

# Cyclone: Analyzing Impacts and Advancing Predictive Capabilities for Coastal Resilience

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## MAJOR CYCLONES SINCE 1970 AND NUMBER OF DEATHS

**1970:** Around 5 lakh

**1985:** 11,069

**1991:** 1.4 lakh

**2007 Sidr:** 4,000

**2009 Aila:** 200

**2019 Bulbul:** 19

## CATEGORIES

Cyclonic Storm  
**62-88 kmph**

Severe Cyclonic Storm  
**89-117 kmph**

Very Severe Cyclonic Storm  
**118-160 kmph**

Extreme Cyclonic Storm  
**161-220 kmph**

Super Cyclonic Storm  
**221 kmph and above**

SOURCE: REGIONAL SPECIALISED  
METEOROLOGICAL CENTRE FOR TROPICAL  
CYCLONES OVER NORTH INDIAN OCEAN



A woman sits in her destroyed house at Basara refugee camp in Sittwe on 16 May 2023, after cyclone Mocha made landfall.  
(Photo by SAI Aung MAIN/AFP).

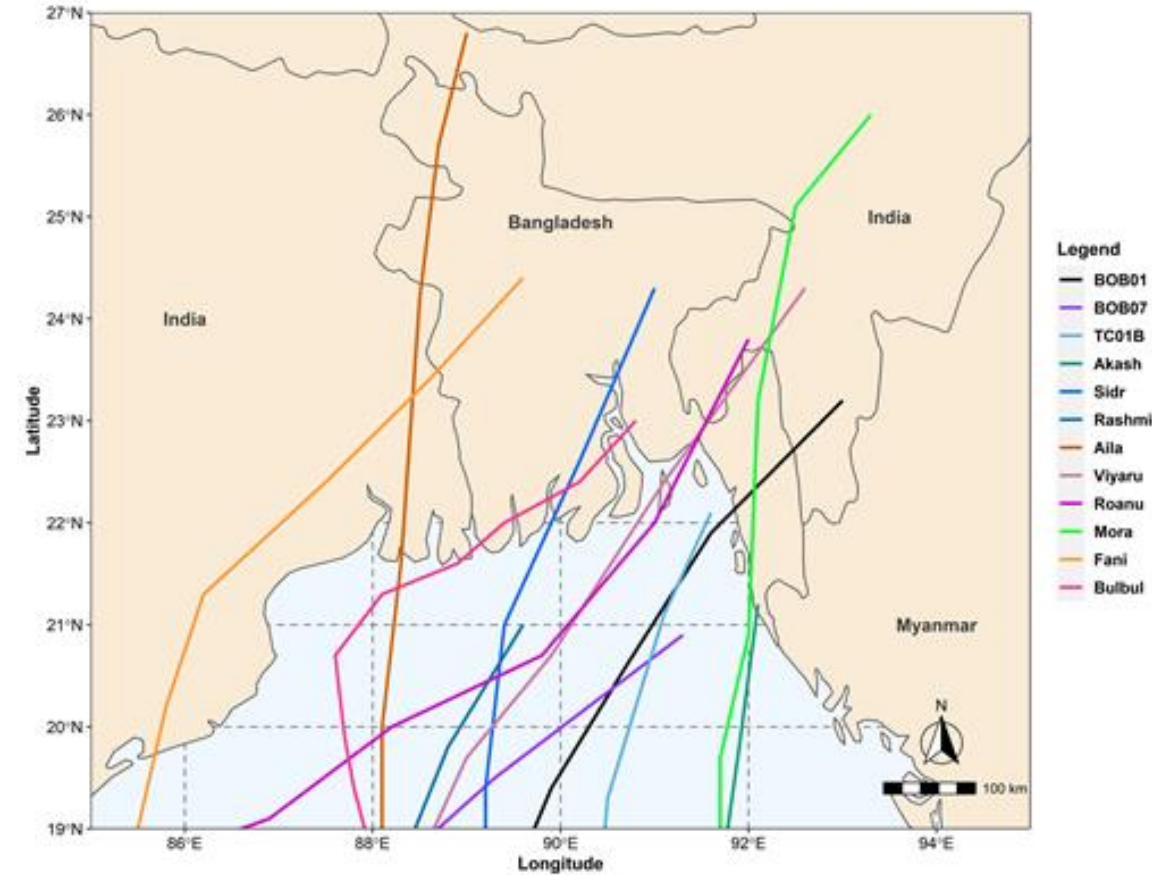
## Introduction

Bangladesh frequently experiences hydro-meteorological hazards, primarily cyclones and cyclone-induced heavy rainfall. These events can result in floods, landslides, and destructive storm surges when cyclones are particularly powerful.

**Accurate TC tracking is crucial for predicting surge heights.**

## Objectives

- Evaluating the Numerical Simulation of Cyclones
- Assessing Resilience Strategies



Selected Cyclones over the Bay of Bengal (1991-2019)  
(Source: JTWC best track archive)



# Data and Method

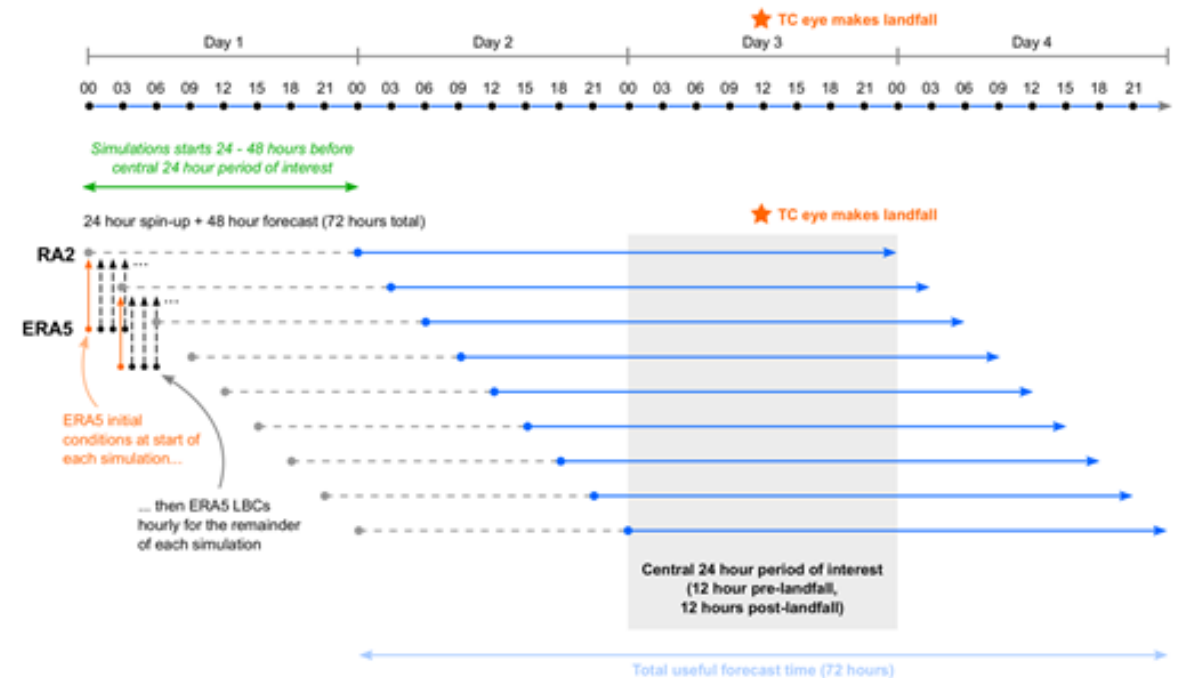
Met Office Unified Model (MOUM) simulated 12 historical cyclones over the BoB using an improved regional atmospheric configuration.

MOUM generated 9 ensemble TC forecasts at two resolution 4.4 km and 1.5km.

The cyclone track from the MOUM was determined for each ensemble by extracting the locations of the minimum pressure at an hourly basis from each of the “Time series ensemble” file (tsens file) for each storm.

The JTWC best track was compared with the MOUM ensembles and IMD at similar time periods and the average track error was found from the cyclone initiation to landfall.

Calculation on the track difference, landfall location and time was made in R using the geosphere package.



The sequence of 9 ensembles from the MOUM showing its boundary data. Each of the blue lines represent the duration of each of the 9 ensemble members (Steptoe et al.,2021).

Steptoe, H., Savage, N. H., Sadri, S., Salmon, K., Maalick, Z., & Webster, S. (2021). Tropical cyclone simulations over Bangladesh at convection permitting 4.4 km & 1.5 km resolution. *Scientific data*, 8(1), 1-12.

