily discharge data has been generated from the stage-discharge relationship by constructing the rating curve. Model linearly interpolate it for every time step of the calculation. Each tropical cyclone has a 9 member ensemble and comprises of time-series and footprints at resolutions of 4.4km and 15km based on the Met Office Unified Model dynamically downscaling ECMWF ERA5 data. The catalogue contains the following tropical cyclones (landfall date): BOBo1 (30/04/1991 00:00) BOBo7 (25/11/1995 09:00) TC01B (19/05/1997 15:00) Akash (14/05/2007 18:00) Sidr (15/11/2007 18:00) Rashmi (26/10/2008 21:00) Aila (25/05/2009 06:00) Viyaru (16/05/2013 09:00) Roanu (21/05/2016 12:00) Mora (30/05/2017 03:00) Fani (04/05/2019 06:00) Bulbul (09/11/2019 18:00). The maximum water level (tide and surge) for each ensemble of each of the 9 cyclones are generated by simulating Delft3D model using the wind and pressure field generated by the Met Office Unified Model (as mentioned above).

IWFM-BUET

Institute of Water and Flood Management (IWFM), Bangladesh University of Engineering and Technology (BUET) [read more](#)

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Super Cyclone Amphan
Delft3D model using JTWC Track
May 20 at 12:00 UTC @ IWFM-BUET
Contact: saiful3@gmail.com

Surge Height (m):

0.0 - 0.5
0.5 - 1.0
1.0 - 1.5
1.5 - 2.0
2.0 - 2.5
2.5 - 3.0
3.0 - 3.5
3.5 - 4.0

A map of the Bay of Bengal showing the surge height simulation for Super Cyclone Amphan. The map includes a color-coded legend for surge height in meters, ranging from 0.0 to 4.0. The highest surge is shown along the coastlines of Bangladesh and India, with values up to 3.5 meters or higher. A red line indicates the JTWC track of the cyclone. The map also shows the coastline, major rivers, and bathymetry.

Data set catalogue of all historical cyclones simulated by UK Met office and IWFM, BUET



The Global Window to Free and Commercial
Environmental and Risk Data, Tools and Services

Feedback

Create Organization



Data and Resources

Documentation:

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Cyclone BOBo1 1991 Time Series
30/04/1991

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Cyclone BOBo7 1995 Time Series
25/11/1995

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Cyclone TC01B 1997 Time Series
19/05/1997

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Cyclone Akash 2007 Time Series
14/05/2007

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Cyclone Sidr 2007 Time Series
15/11/2007

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Cyclone Rashmi 2008 Time Series
26/10/2008

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Cyclone Aila 2009 Time Series
25th May 2009

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Cyclone Roanu 2016 Time Series
21/05/2016

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Cyclone Viyaru 2013 Time Series
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Cyclone Mora 2017 Time Series
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Cyclone Fani 2019 Time Series
04/05/2019

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Cyclone Bulbul 2019 Time Series
09/11/2019

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Ensemble Footprints - Wind Speed of Gust - ...
1Hr Max in m/s

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Ensemble Footprints - Air Pressure at Sea Level - ...
1Hr Min in Pa

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Capacity Building Training by PIK and BUET in Dhaka

“Short Course on Climate Input Data Processing and Analysis”, 19-21 June 2019

- The course covers handling data from global and regional climate observations and simulations via theoretical and practical exercises. The course will cover:
- - Acquisition of climate data
- - Preparation and manipulation of netCDF files (standard format for climate data)
- - Analysis and visualization of climate data using python
- - Analysis and adjustment of model inherent biases



Upcoming Training on Regional Sea Level Rise Projections

Training workshop on sea-level rise in South Asia and the use of Bangladesh sea-level projections.

