A high-resolution robust operational flood forecasting system over the Bengal Delta: The Band-SOS project

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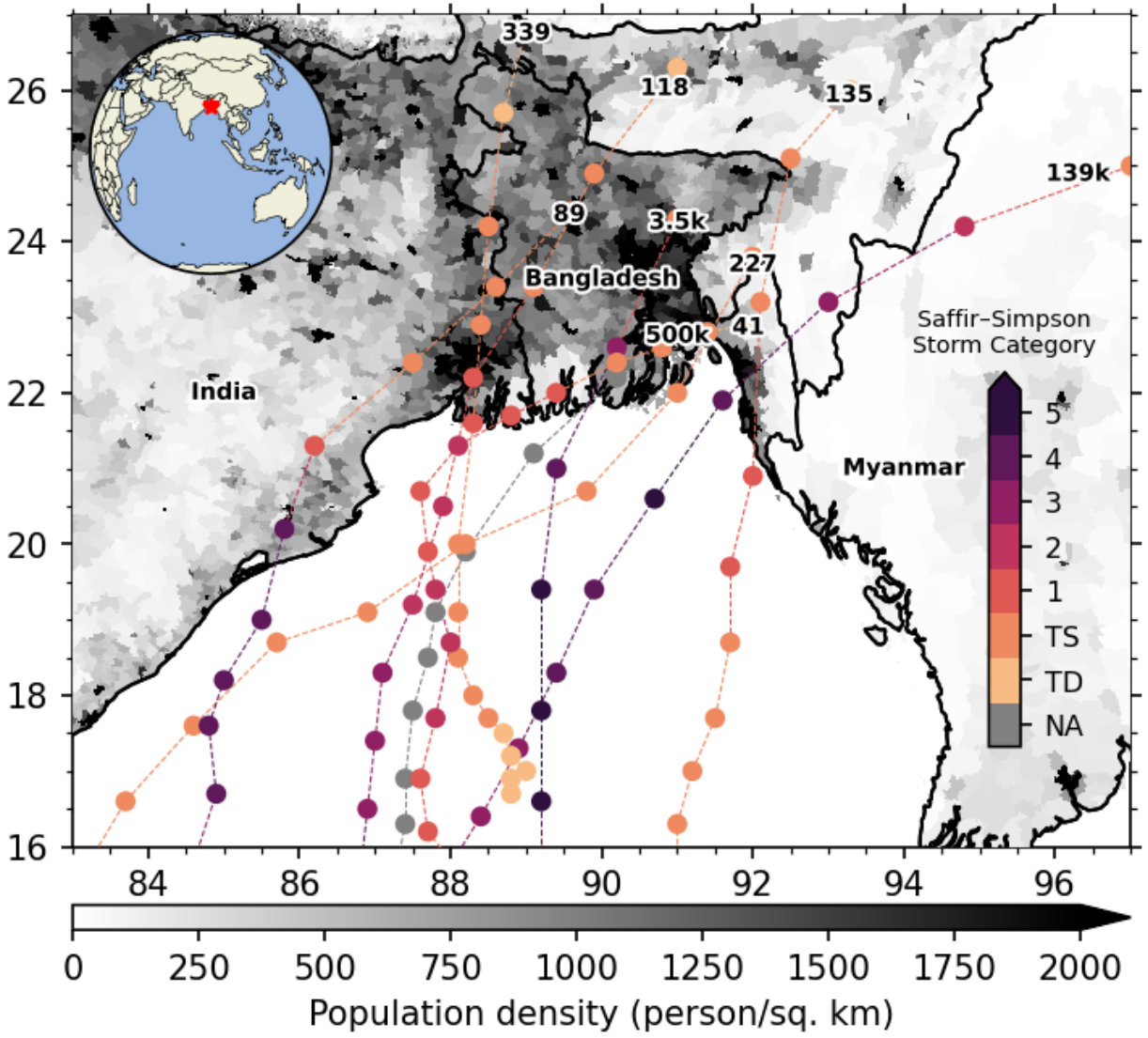
Cyclone exposure in the Bengal Delta

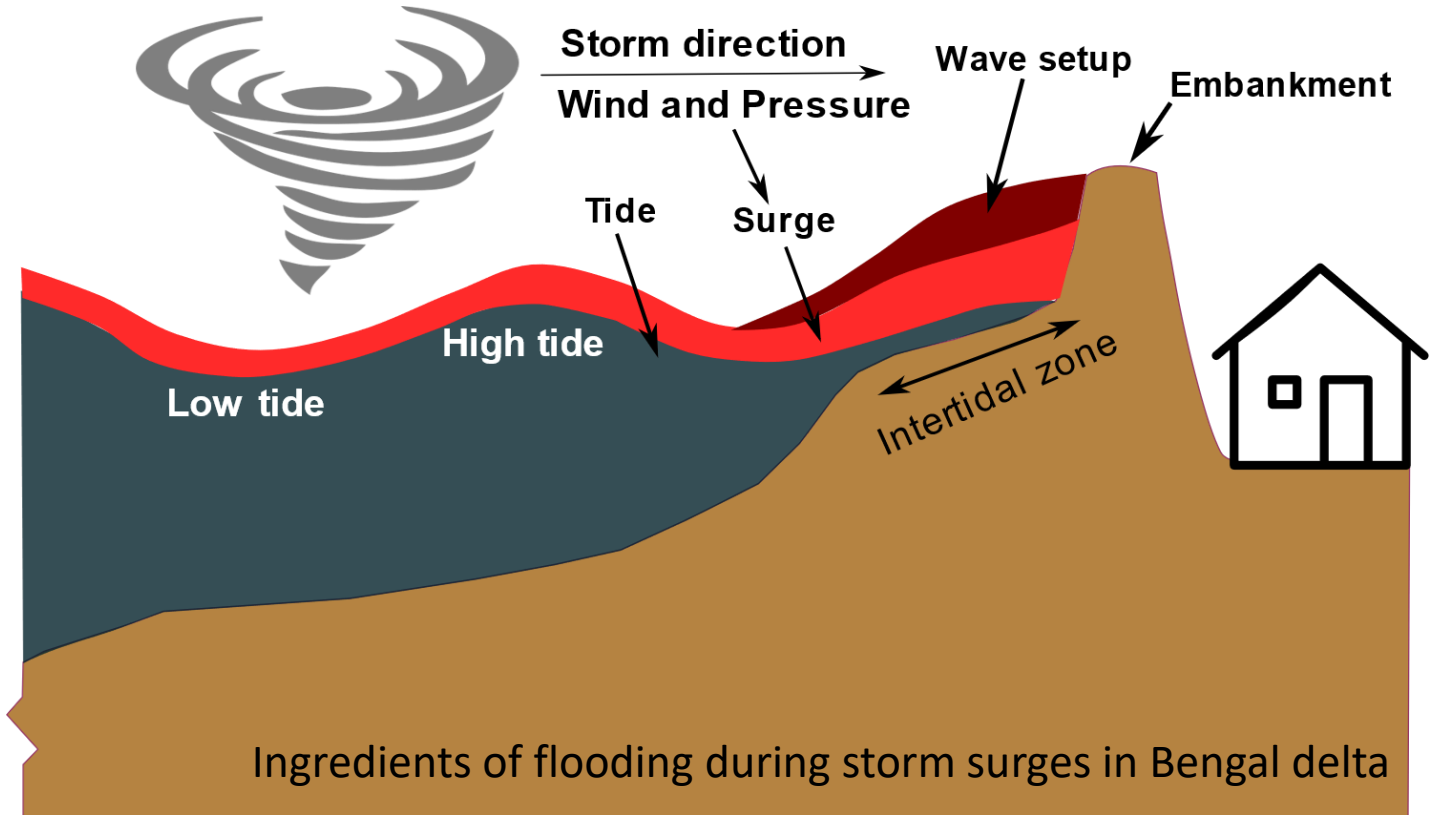
Ganges-Brahmaputra (Bengal) delta is –

- densely populated (150M+ habitants)
- Very low-lying coastal zone (<3m)
- highly vulnerable to
  - Fluvial – riverine flood
  - Coastal – high tide and storm surge flood

- More than **half a million casualty** since 1970 – deadliest place for coastal flooding hazard.
- Ever rising economic damage.



Ingredients of cyclonic inundations in the Bengal Delta



Wave ⟷ Surge ↕ Tide = **Total water level** if >Embankment/Topography ↕ Inland flooding

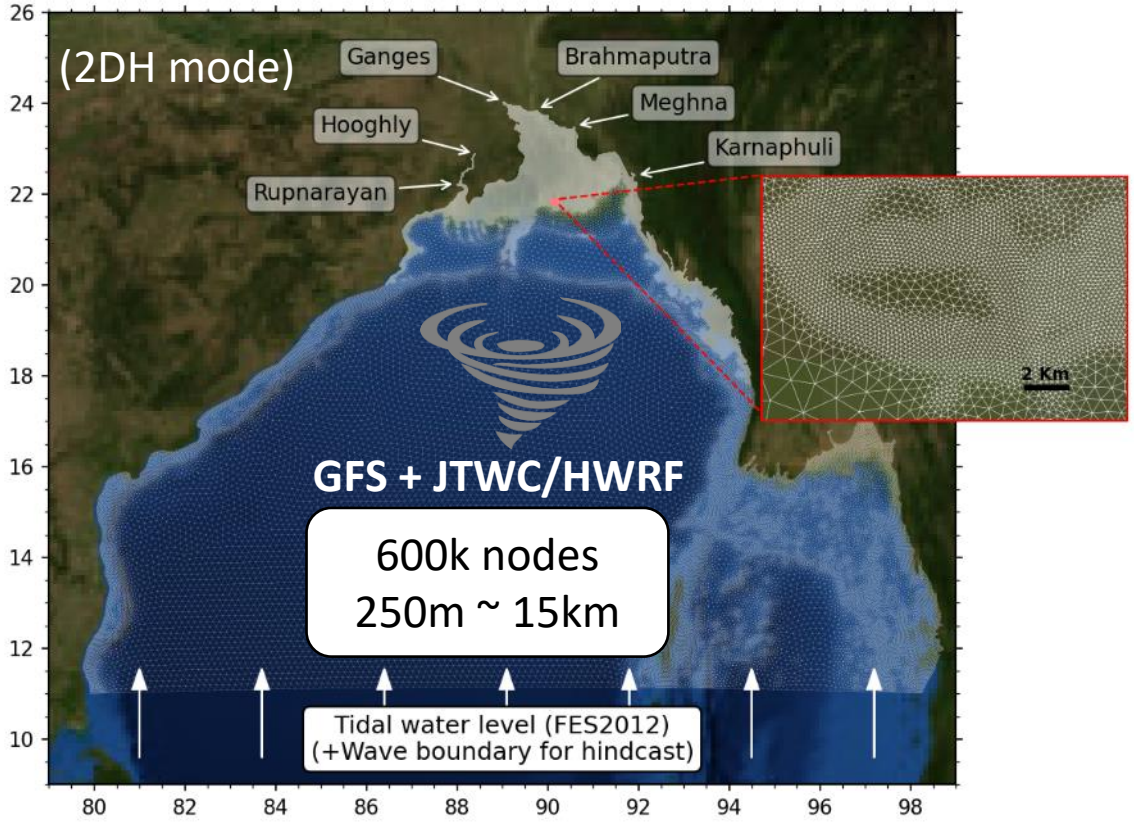
It is the practice in the Bengal delta region –