# Results

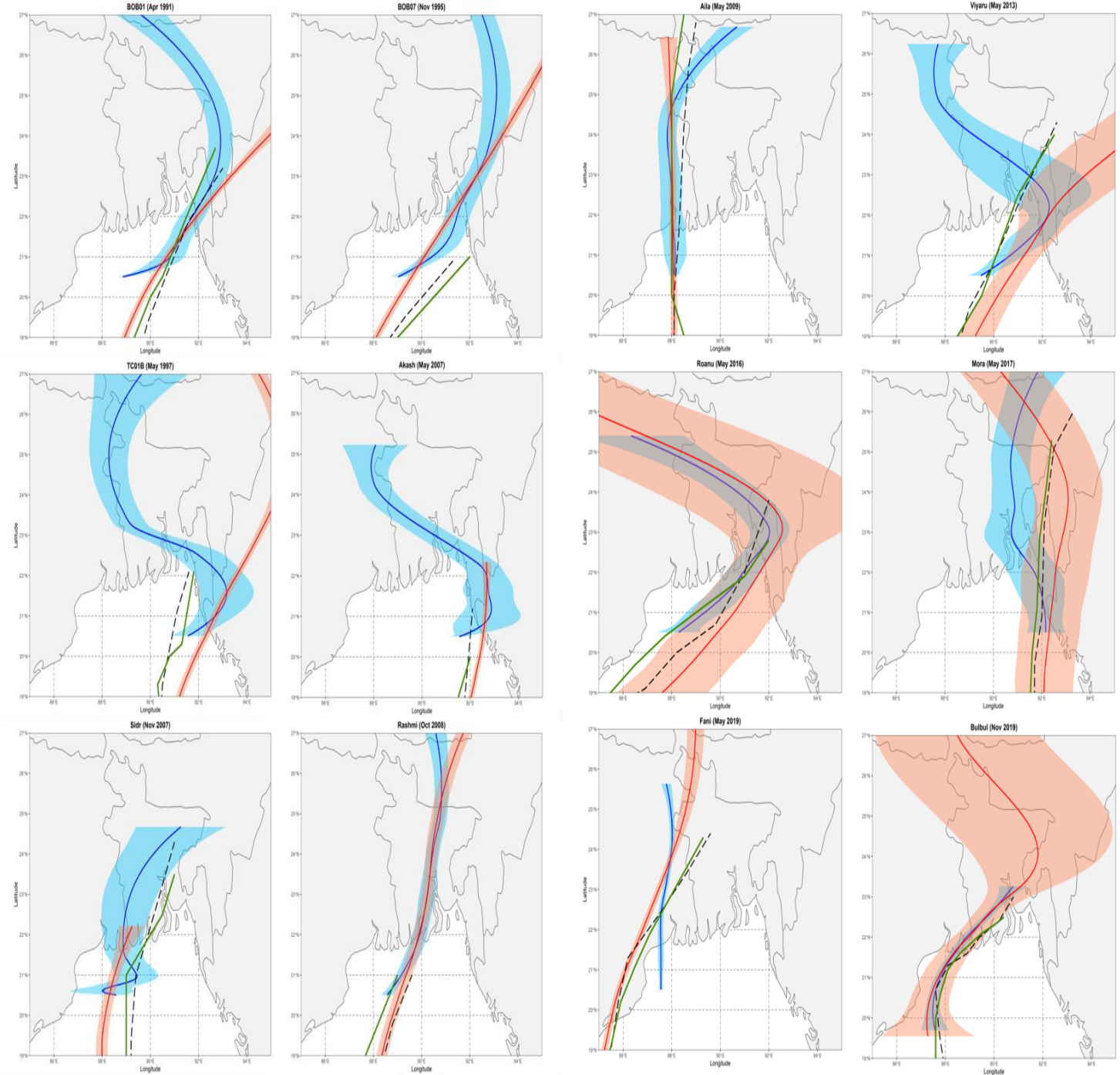
4.4 km MOUM ensembles in red

1.5 km ensembles in blue

The shaded area represents the area of uncertainty of the forecasts.

The best tracks from JTWC in black dashed and RSMC/IMD tracks in solid green

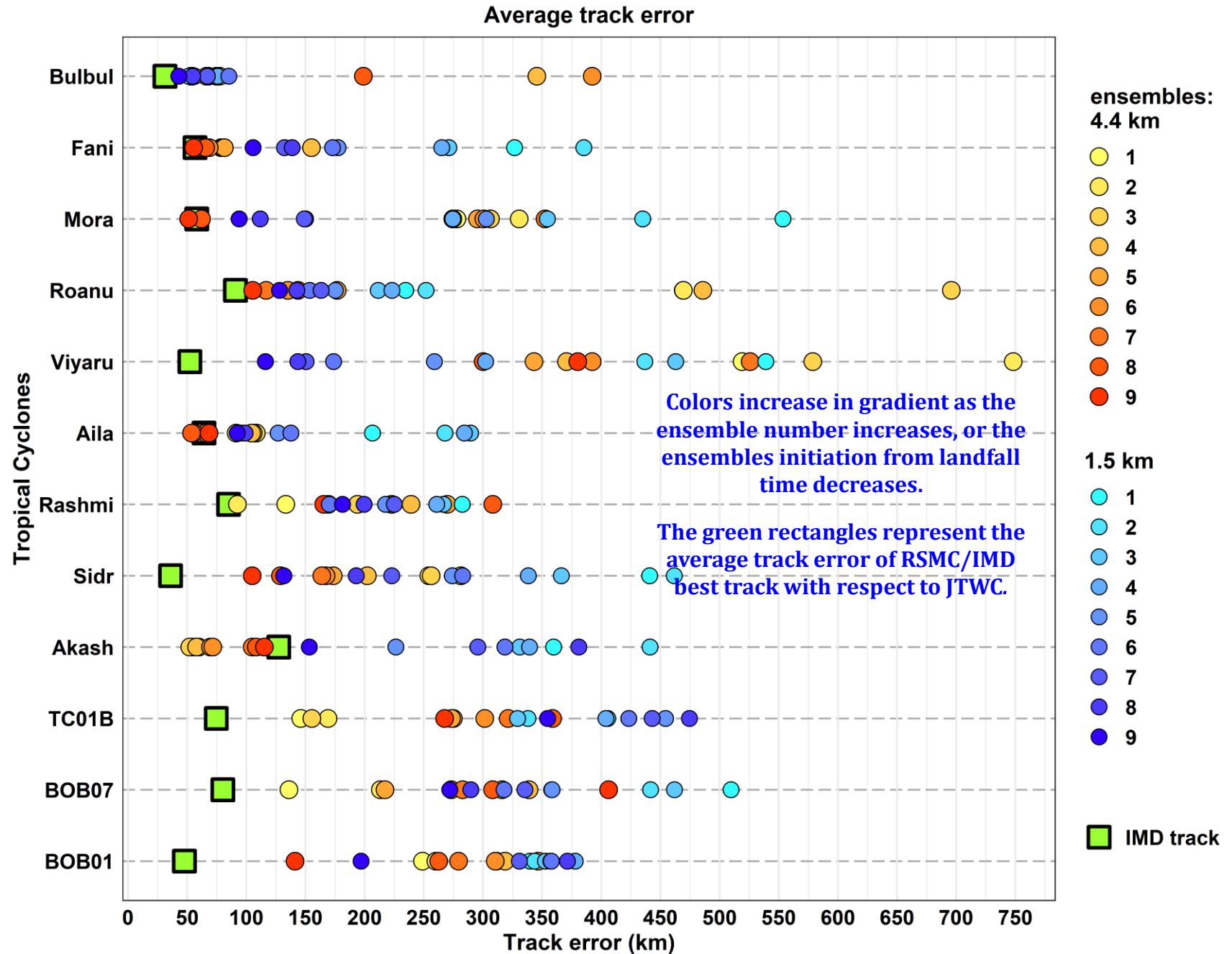
**Ensembles are overestimating the time and are travelling faster.**



# Average Track Error

In general, the IMD tracks seemed to align better with JTWC tracks than the ensembles as observed from its average track error of around 75 km which is around 4 times lower than the error in other MOUM ensembles.

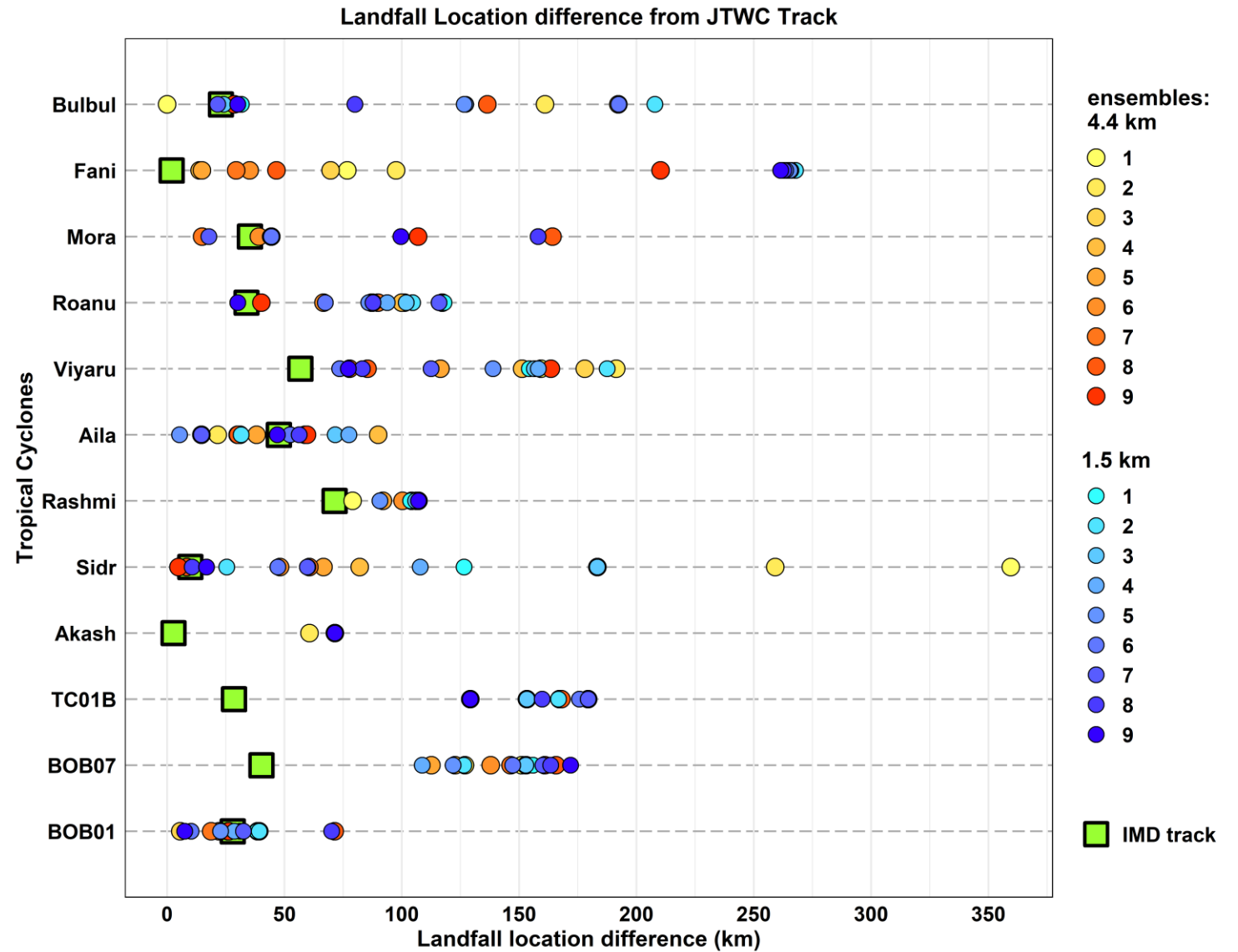
Within the ensembles, ensembles 7,8,9 which were started at 18,15 and 12 hours respectively, had lower average track errors for most cyclones from the cyclone landfall.



