3D seamless cross-scale modelling of tides and their seasonality in the GBM (Ganges-Brahmaputra-Meghna) delta

F. Toublanc, F. Durand, J. Khan, Y. Krien, V.R. Sherin, X. Bertin, AKM Saiful Islam, V. Suneel

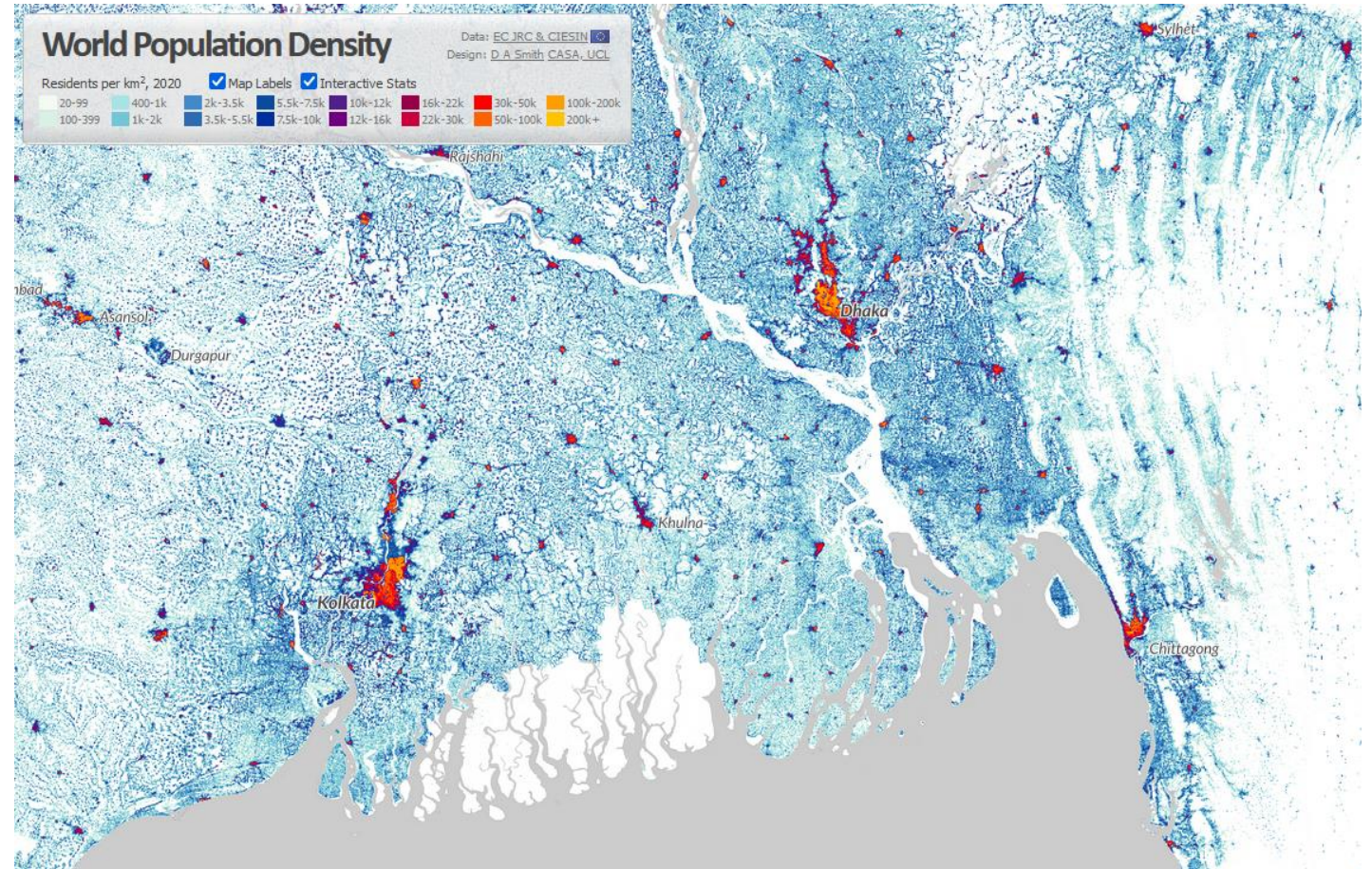**COSS-TT meeting – Brest – June 2025**

florence.toublanc@univ-tlse3.fr

The Bengal delta

Largest delta in the world

Densely populated: more than 150M people