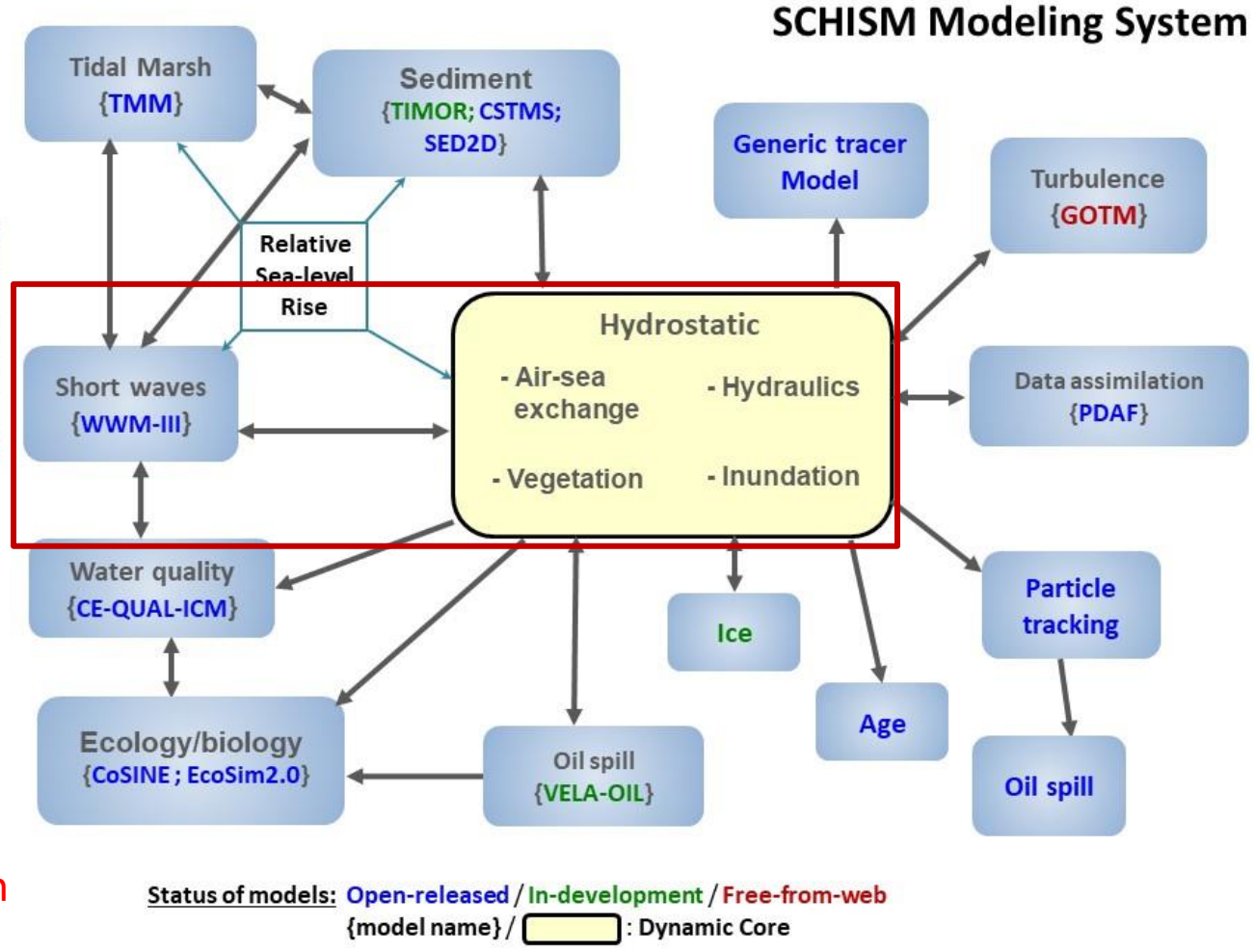
- to model without inland flooding (e.g. Bangladesh Meteorological Department)
- to de-couple tide from surge (separate tide and surge simulations)
- to model without waves (e.g. INCOIS)

Coupled tide-surge-wave modelling is essential, yet a viable and efficient real-time-capable system was missing

Seamless cross-scale coastal modelling platform

Coupled Tide-Surge-Wave model - SCHISM-WWM



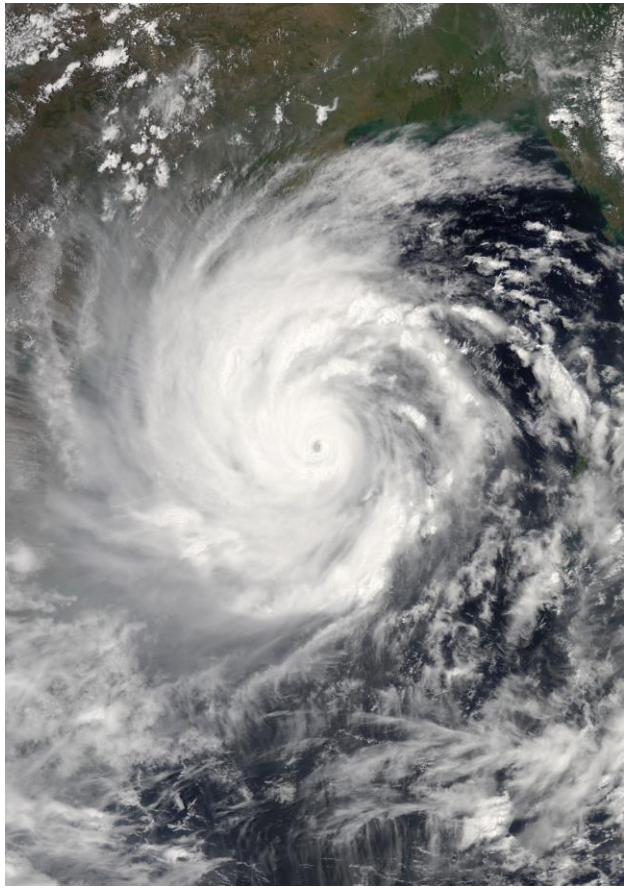


- Based on custom bathymetry of Krien et al 2016. and Khan et al. 2019 with intertidal bathymetry and Embankments.
- Best performing published tide model over Bengal. ~2-5 times improvement from Global model (PhD Khan 2021).
- Merged GFS and analytic wind/pressure fields to ensure correct representation of the cyclonic forcings.

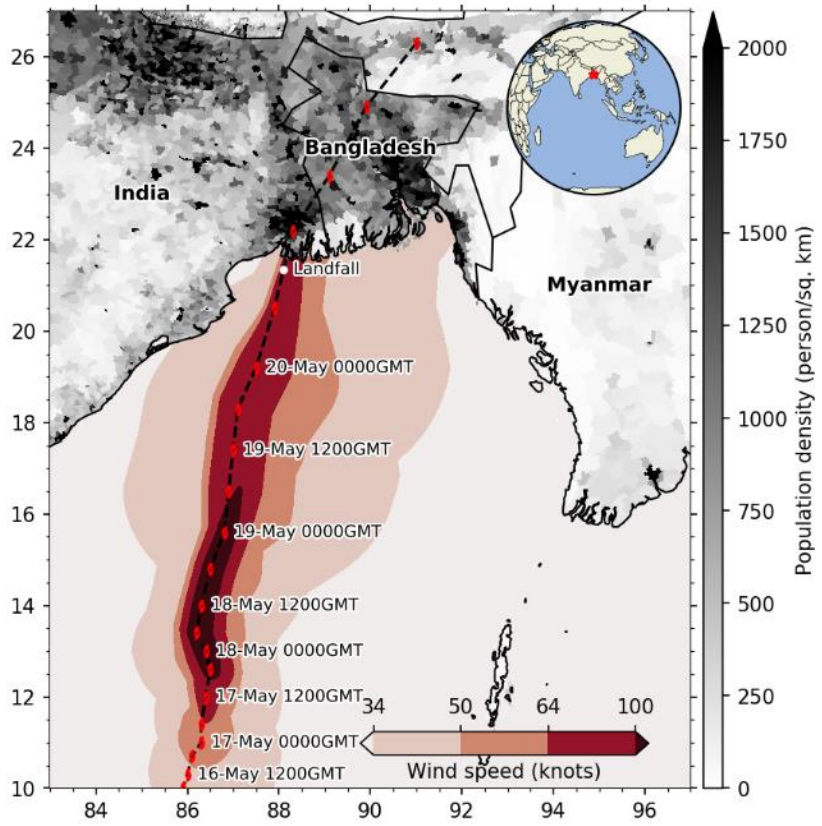
- Semi-implicit/Implicit schemes ~ allows large timesteps.
- 300 sec for SCHISM, 1800 sec for WWM-III

Cyclone Amphan: A benchmark event

18/5/2020



cyclone Amphan track

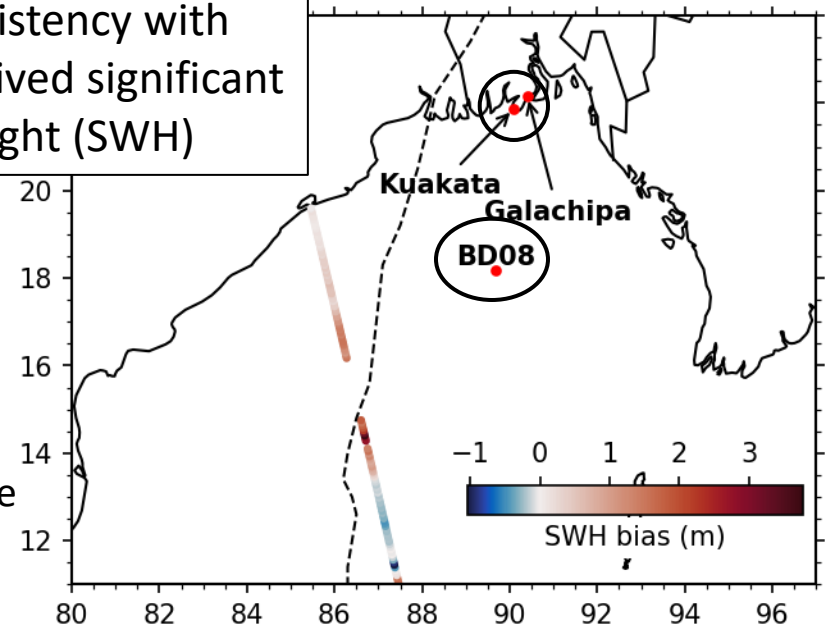


- **Category 5, 920hPa, 1min max-wind 260km/h**
- **126 fatalities**
- **13M$ of damages**