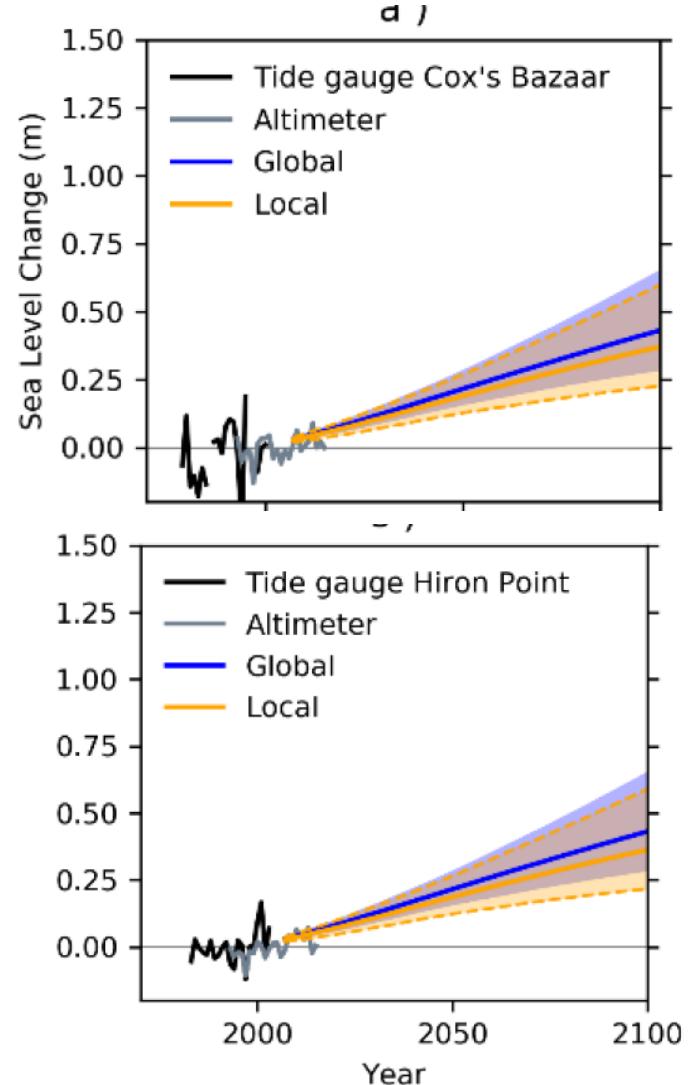
Asia Regional Resilience to a Changing Climate (ARRCC), Work Package 3: Climate Analytics for Risk Information and Services South Asia (CARISSA) , Activity 5: Future sea-level risk information and services

Contact: Benjamin Harrison, UK Met office
Email: benjamin.harrison@metoffice.gov.uk