# Landfall Location Error

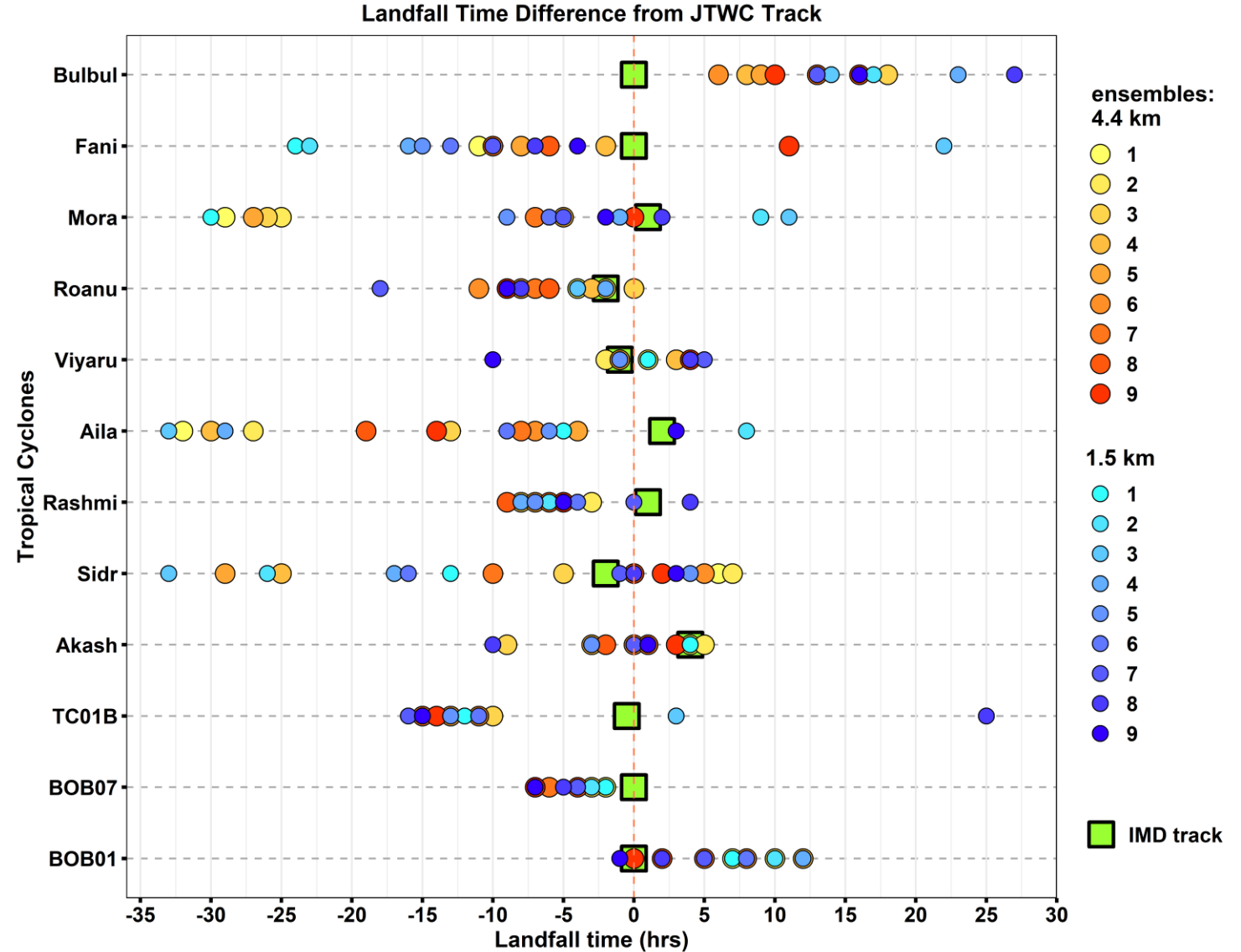
The landfall location of IMD varies from JTWC by an average of around 30 km.

In some storms, the MOUM ensembles predicted the TC landfall better than IMD's best track.



# Landfall Time Error

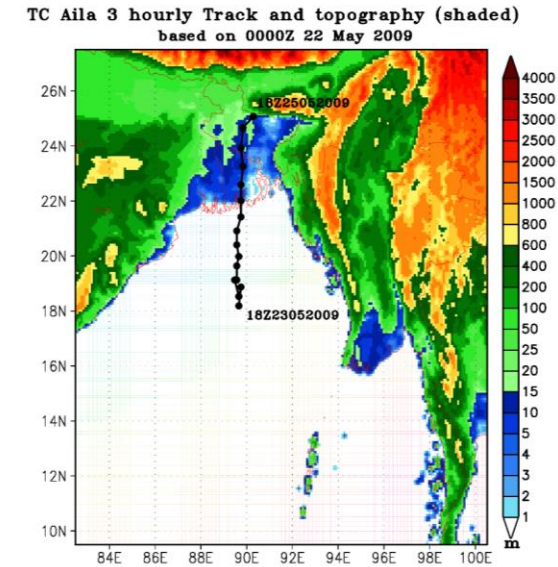
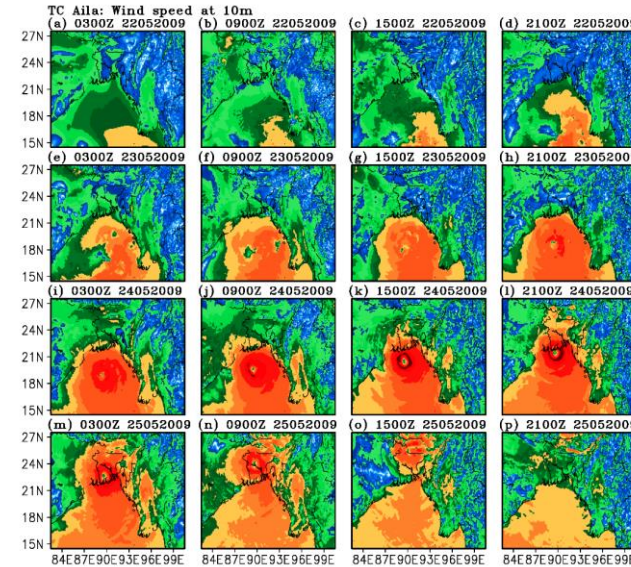
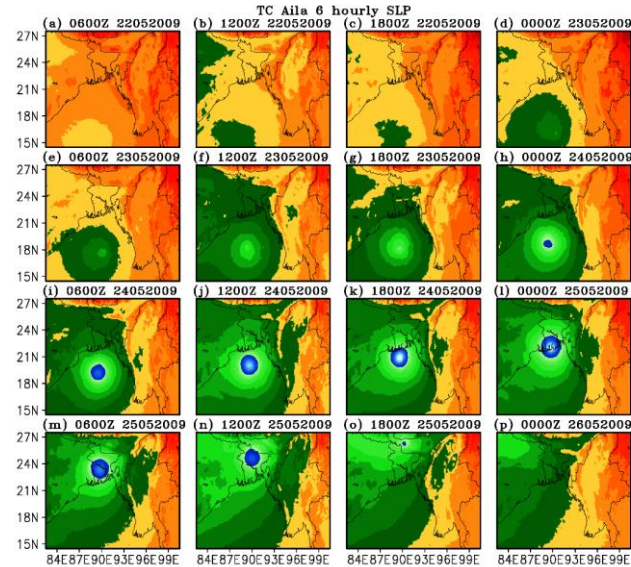
The higher resolution forecasted ensembles are better at simulating the TC location, time and general track in most of the cases.