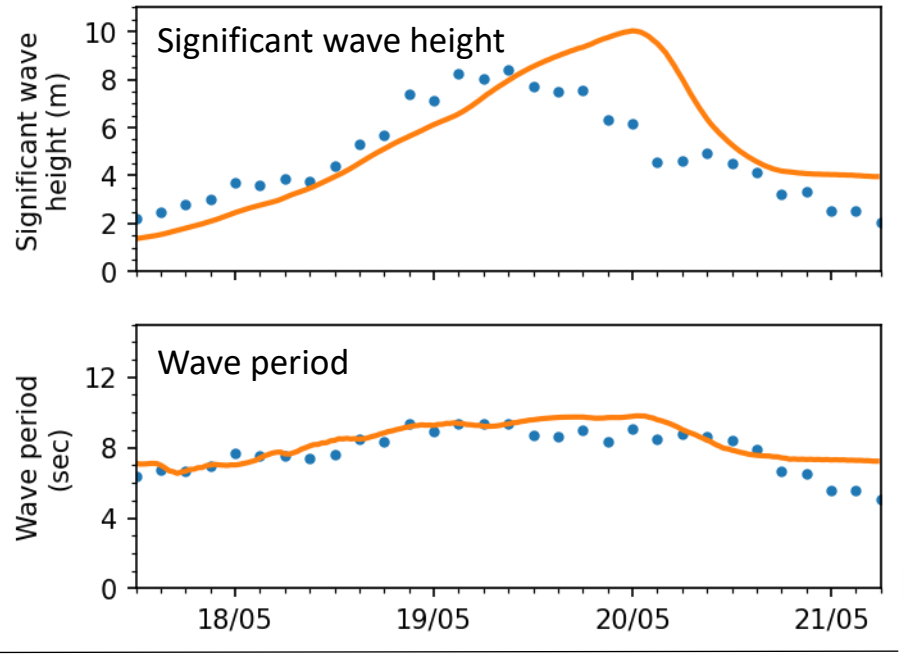
Amphan is the strongest and the costliest event in the Bay of Bengal since 2000

Validation of the modelled hindcast

Good consistency with altimetry-derived significant wave height (SWH)

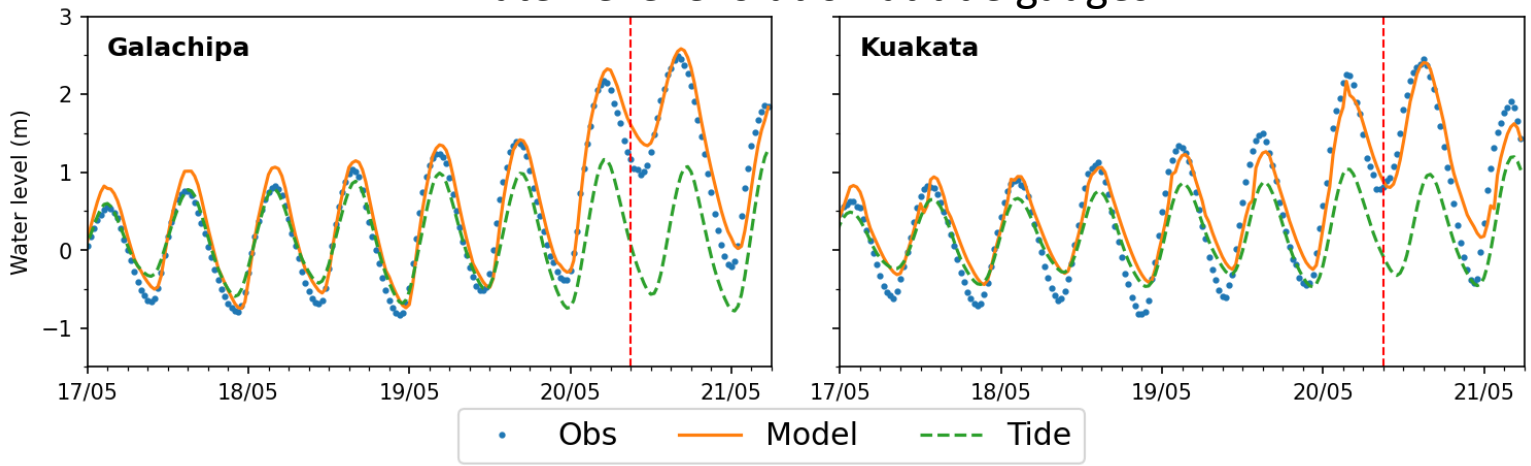


Buoy data source
INCOIS, India



<20% Error

Water level evolution at tide gauges

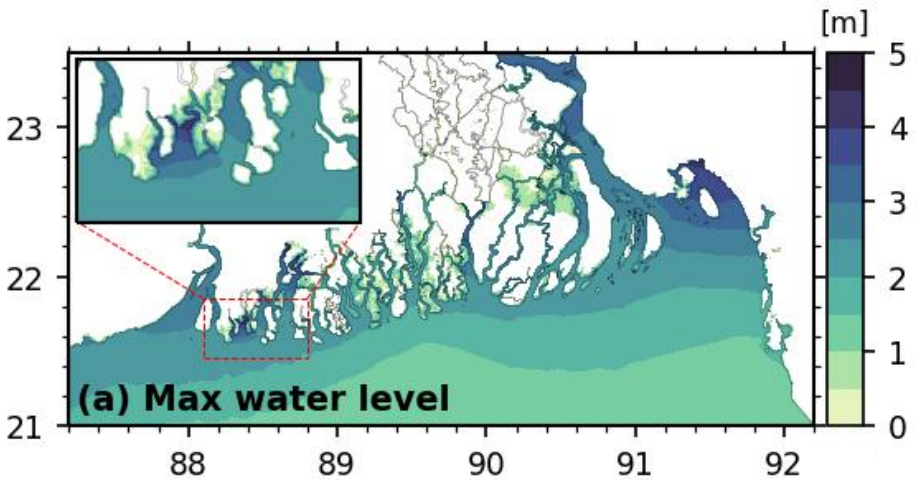


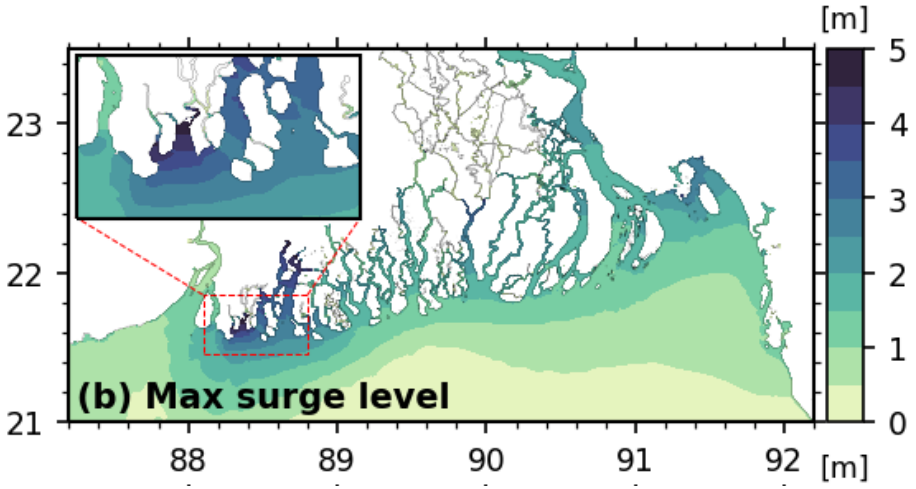
Water level data source
BIWTA, Bangladesh

Excellent prediction of storm surge water level at 5 coastal stations (2 shown)

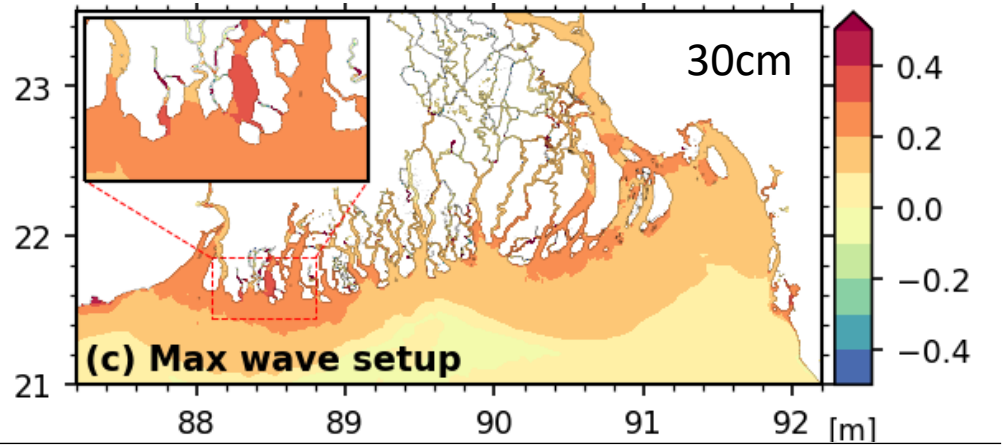
In hindcast, the model well predict the sea state and storm surge water level.

Do we really need coupled tide-surge-wave modeling?