Possible Date: 23rd- 26th November 2020,
0900-1230 GMT

Venue: Online

Organized by: Climate Change Study Cell,
IWFM, BUET



Possible applications of this study

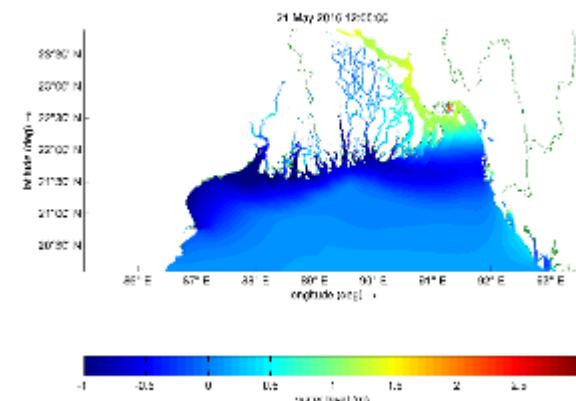
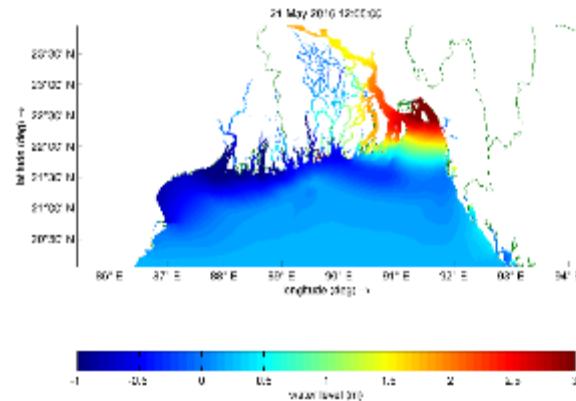
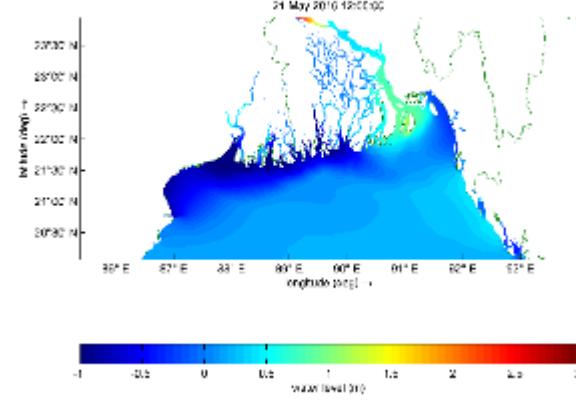
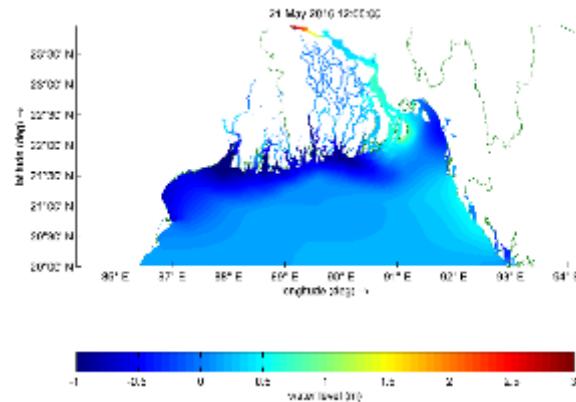
- Simulate this models before any cyclone occur in the Bay of Bengal to know the possible storm surge inundation depth and patterns
- Can be applied for adaptation planning such as building resilient coastal infrastructure or generate scenarios with nature based solution
- Climate attribution studies and loss and damage scenarios
- Possible future inundation considering sea level rise
- Updating of national planning documentation such as Bangladesh Delta Plan 2100, NAP etc.
- Data is freely available and can be downloaded from Oasis Hub for research, academic and any other studies or climate negotiations

Publications on cyclone and storm surges

- [Projected changes of inundation of cyclonic storms in the Ganges–Brahmaputra–Meghna delta of Bangladesh due to SLR by 2100.](#) Journal of Earth System Science, 23, 1409-1429.
- [Towards improved storm surge models in the northern Bay of Bengal.](#) Continental Shelf Research, 135, pp.58-73. doi:10.1016/j.csr.2017.01.014.
- [Mapping of Climate Vulnerability of the Coastal Regions of Bangladesh using Principal Component Analysis.](#) Applied Geography, 102, 47-57.
- [Seasonal modulation of M2 tide in the northern Bay of Bengal.](#) Continental Shelf Research, 137:154-162, doi:10.1016/j.csr.2016.12.008.
- [Tidal intrusion within a mega delta: An unstructured grid modelling approach.](#) Estuarine, Coastal and Shelf Science, 182(5):12-26, doi:10.1016/j.ecss.2016.09.014.
- [Improved bathymetric dataset and tidal model for the northern Bay of Bengal.](#) Marine Geodesy. 39(6), pp. 422-438, doi:10.1080/01490419.2016.1227405.
- [Modelling the increased frequency of extreme sea levels in the Ganges–Brahmaputra–Meghna delta due to sea level rise and other effects of climate change.](#) Environ. Sci.: Processes Impacts, 2015 (17) 1311-1322 , doi:10.1039/C4EM00683F.
- [Field investigation on the performances of the coastal structures during Cyclone SIDR,](#) Natural Hazards Review, ASCE, Vol. 12, pp. 111-116.031 doi:10.1061/(ASCE)NH.1527-6996.0000