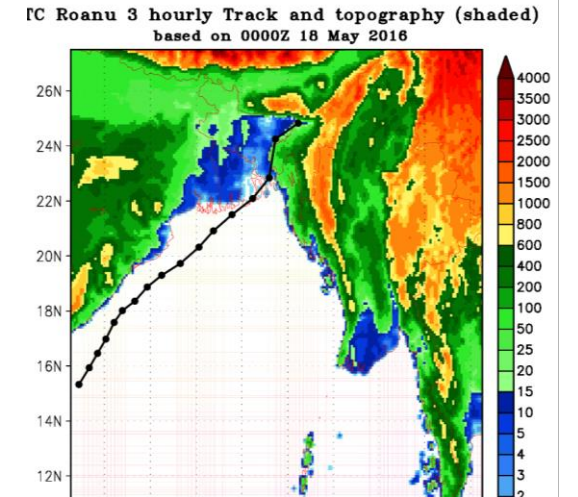
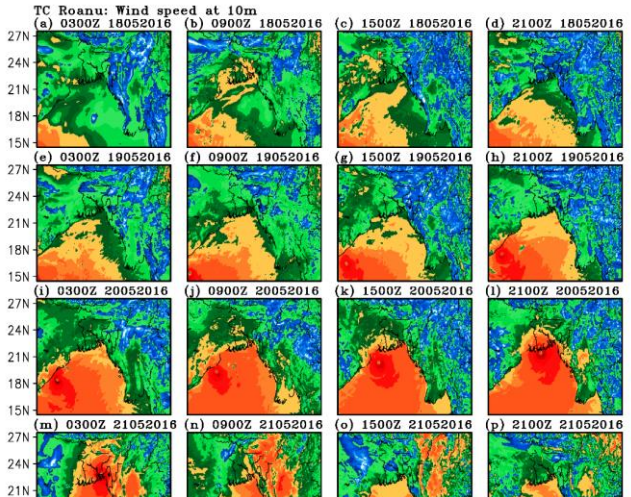
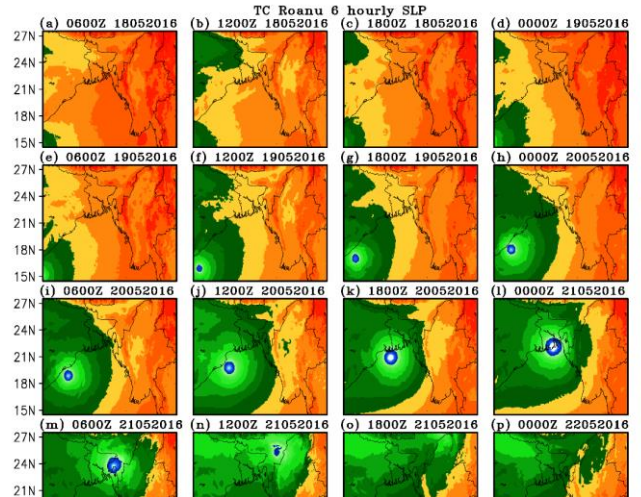


# Weather Research and Forecasting (WRF) Model Simulation

TC Aila, May 2009



TC Roanu, May 2016



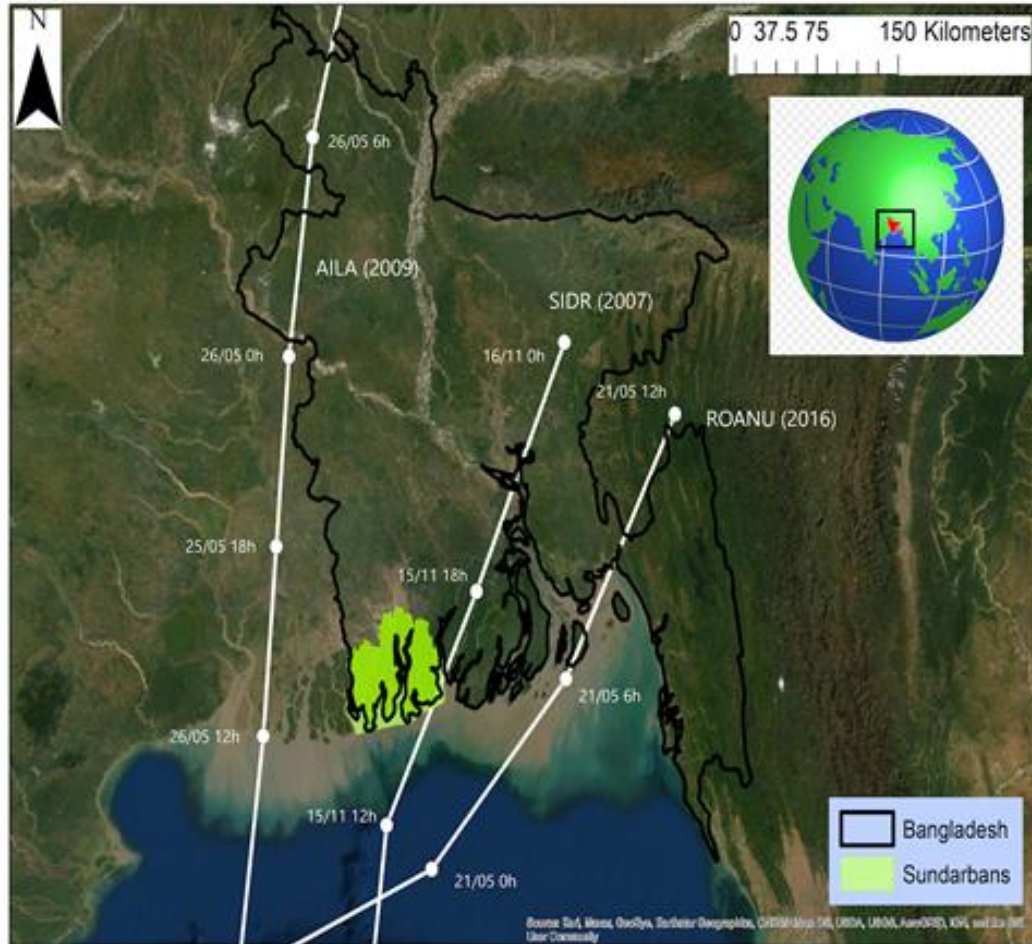
21May 2016	Time		Best-track		WRF		Error
	UTC		Lat.	Long.	Lat.	Long.	Distance
	0300		21.5	90.3	21.9822	89.7862	75.44 km
	0600		21.9	91.0	22.1729	90.6096	50.40 km

## Trigger for Anticipatory Action based on probability

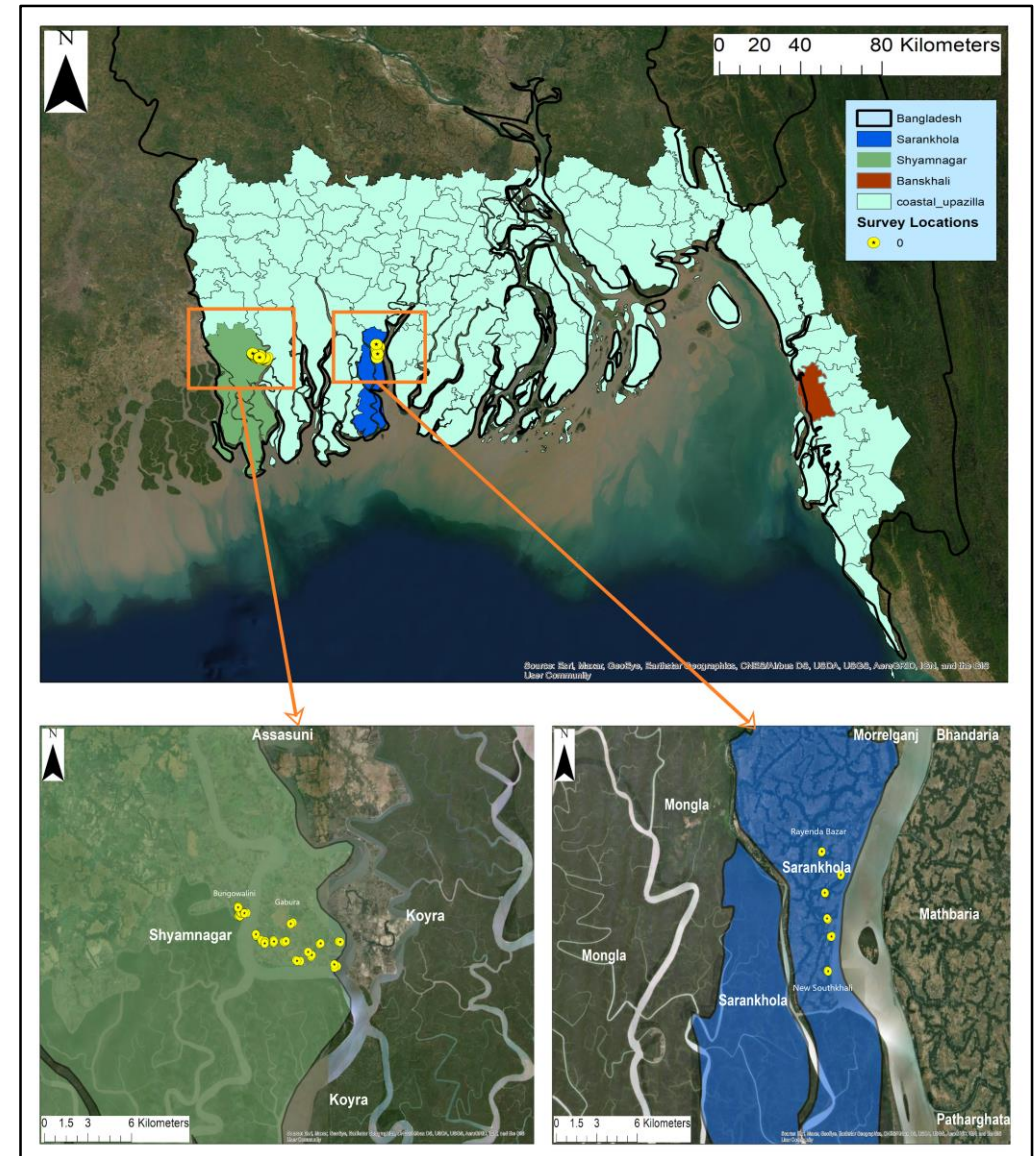
Triggering parameters	SLP (mb)	<998	994	988	980	<945
	Rainfall (mm)	>30	100	170	230	>450
	Wind speed (Km/h)	>70	100	120	150	>210
Probability (%)	<b>90</b>	Trigger				
	<b>80</b>		Trigger			
	<b>70</b>			Trigger		
	<b>60</b>				Trigger	
	<b>50</b>					Trigger
Possible Damage if not Triggered Anticipatory Action	Crop Damage (ha)	<10K	25K	60K	100K	>170K
	House Damage (Count)	<10K	60K	150K	300K	>500K
	Deaths (head count)	<150	500	2K	5K	>10K
	Overall Damage (billion USD)	<0.5	1	1.5	2	>2.5