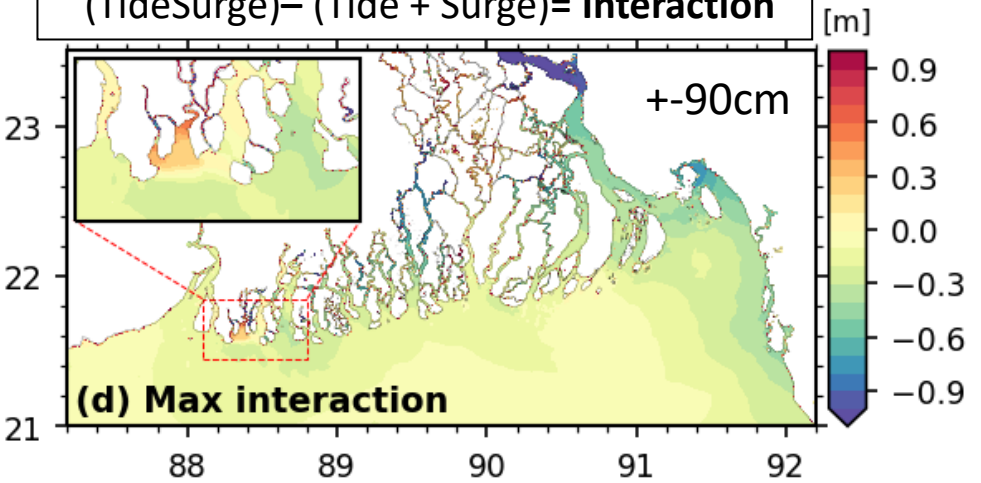




(WL with wave) – (WL without wave) = **Wave setup**



(TideSurge)– (Tide + Surge)= **Interaction**

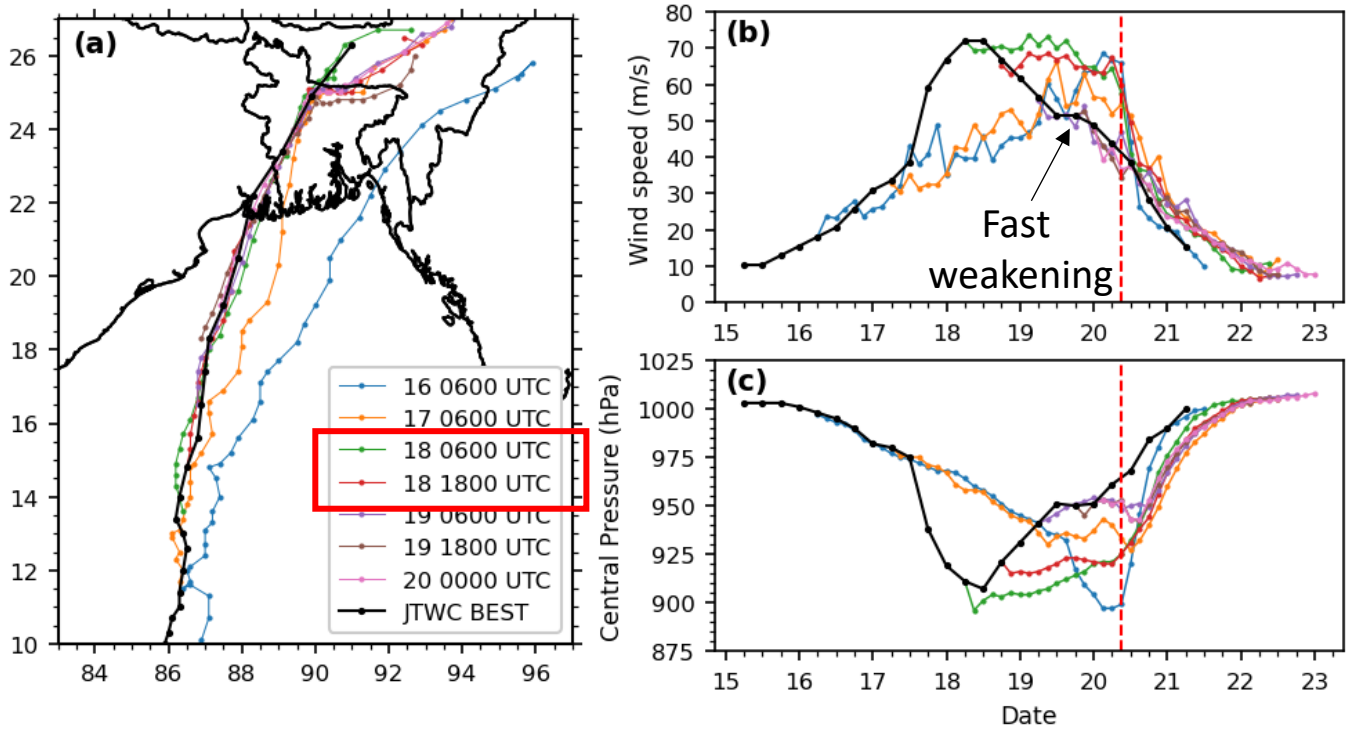


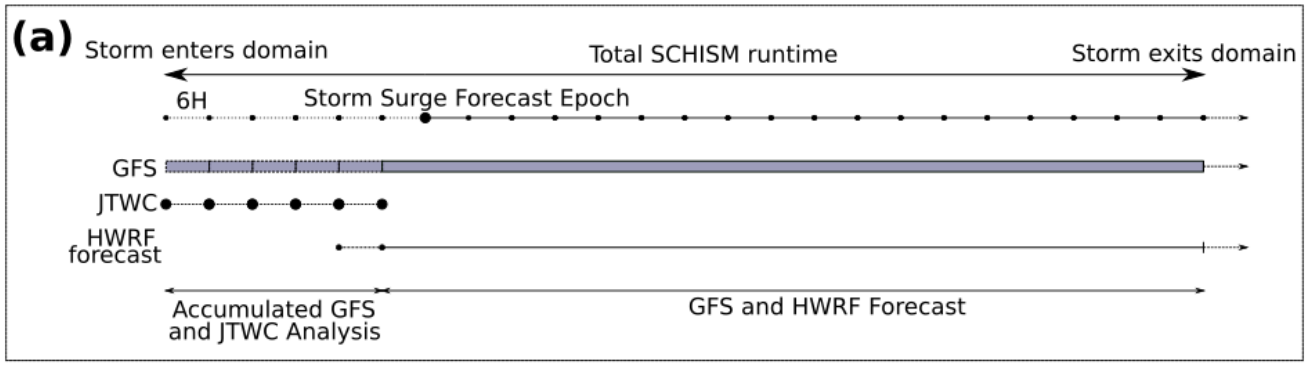
The contribution of the individual processes are non-negligible.

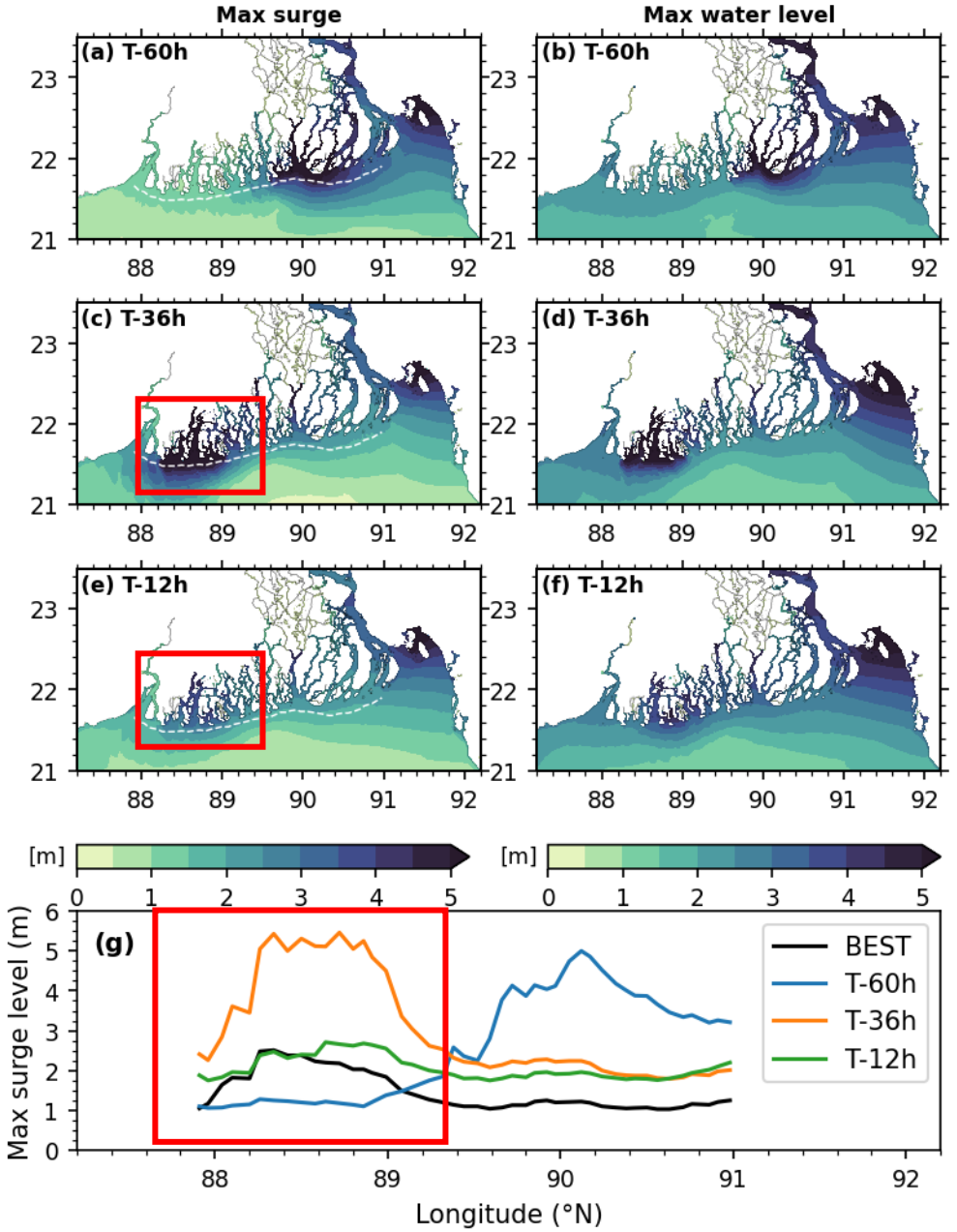
This calls for a coupled tide-surge-wave forecasting model for real-time operations

How are we doing in the forecast mode?