Thank you

Water level of Cyclone Roanu using (a) MOHC ensemble 5 and (b) 6



Water level of Cyclone Roanu using (c) WRF (d) JTWC data

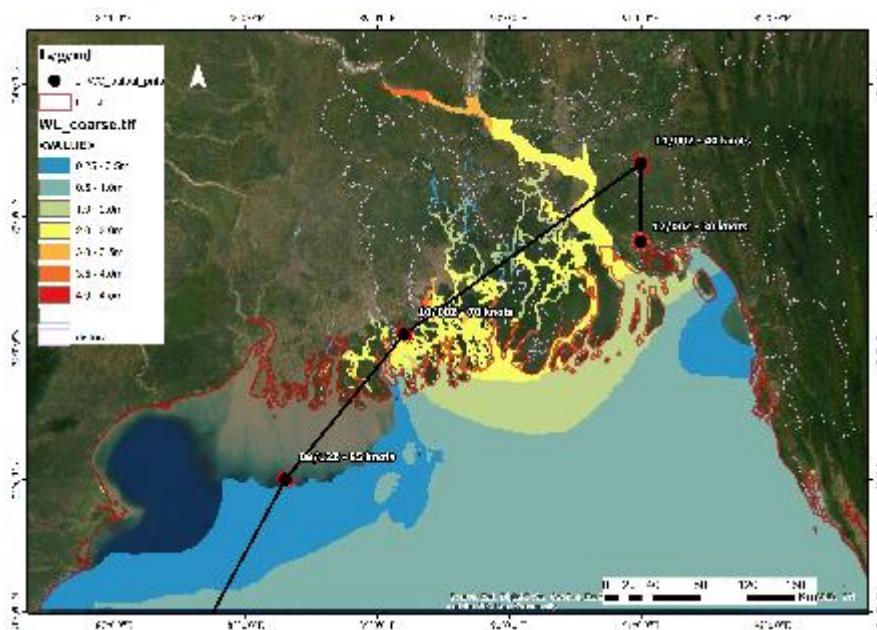
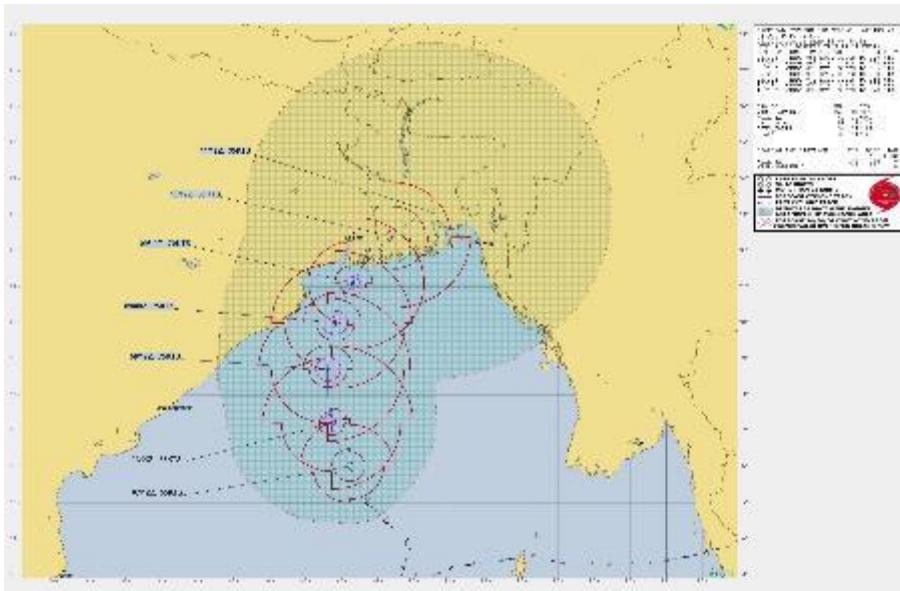
Extra Slides