# Storm Surge-Induced Risk Assessment and Vulnerability Mapping



Tracks of the cyclones and corresponding upazilas where the questionnaire survey took place to collect the field data



# Inundation Data from Model

## Delft3D model

### Bathymetry Data:

General Bathymetric Chart of the Oceans (GEBCO)  
Bangladesh Water Development Board (BWDB)

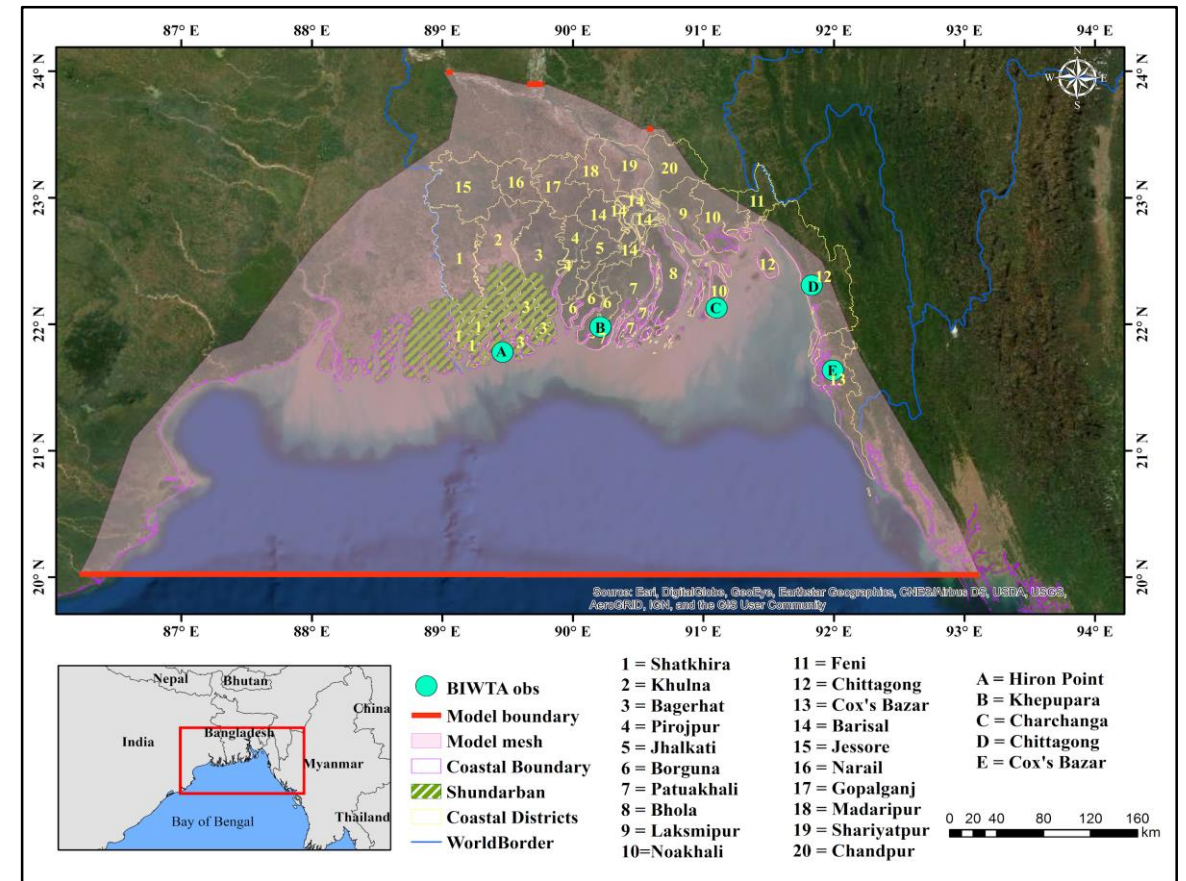
### Polder height info:

Bangladesh Inland Water Transport Authority (BIWTA)

TPXO 7.0 tidal constituents and open boundaries

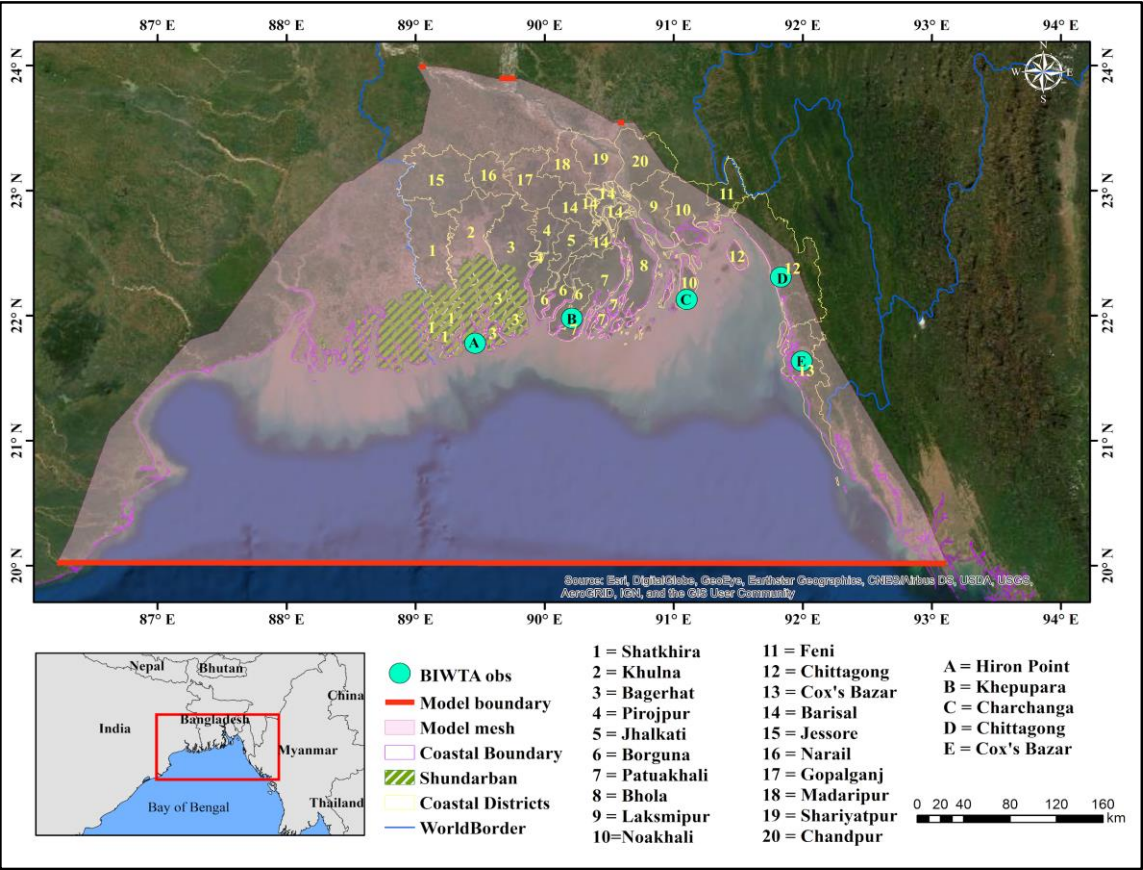
Discharge Data: BWDB.

The model was calibrated for 3 months, considering only the tidal forcing at the southern ocean boundary.