NOAA/HWRF Track forecast - Landfall on 20 May

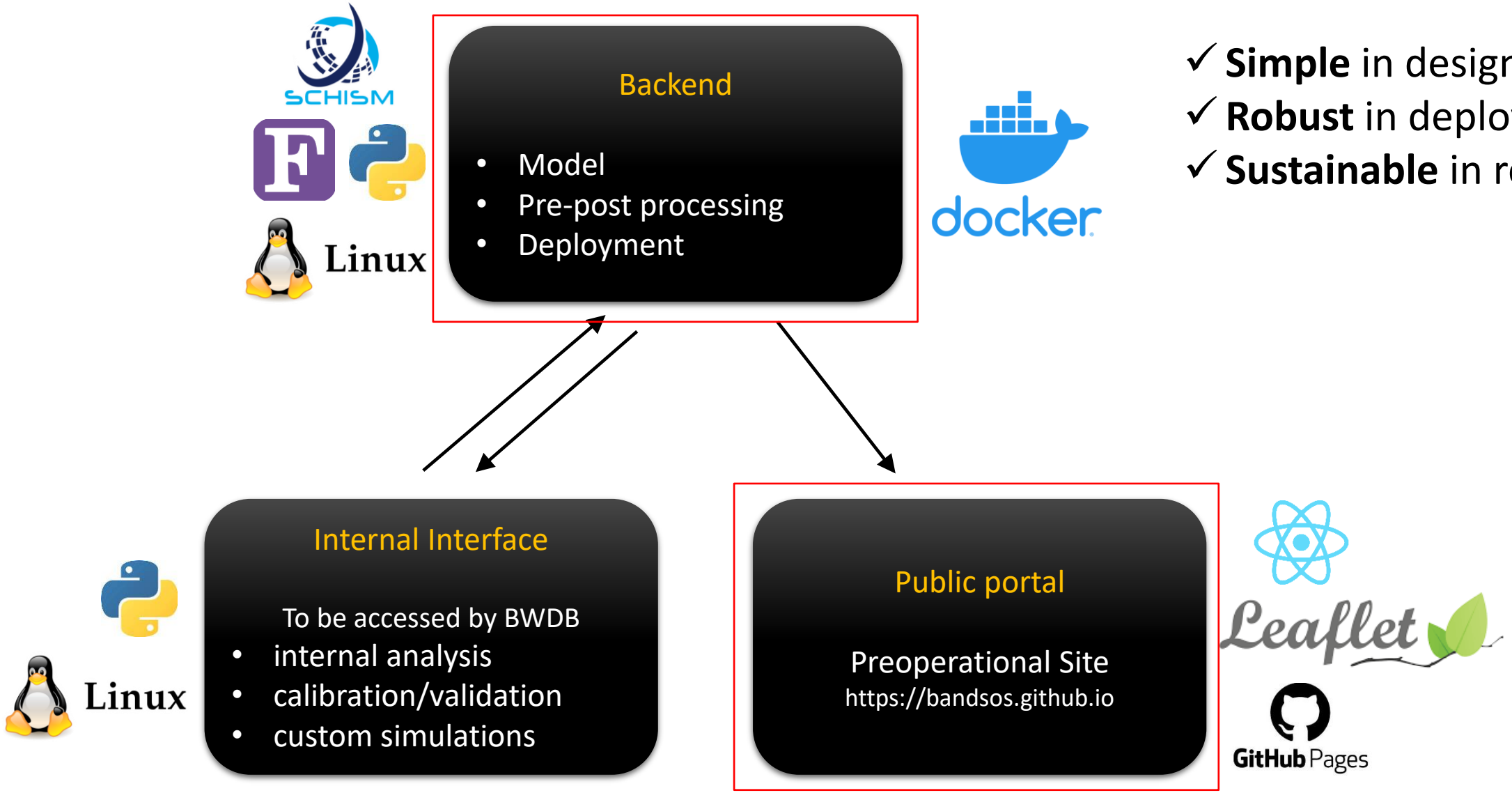






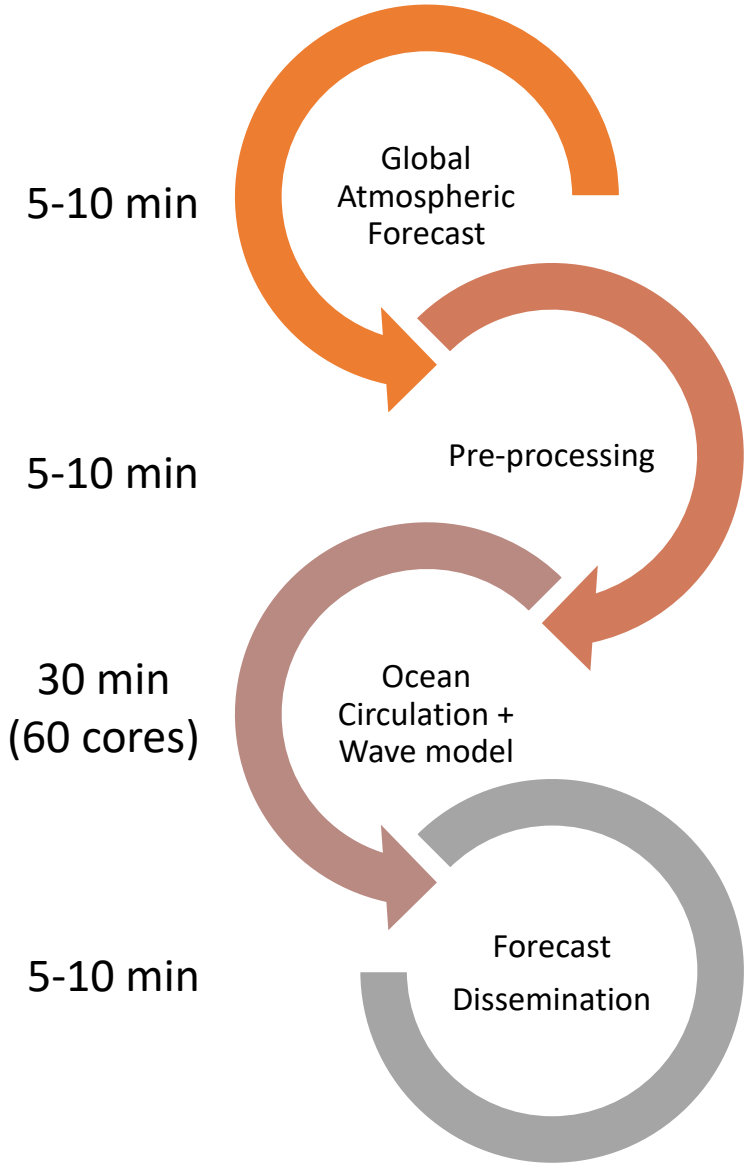
Actionable forecast with about 2 days lead-time

Band-SOS platform for coastal flood forecasting



- ✓ **Simple** in design
- ✓ **Robust** in deployment
- ✓ **Sustainable** in resources

Implemented forecasting cycle



Step 1. Getting the atmospheric fields (Trigger)

a) Normal: GFS forecast (4 times a day – 00, 06, 12, 18).
b) Cyclone: Background atmosphere from "merged" GFS forecasts (6 hourly), and cyclone track and strength from satellite observation (previous cycles) and high-resolution forecast (HWRF)

Step 2. Preprocessing

a) Model configuration
b) Tidal water level, and riverine discharge
c) Atmospheric fields

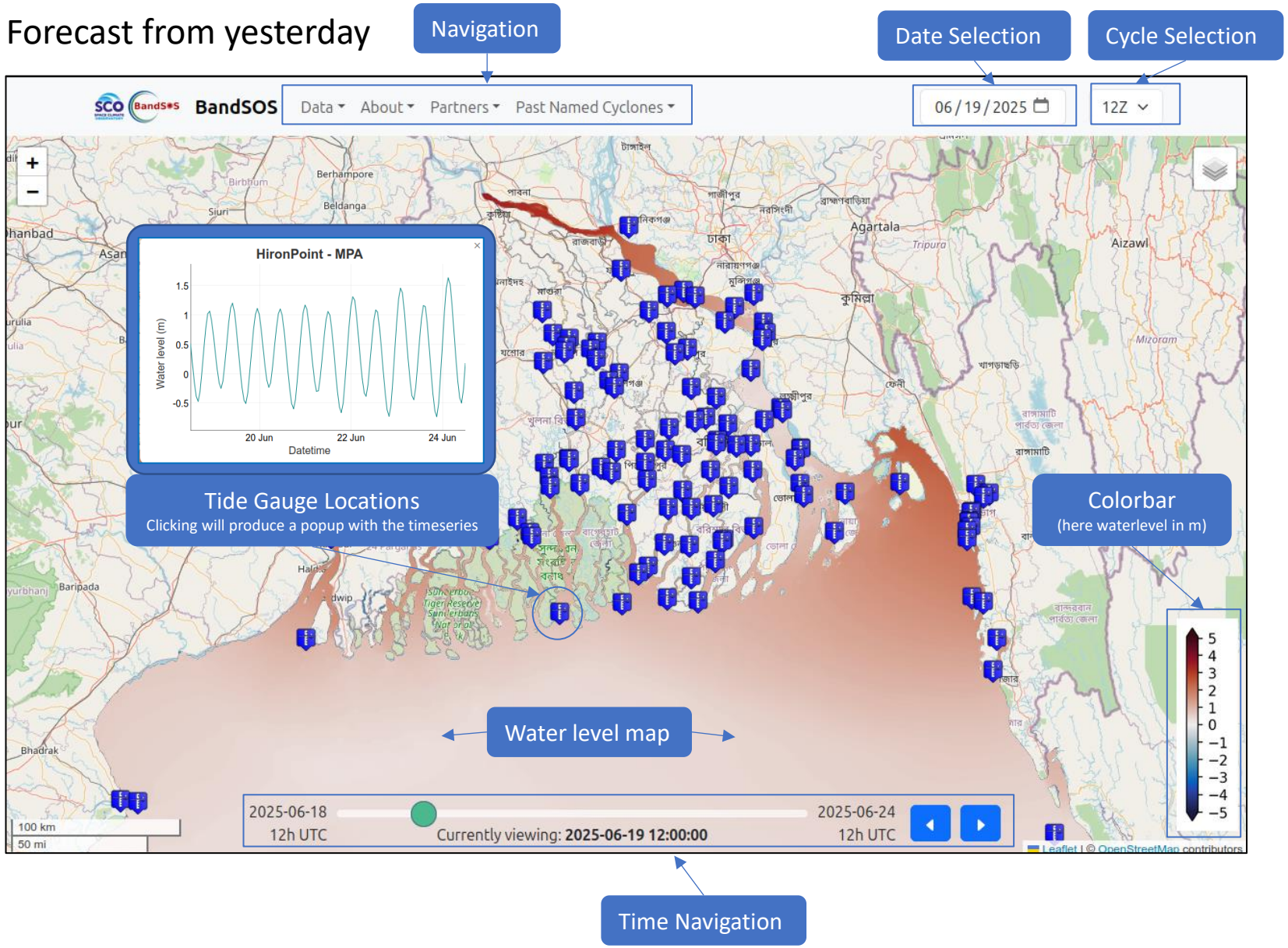
Step 3. Water level and inundation computation with SCHISM-WWM.

Step 4. Distribution of results to the portal

In a 60-core machine, the forecast cycle is completed within an hour.