Publications on floods and climate change

- [Attributing the 2017 Bangladesh floods from meteorological and hydrological perspectives](#). Hydrology and Earth System Sciences, 23, 1409-1429, doi:10.5194/hess-23-1409-2019
- [Attributing the 2017 Bangladesh floods from meteorological and hydrological perspectives](#). Hydrology and Earth System Sciences, 23, 1409-1429, doi:10.5194/hess-23-1409-2019
- [Determining Flash Flood Danger Level at Gauge Stations of the North East Haor Regions of Bangladesh](#). Journal of Hydrological Engineering, 24(4), 05019004.
- [Observed Trends in Climate Extremes over Bangladesh from 1981 to 2010](#). Climate Research , 77(1), 45-61.
- [Future floods in Bangladesh under 1.5°C, 2°C and 4°C global warming scenarios](#). Journal of Hydrological Engineering, 23(12), 04018050.
- [Challenges for flood risk management in flood prone Sirajganj region of Bangladesh](#). Journal of Flood Risk Management, e12450.
- [A global network for operational flood risk reduction](#). Environmental Science & Policy, 84, 149-158.
- [Regional changes of precipitation and temperature over Bangladesh using bias corrected multi-model ensemble projections considering high emission pathways](#). International Journal of Climatology, 38(4), 1634-1648. doi: 10.1002/joc.5284.
- [Assessing High-End Climate Change Impacts on Floods in Major Rivers of Bangladesh Using Multi-Model Simulations](#). Global Science and Technology Journal, 6(2), 1-14.
- [Impact of High-End Climate Change on Floods and Low Flows of the Brahmaputra River](#). Journal of Hydrologic Engineering, 22 (10), doi: 10.1061/%28ASCE%29HE.1943-5584.0001567.
- [Extreme flows and water availability of the Brahmaputra River under 1.5°C and 2°C global warming scenarios, Climatic Change](#), pp 1-17, doi: 10.1007/s10584-017-2073-2.
- [Hydrological response to climate change of the Brahmaputra basin using CMIP5 General Circulation Model ensemble](#). Journal of Water and Climate. doi:10.2166/wcc.2017.076.
- [Assessing extreme rainfall trends over the northeast regions of Bangladesh](#), Theoretical and Applied Climatology, 1-12, doi: 10.1007/s00704-017-2285-4.

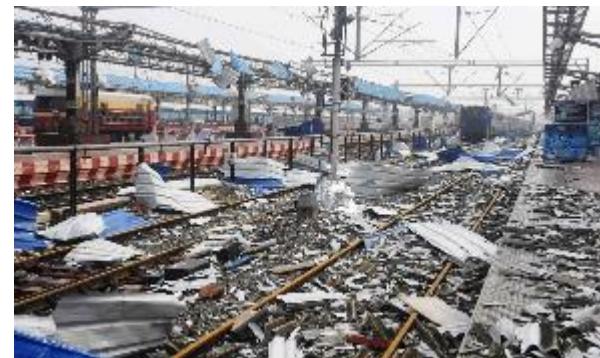
Tropical Cyclone Bulbul (5-11 Nov 2019)

- Formed: November 5, 2019
- Dissipated: November 11, 2019
- Highest winds:
- 3-minute sustained: 140 km/h (85 mph)
- 1-minute sustained: 195 km/h (120 mph)
- Lowest pressure: 976 hPa (mbar); 28.82 inHg
- Fatalities: 41 total
- Damage: \$3.37 billion (2019 USD)
- Areas affected: Thailand, Myanmar, Andaman and Nicobar Islands, Eastern India, Bangladesh