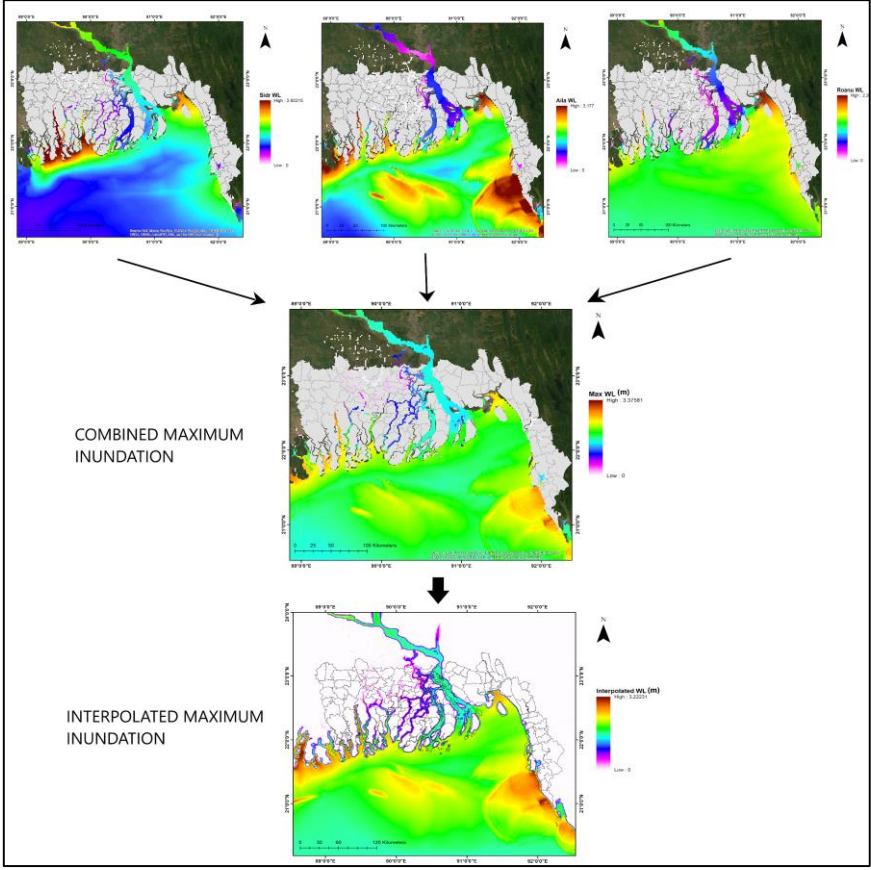




# Inundation Map by using Delft3D Model



Model Domain



Total inundation

Maximum inundation information for cyclone Sidr, Aila, and Roanu have been collected from the storm surge model.

It has been found that a total of 6.7% of the coastal area was inundated with 0 to 3.37m of flooding generated by these three cyclones.

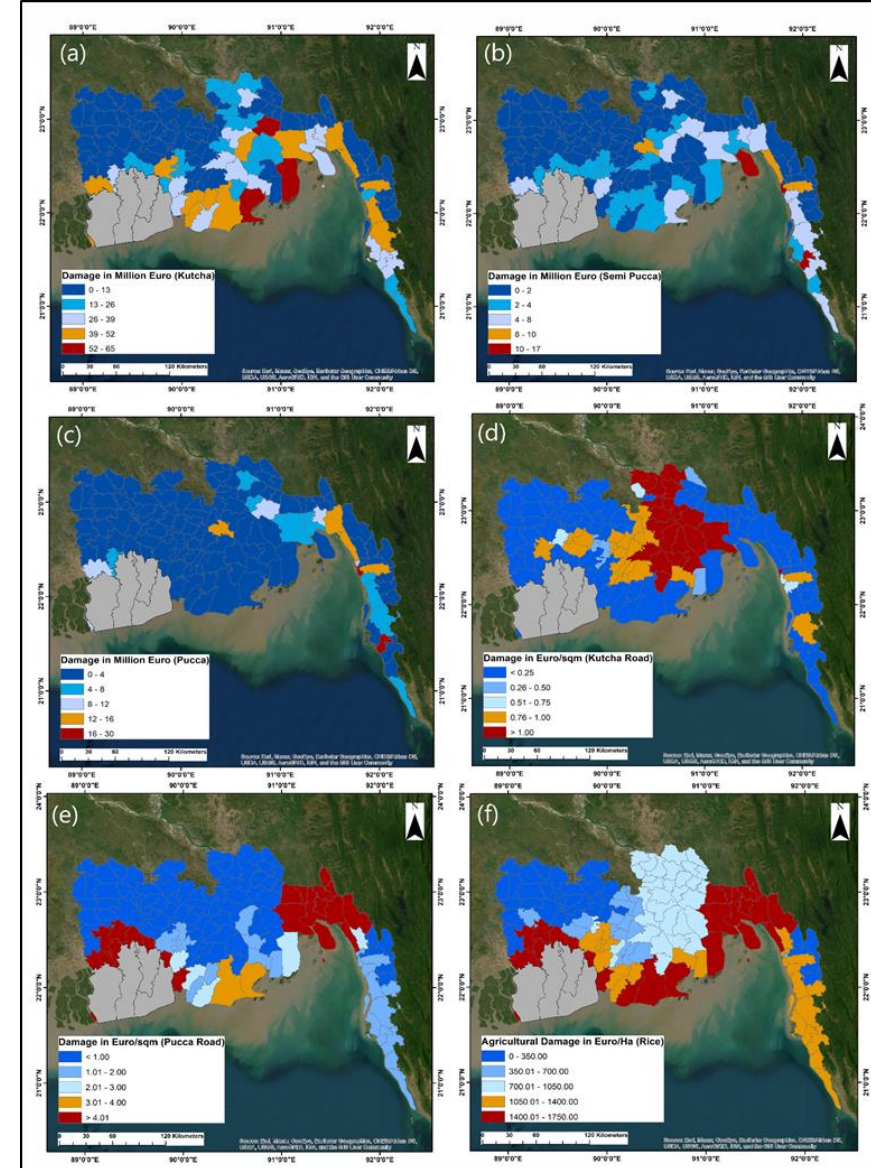


# Vulnerability Maps of the coastal areas

From the interpolated extent of maximum water level and using the depth-damage functions generated from the curves, upazila-wise damage values for each damage category, i.e., house, roads and agriculture, have been calculated and shown spatially in Figure (a-f). It has been found that maximum damage up to 65 Million euros can be experienced for kutchha houses in some upazilas of Barisal and Patuakhali with a surge height of a maximum of 3.22 meters.



Typical building and road categories in the study area - (a) Kutchha house (b) Semi Pucca house (c) Pucca house (d) Mud road (e) Single brick road (f) Double brick road.



Damage vulnerability mapping from depth-damage function for (a) Kutchha house, (b) Semi pucca house, (c) Pucca house, (d) Kutchha road, (e) Pucca road, and (f) Agricultural production (rice).

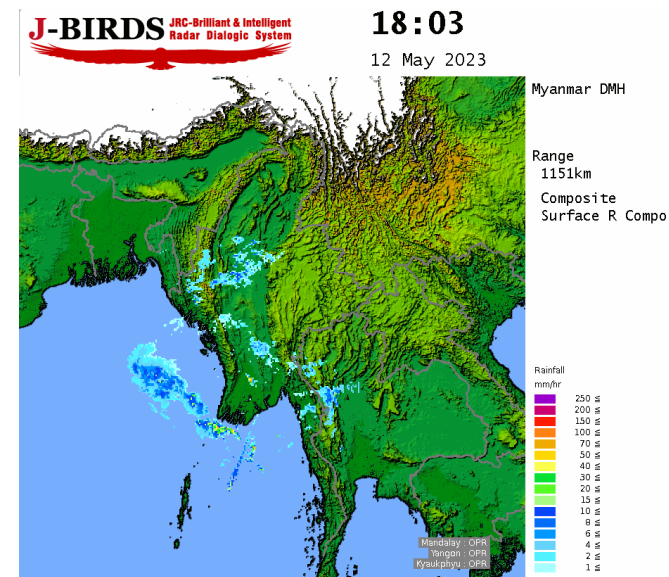
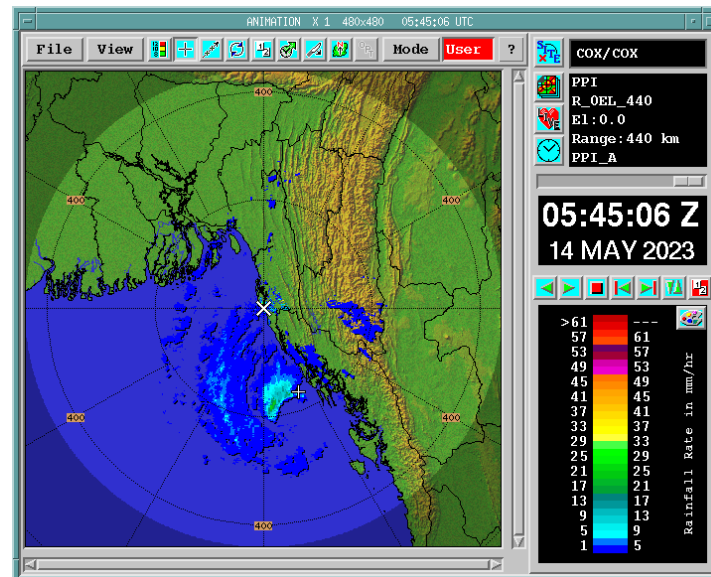


## Tropical Cyclone “Mocha” (pronounced Mokha)

- Mocha may make landfall at coasts of Cox’s Bazar and Myanmar Sunday afternoon
- People in coastal areas worried over damaged embankments
- Fear of crop damage, landslides grows
- Rohingya camps are at risk of disaster