Public interface / Web portal

Forecast from yesterday



- Open-source and simple
- Static-hosting
  - No database
  - Structured directory/files
- Ability to revisit previous forcasts

Visit the portal at

https://bandsos.github.io

Application in decision-making for coastal flooding disaster management

Named cyclones during 2023-2024

Bangladesh Water Development Board
A key-player in the Bangladesh Disaster Management Framework

Q. Who are to move and to take shelter?

Before BandSOS
No information on potential flooding, whole coastline is advised to take shelter (17 districts)

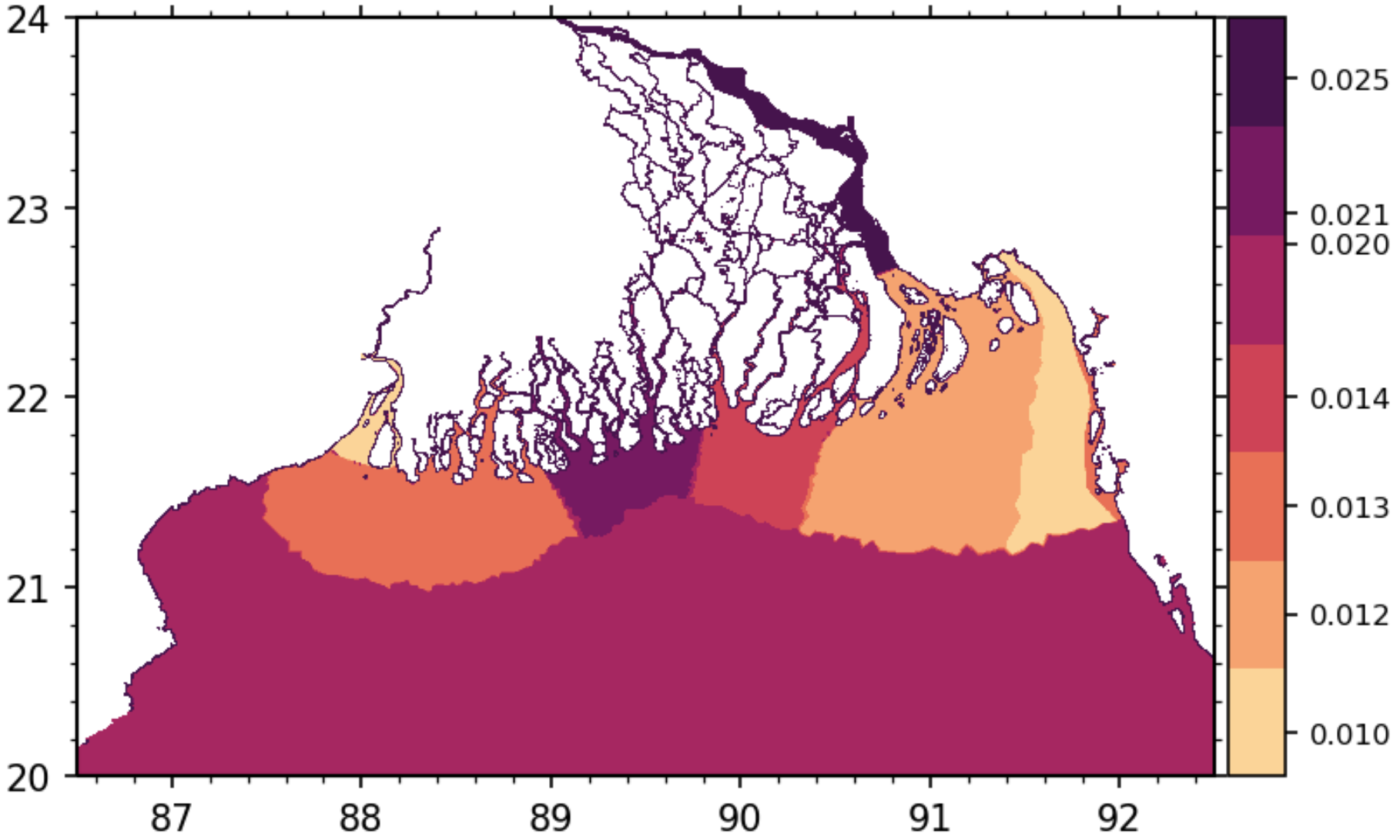
After BandSOS (Starting 2024)

- District level advice on expected flooding, advice on taking shelter
- Tidal flooding forecast for monsoonal depression events
- Boundary condition for National River Model

Thank you!

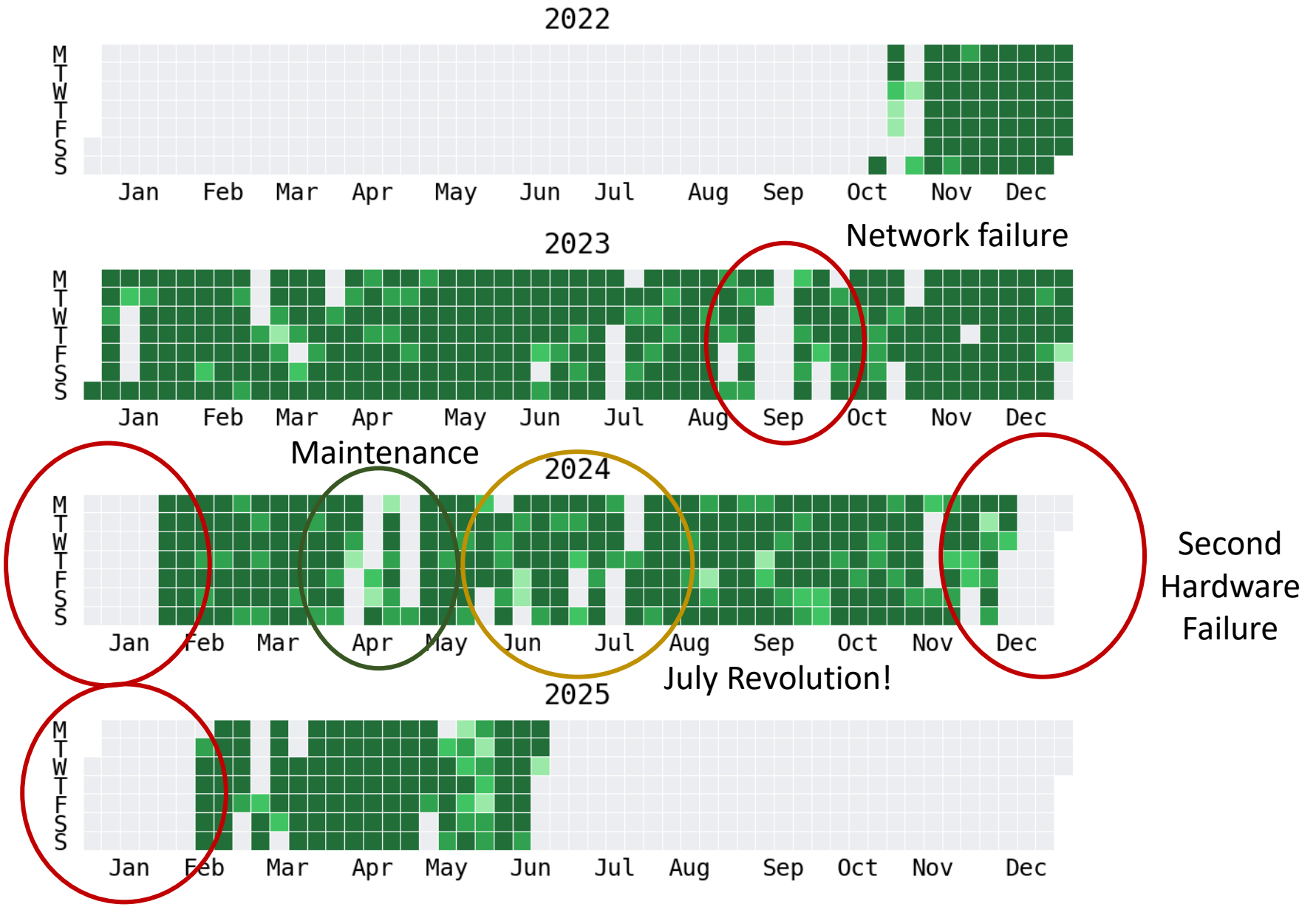
Additional slides

Distributed bottom friction parameterization



Khan 2021 (PhD Thesis)

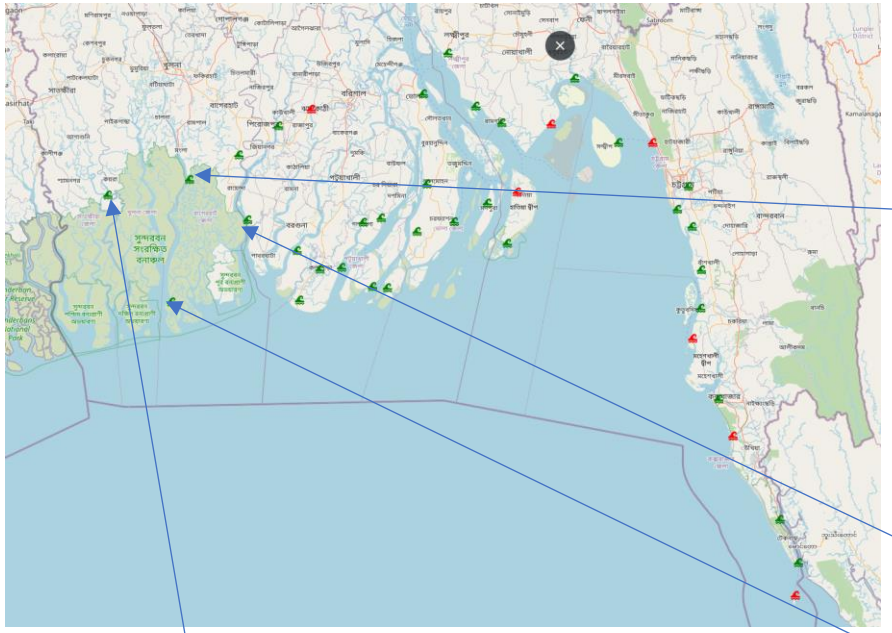
Deployment and Runtime Performance/Issues



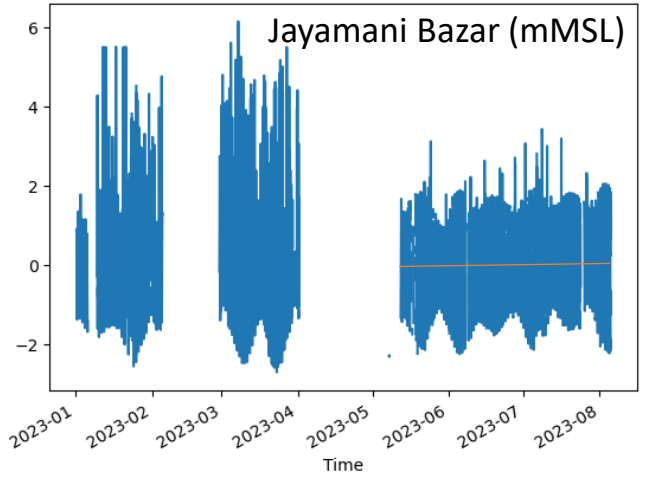
Relatively robust operation in a challenging computational environment

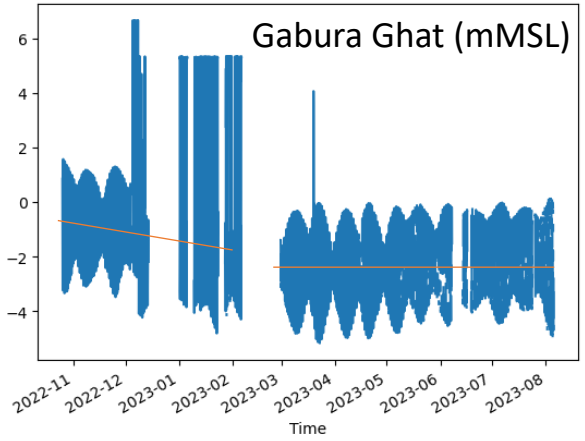
Collaboration with BWDB

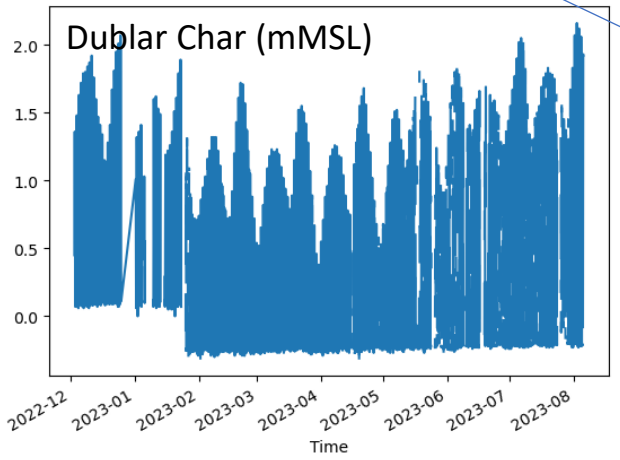
New auto-gauge stations of BWDB, funded by WB