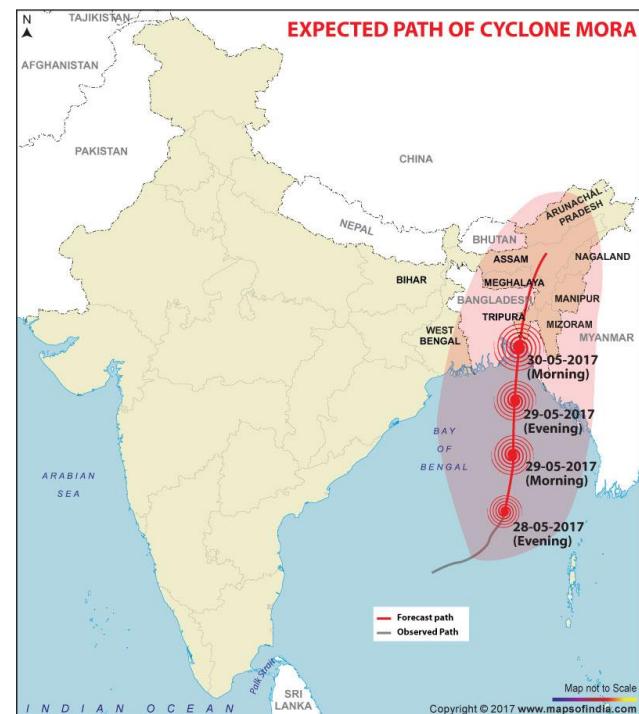
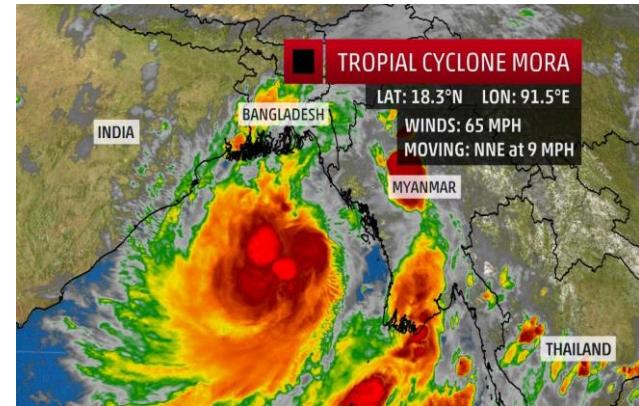
Tropical Cyclone Fani (26 April-5 May 2019)

- Formed: 26 April 2019
- Dissipated: 5 May 2019
- Highest winds:
- 3-minute sustained: 215 km/h (130 mph)
- 1-minute sustained: 250 km/h (155 mph)
- Lowest pressure: 932 hPa (mbar); 27.52 inHg (Estimated at 917 mbar by JTWC)
- Fatalities: 89 total
- Damage: \$8.1 billion (2019 USD)
- Areas affected: Odisha, West Bengal, Andhra Pradesh, East India, Bangladesh, Bhutan, Sri Lanka



Tropical Cyclone Mora (28-30 May 2017)

- Formed: May 28, 2017
- Dissipated: May 31, 2017
- Highest winds:
- 3-minute sustained: 110 km/h (70 mph)
- 1-minute sustained: 150 km/h (90 mph)
- Lowest pressure: 978 hPa (mbar);
28.88 inHg
- Fatalities: 135 total
- Damage: \$297 million (2017 USD)
- Areas affected: Sri Lanka, Andaman and Nicobar Islands, East India, Northeast India, Bangladesh, Myanmar, Bhutan, Tibet



Tropical Cyclone Roanu - 21st May 2016

Formed: 19 May 2016

Dissipated: 23 May 2016

Highest winds:

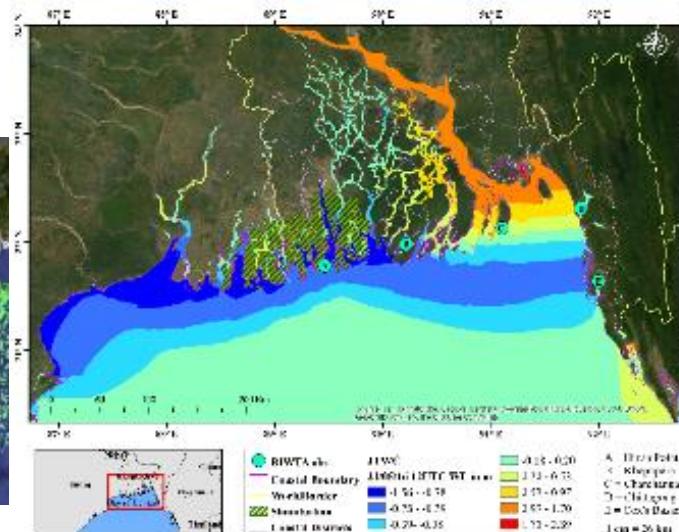
- 3-minute sustained: 85 km/h (50 mph)
- 1-minute sustained: 110 km/h (70 mph)

Lowest pressure: 983 hPa (mbar)

Fatalities: 135 total, 99 missing

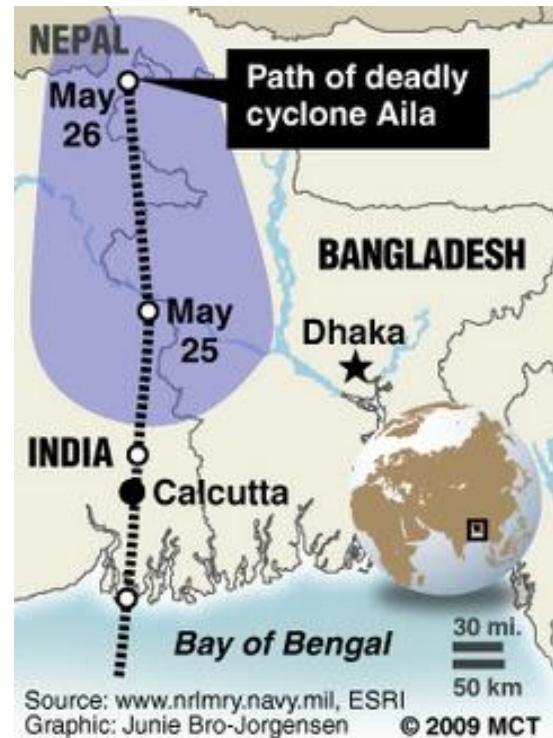
Damage: \$2.03 billion (2016 USD)

Areas affected: Sri Lanka, East coast of India, Bangladesh, Myanmar, Yunnan



Tropical Cyclone Aila (17-27 May 2009)

- Formed: May 25, 2009
- Dissipated: May 27, 2009
- Highest winds:
- 3-minute sustained: 110 km/h (70 mph)
- 1-minute sustained: 120 km/h (75 mph)
- Lowest pressure: 968 hPa (mbar); 28.59 inHg
- Fatalities: 339 total
- Damage: At least \$1 billion (2009 USD)
- Areas affected: India, Bangladesh



Tropical Cyclone Sidr (11-15 Nov 2007)

- Formed: November 11, 2007
- Dissipated: November 16, 2007
- Highest winds:
- 3-minute sustained: 215 km/h (130 mph)
- 1-minute sustained: 260 km/h (160 mph)
- Lowest pressure 944 hPa (mbar); 27.88 inHg (Estimated at 918 mbar by JTWC)
- Fatalities: 3,447–15,000 total
- Damage: \$2.31 billion (2007 USD)
- Areas affected: Andaman Islands, Bangladesh, West Bengal, Northeast India