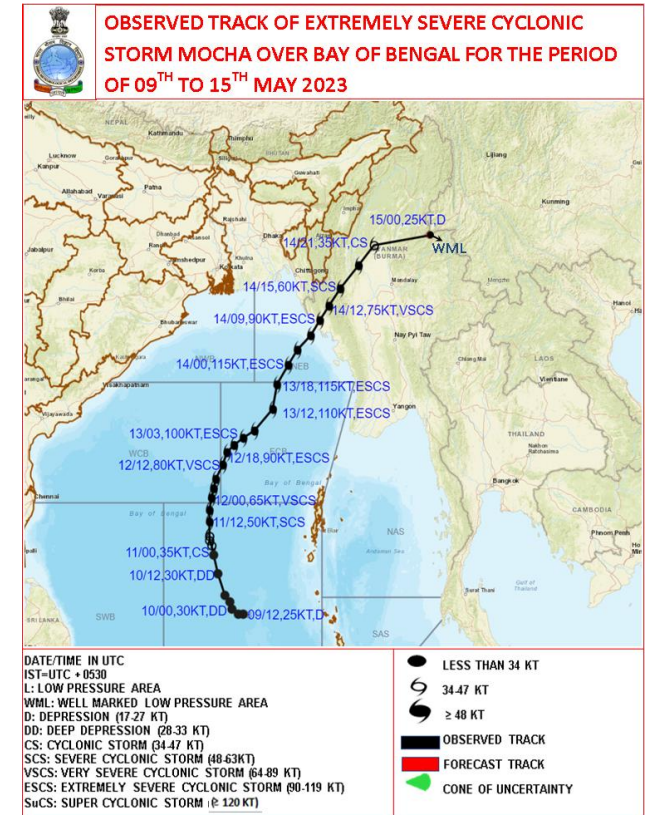
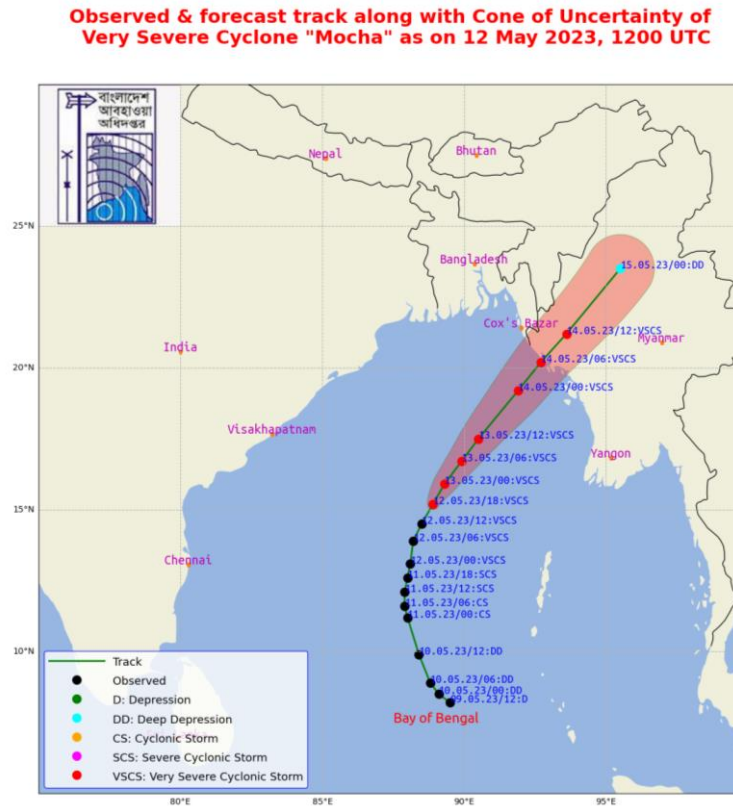
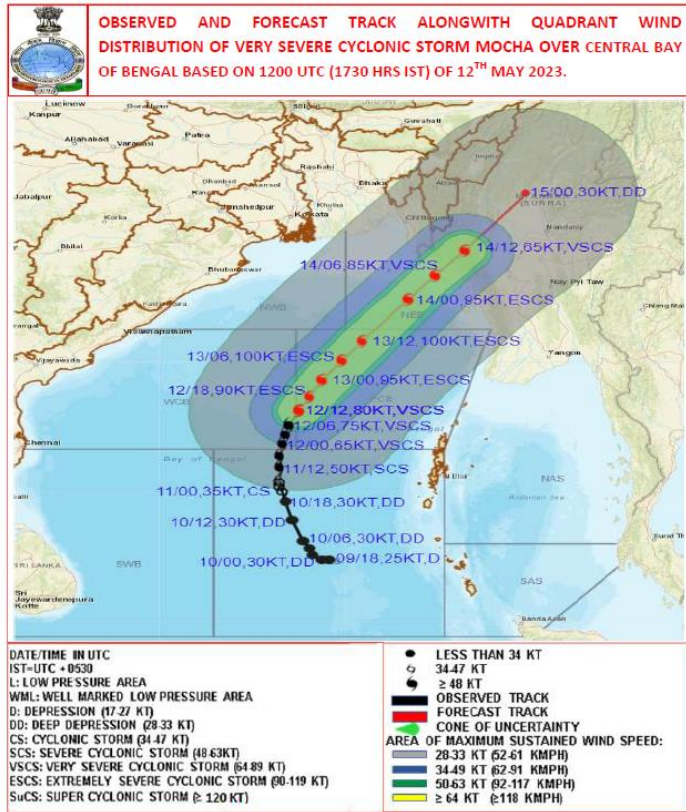
# Radar information during Tropical Cyclone "Mocha"



Source: BAF Met, BMD, MMH

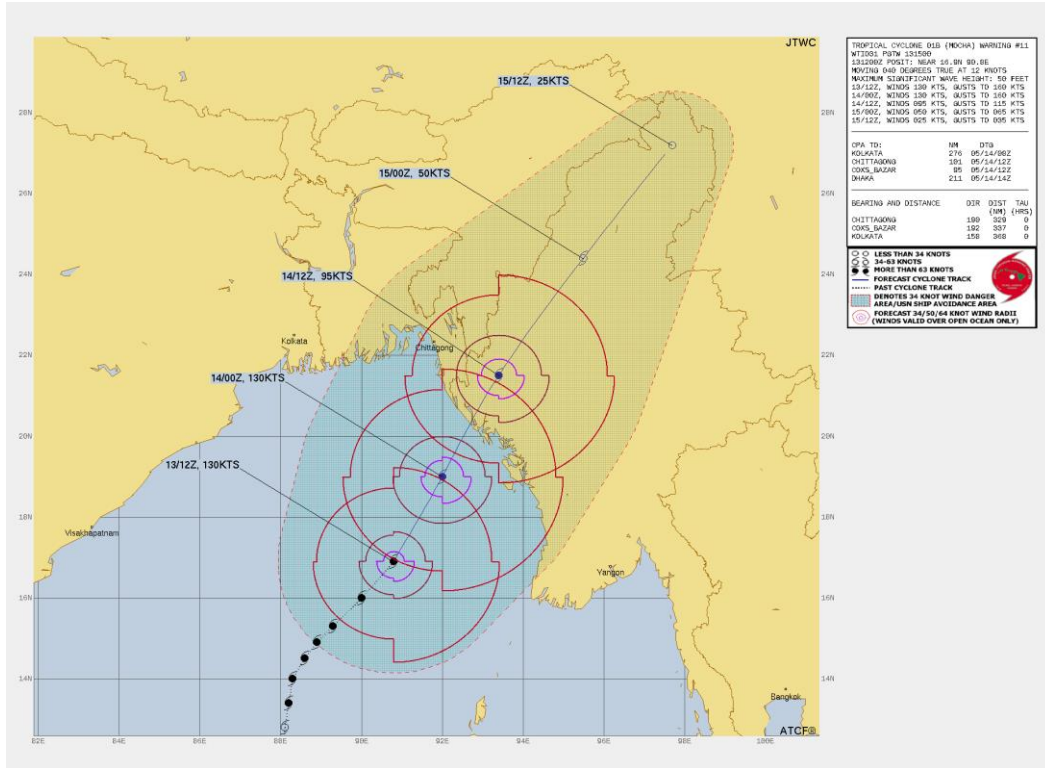


# Tropical Cyclone "Mocha" (pronounced Mokha)



Source: IMD, BMD

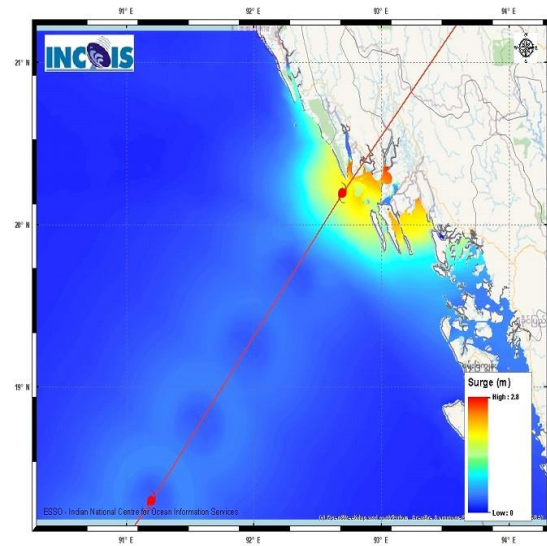
# Tropical Cyclone “Mocha” Storm Surge Guidance



## STORM SURGE GUIDANCE BASED ON 06UTC OF 13<sup>TH</sup> MAY, 2023

### STORM SURGE GUIDANCE (GRAPHICS ATTACHED) FOR NORTH MYANMAR AND ADJOINING SOUTHEAST BANGLADESH COASTS

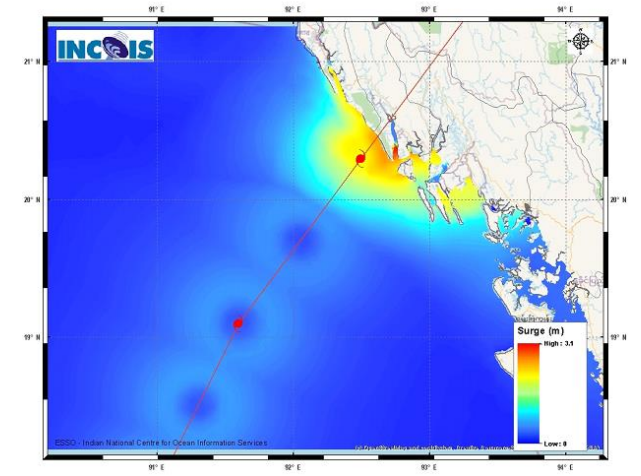
Storm surge with height of about 2.5-3.0 m above the astronomical tide is likely to inundate low lying areas of north Myanmar and adjoining southeast Bangladesh coasts during the time of landfall.