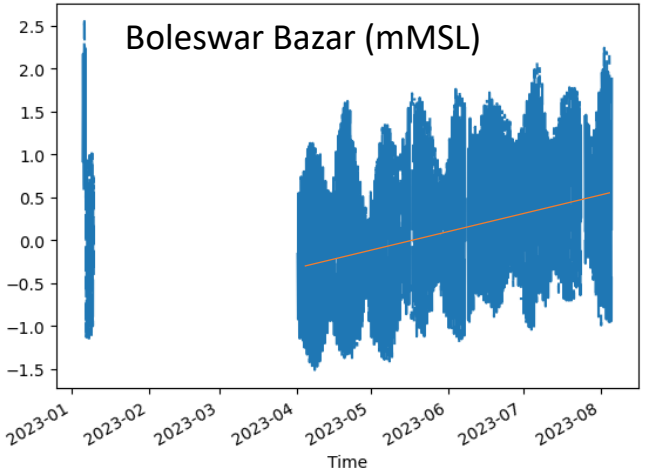


40 Tide gauges

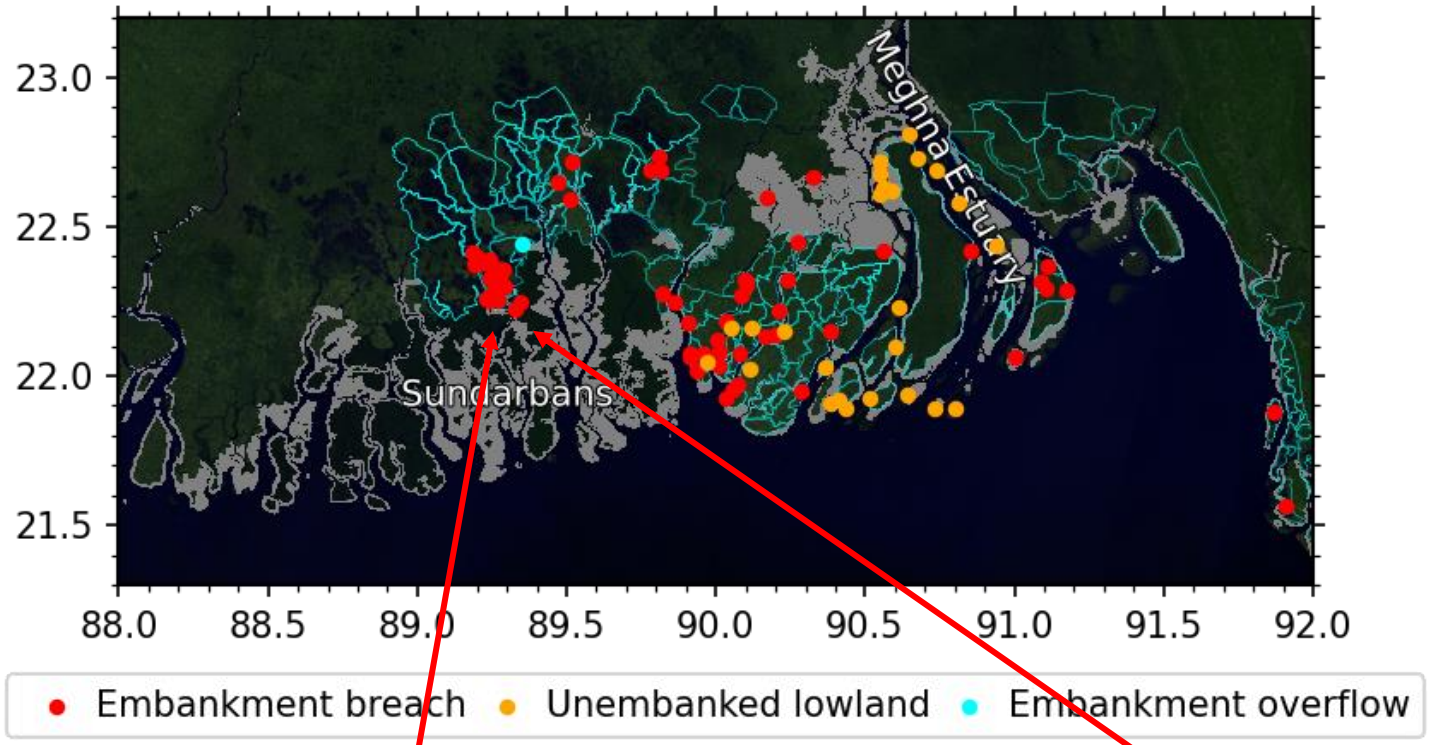








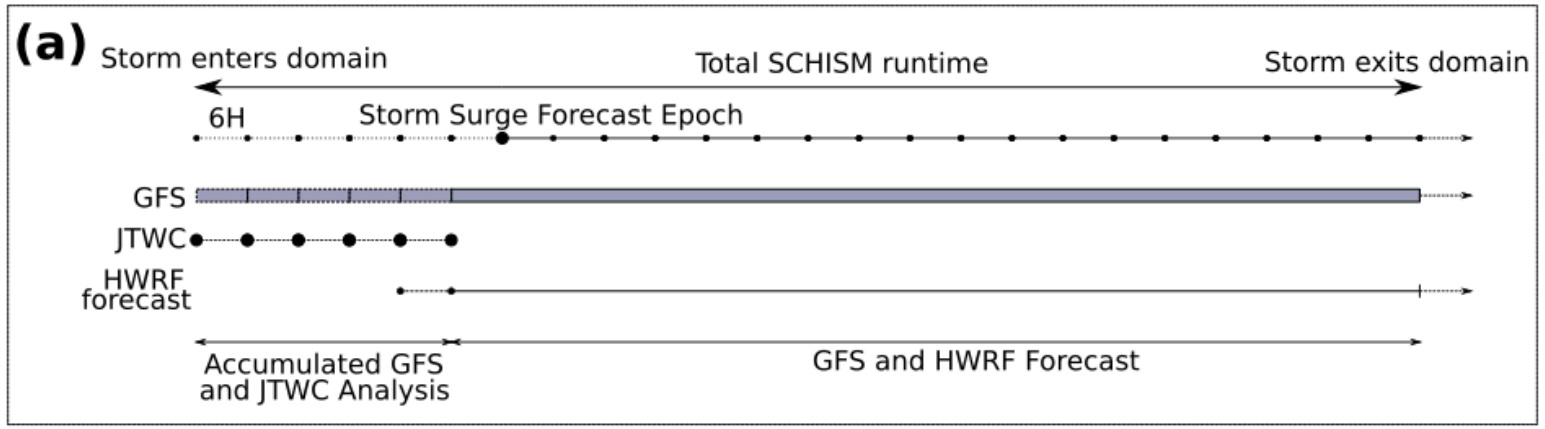
What about the inundation?

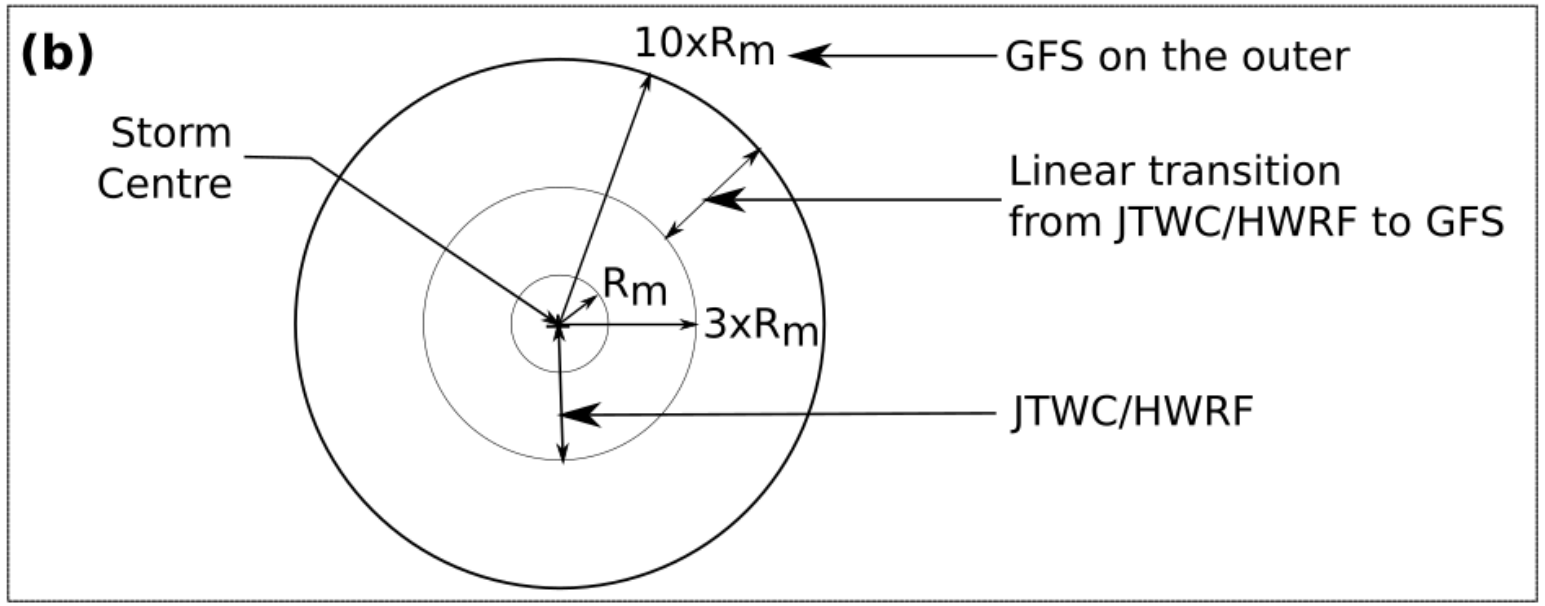


Inland flooding by breaching calls for regular monitoring of embankments status.

The storm surge model can reproduce the extreme **water level** and **inundation**.

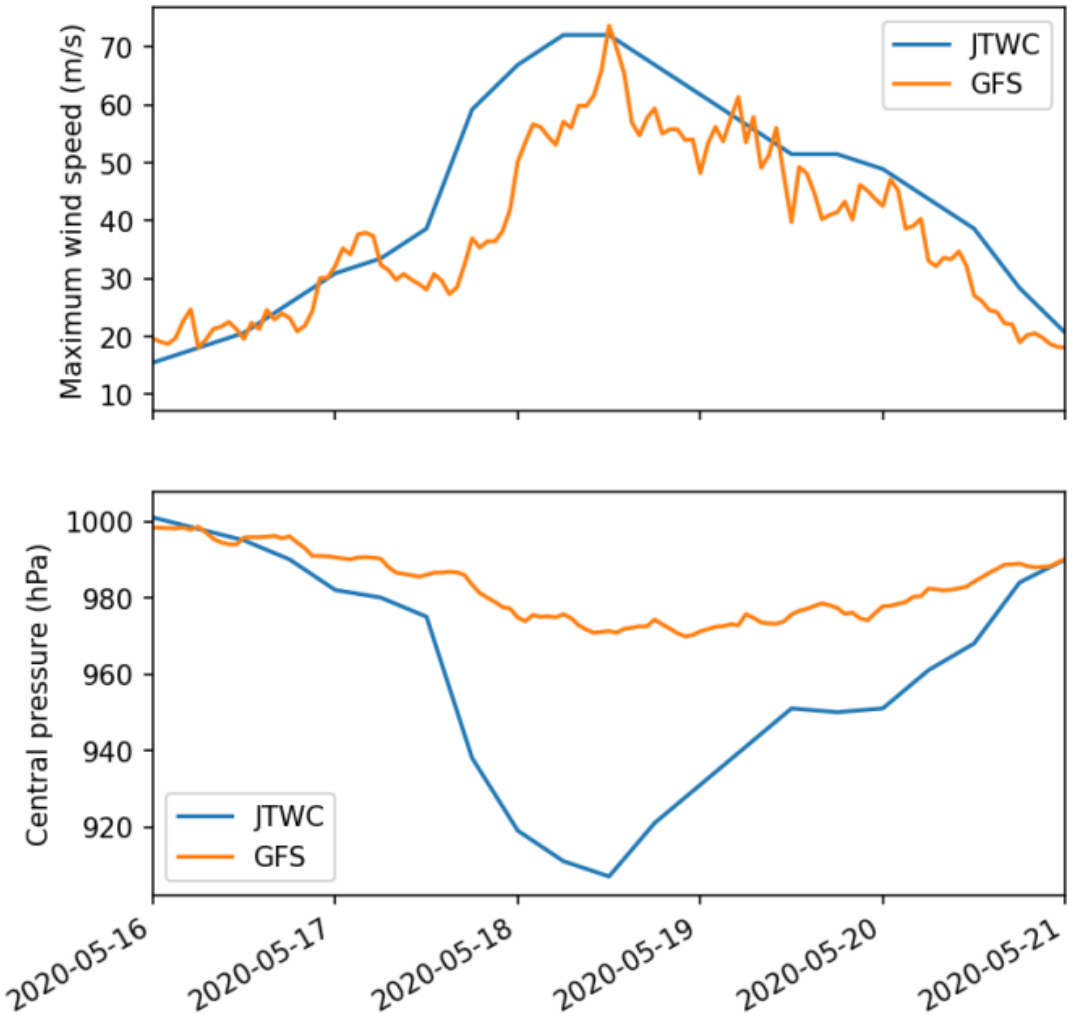
How are Wind and Pressure fields are prepared?

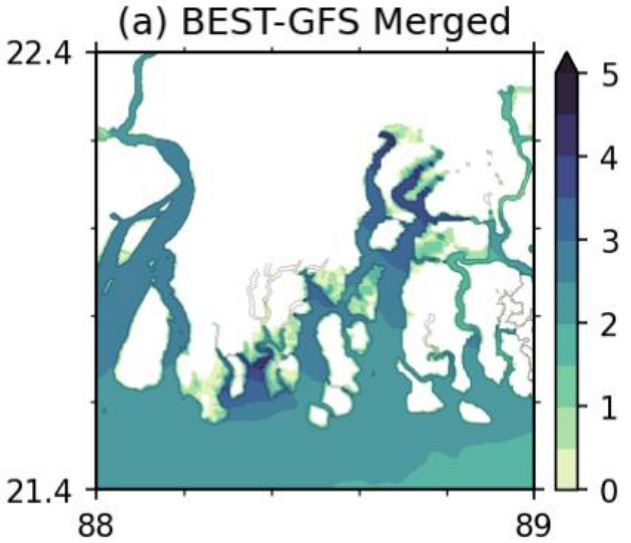


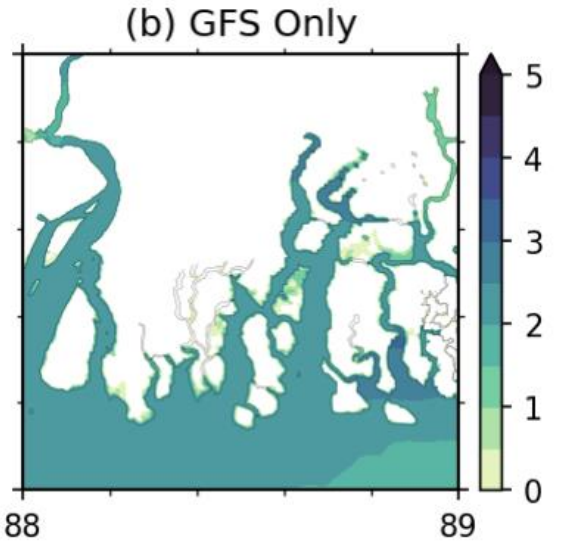


- Combined Holland 1980 and Emanuel and Rotanno 2011 Model for Wind.
- Holland 1980 model for pressure.
- Merged with background GFS Analysis/Forecast.

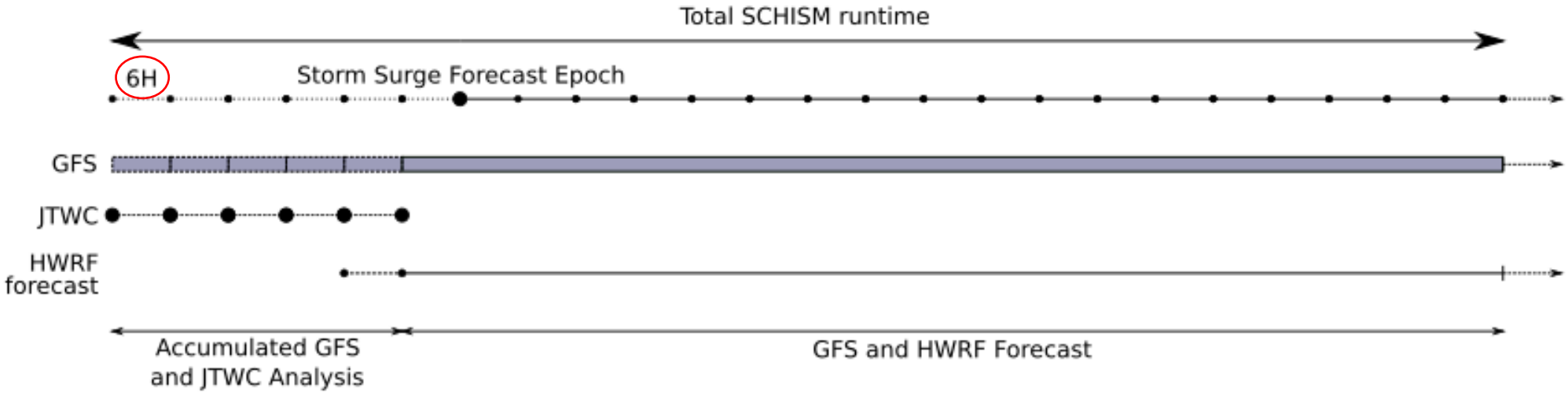
Why not use GFS forecast directly?



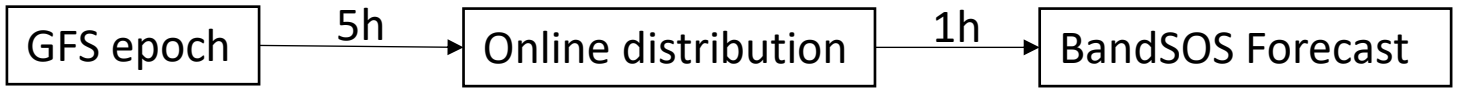




Details on the rolling forecasting scheme



A new forecast is computed every 6 hours, for the next 5 days
4 forecasts are published a day corresponding to GFS forecast at 00, 06, 12, 18 UTC



A new BandSOS forecast is corresponding to a GFS epoch (e.g., 00Z) is only available 6 hours later (at 06h00 UTC).

Summary and Perspective

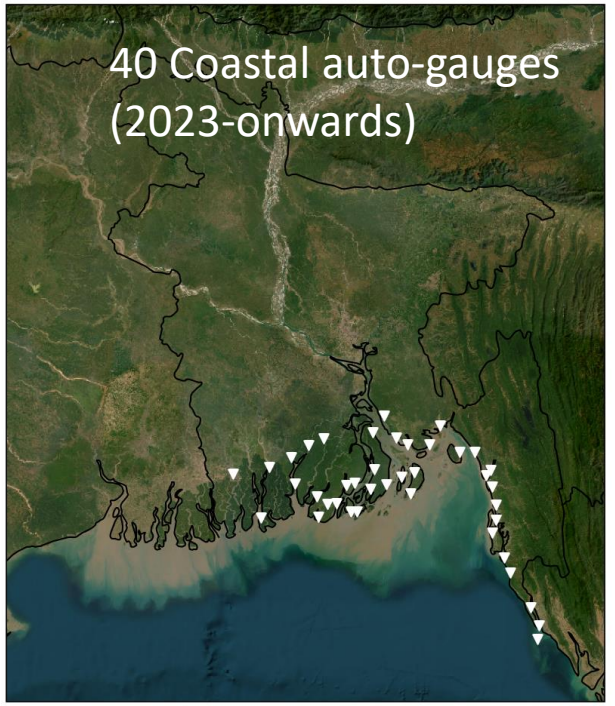
- Coupled **tide**, **surge**, **wave model** → More realistic forecast
- BandSOS → **real-time**, **robust**, **cost-effective** pre-operationalized flood forecasting system
  - Providing 5-day forecast, updating 4 times daily
- Coastal forecasting system demonstration → decision-making tool

Major weak point to resolve – Dependence on **GFS + HWRF forecast**

- No backup solution is in place yet.

Ongoing collaborative effort with BWDB –

- Improvements of
  - river bathymetries (cf Talk of Florence yesterday)
  - embankment heights
- Develop danger levels (Based on return levels of Khan et al. 2022)
- Continuous validation with recently available auto-gauges



Compound flooding from torrential rainfall is not included

See my poster on Madagascar (available in COSS-TT portal)