## STORM SURGE GUIDANCE BASED ON 00UTC OF 14<sup>TH</sup> MAY, 2023

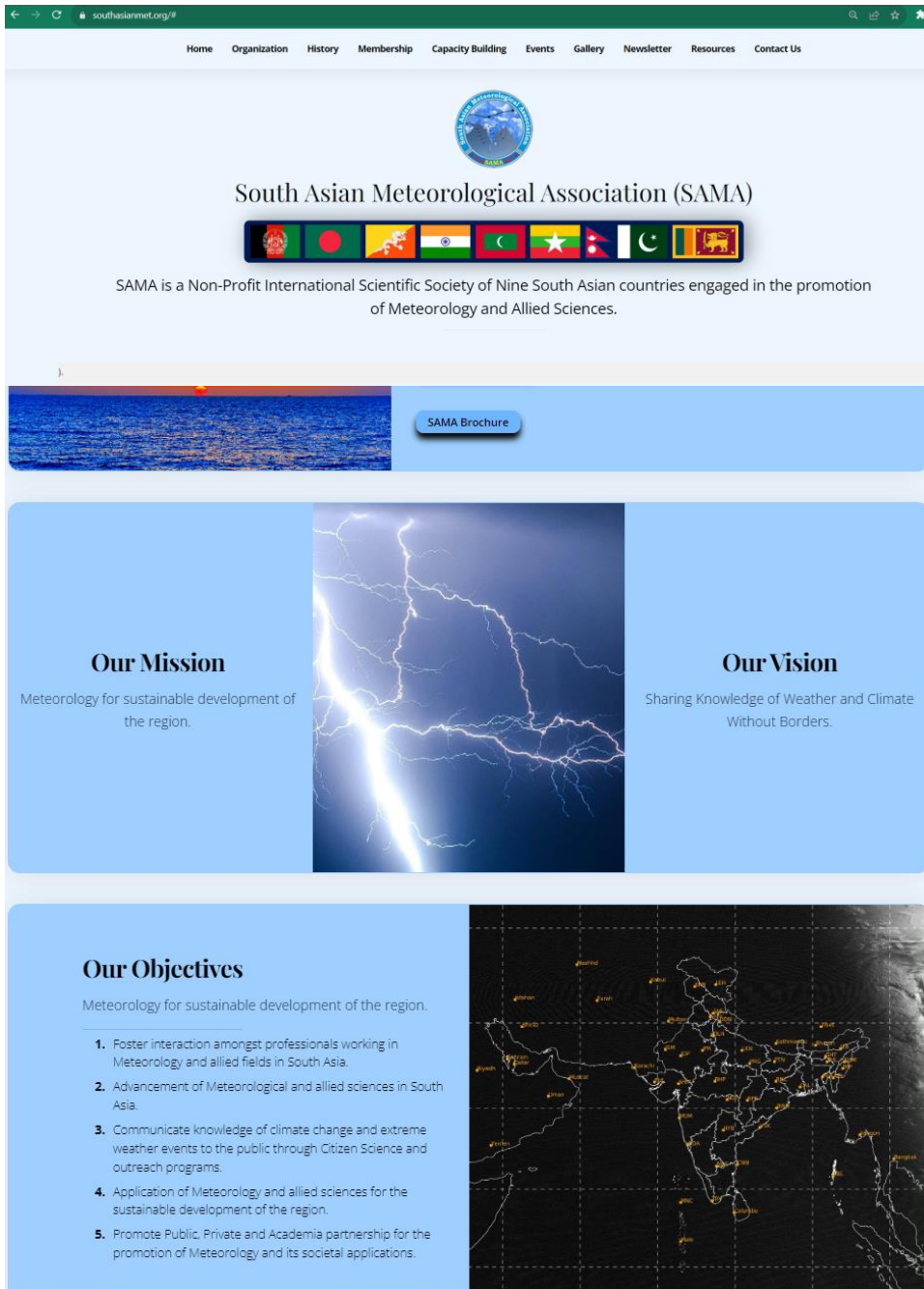
### STORM SURGE GUIDANCE (GRAPHICS ATTACHED) FOR NORTH MYANMAR AND ADJOINING SOUTHEAST BANGLADESH COASTS

Storm surge with height of about 3-3.5 m above the astronomical tide is likely to inundate low lying areas of north Myanmar and adjoining southeast Bangladesh coasts during the time of landfall.



Source: JTWC, INCOIS





## **Tropical Cyclone "Mocha" - Important Alert**

According to the Regional Specialized Meteorological Center (RSMC), Tropical Cyclone "Mocha" is expected to make landfall with a wind speed of 150 km/h or more in **Cox's Bazar, Bangladesh, and Kyaukpyu, Myanmar.**

The cyclone may cause extensive damage in areas like coast and islands. It is likely to bring heavy rainfall, intense winds, and storm surges reaching up to two to three meters higher than normal. Particularly, Saint Martin's Island, Ukhia's Rohingya refugee camp and Kyaukpyu are at high risk.

### **Alert for Vulnerable Areas**

- ➔ **May 12, 2023, Friday:** Extreme caution for fishermen, boat and ship movements, coastal industries, and tourism activities!
- ➔ **May 13, 2023, Saturday:** High caution for fishermen, boat and ship movements, coastal industries, and tourism activities due to heavy rainfall and strong winds!
- ➔ **May 14, 2023, Sunday:** High caution for fishermen, boat and ship movements, coastal industries, and tourism activities due to heavy rainfall, strong winds, and potential landslides!

### **Potential Damages**

- 🚫 Exercise caution and stay away from vulnerable structures!
- 🚫 Avoid crossing weak and flooded roads, high risk of landslides in affected areas!
- 🌳 Beware of falling trees and tree branches!
- 🌾 Extensive damage to crops and gardens is possible!

### **Safety Measures during Cyclone**

- 🌾 **Protect Your Crops:** Harvest mature fruits and crops promptly!
- 🌱 **Shelter and Safeguard:** Provide stakes and covers for vegetable nurseries and fruit gardens!
- ⚠️ **Chemical Precautions:** Avoid using fertilizers and pesticides during thunderstorms, hurricanes, and heavy rainfall!
- 🐄 **Provide Shelter for Livestock:** Keep them in secure sheds during the cyclone!

Remember, in the face of such impending danger, vigilance, preparedness, and safety are of utmost importance.







## **Conclusion**

These insights emphasize the need for collaborative initiatives among meteorological agencies, researchers, and coastal communities to further improve cyclone prediction and preparedness, ultimately strengthening coastal resilience.

Future efforts should encompass a broader scope, examining a more extensive array of cyclones spanning multiple years, to comprehensively assess and compare the best track data.

## **Acknowledgement**

We extend our gratitude to the following organizations for their valuable contributions: BMD, BAF Met, IMD, INCOIS, JTWC, MMH, RSMC, WMO. Their collaborative efforts are instrumental in advancing our understanding and predictive capabilities for cyclone impacts and coastal resilience.

# International Conference on Climate Change 2023

University of Dhaka, Dhaka, Bangladesh

8<sup>th</sup> December 2023

Abstract Submission Begins: October 5, 2023

<https://met.du.ac.bd/conference/>

met.du.ac.bd/conference/

Dept. of Meteorology

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International Conference on Climate Change 2023 will be organized on 08th December 2023 by the Department of Meteorology under the Faculty of Earth and Environmental Sciences, University of Dhaka, Bangladesh. This Conference aims to bring together all leading academic scientists, researchers, and research scholars to exchange and share their experiences and research results on all aspects related to Climate Change. It also provides a premier interdisciplinary platform for researchers, practitioners, and educators to present and discuss the most recent innovations, trends, and concerns as well as practical challenges encountered and solutions adopted to face the challenges of Climate Change.

The mission of this conference is to apprehend the **Earth's weather and climate; convey the perception to scientists and specialists and provide them with the knowledge to serve the community. It is a significant drive to increase collaboration both at the national and international levels.** Numerous natural disasters such as lightning, thunderstorm, flood, cyclone, storm surges, cold/heat waves, droughts, etc. have always been with us, but nowadays they have become more destructive due to the continuing climate change. The participants of this conference will have a transformative professional development experience by bringing together the world's scientific experts to catalyze and advance scientific knowledge about Advancements.

This event has adopted a hybrid mode so that you can participate physically or virtually to present your research work/talk. We believe that this dual platform will help us become closer to each other by sharing our knowledge and experiences.

# Thank You

NOAMI Website: <https://noami.org.bd/>