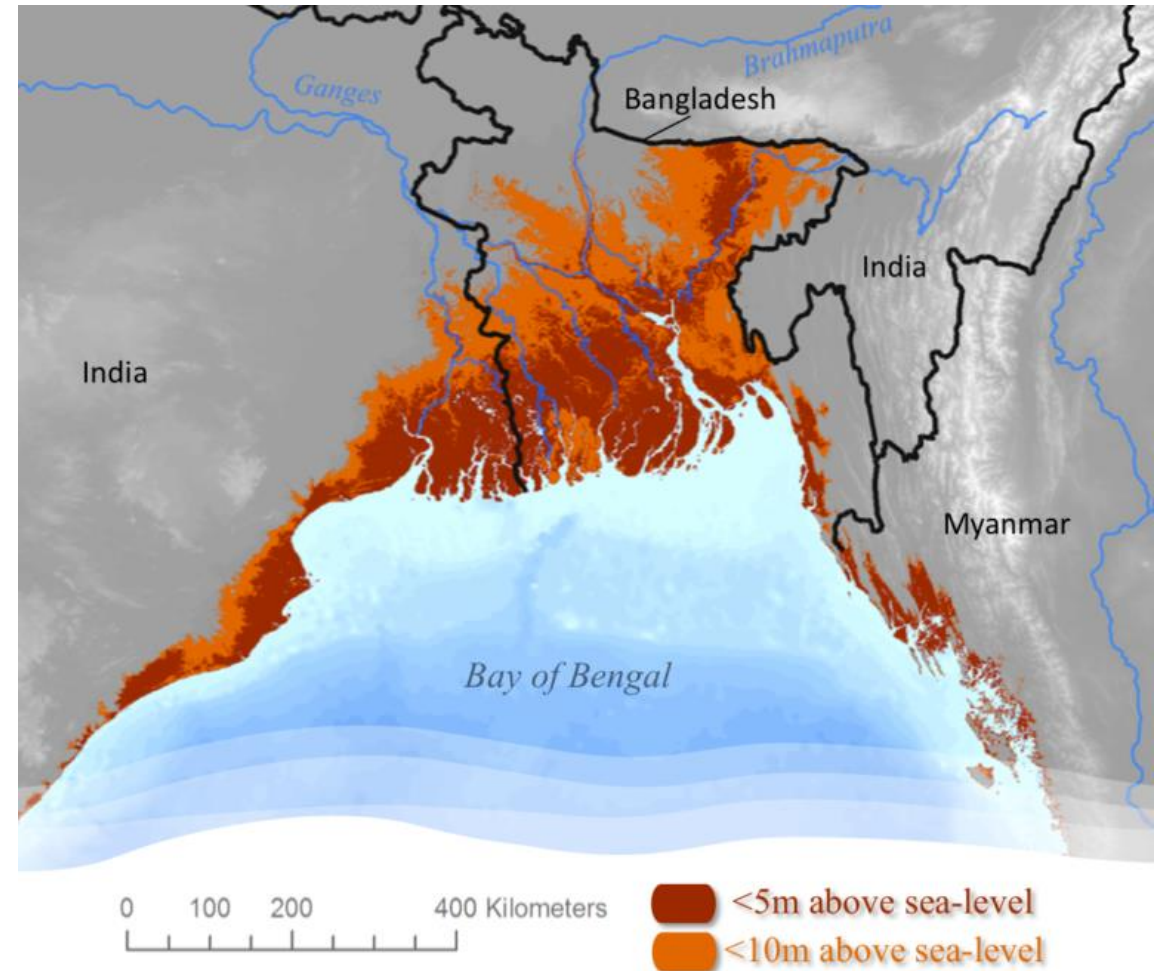https://luminocity3d.org/WorldPopDen/

The Bengal delta

Largest delta in the world

Densely populated: more than 150M people

Low topography: typically less than 3m above mean sea level

Macrotidal: typical tidal range above 4m
Tidal influence up to more than 100km inland

0   100   200   400 Kilometers

■ <5m above sea-level
■ <10m above sea-level

ANR Delta

The Bengal delta

Largest delta in the world
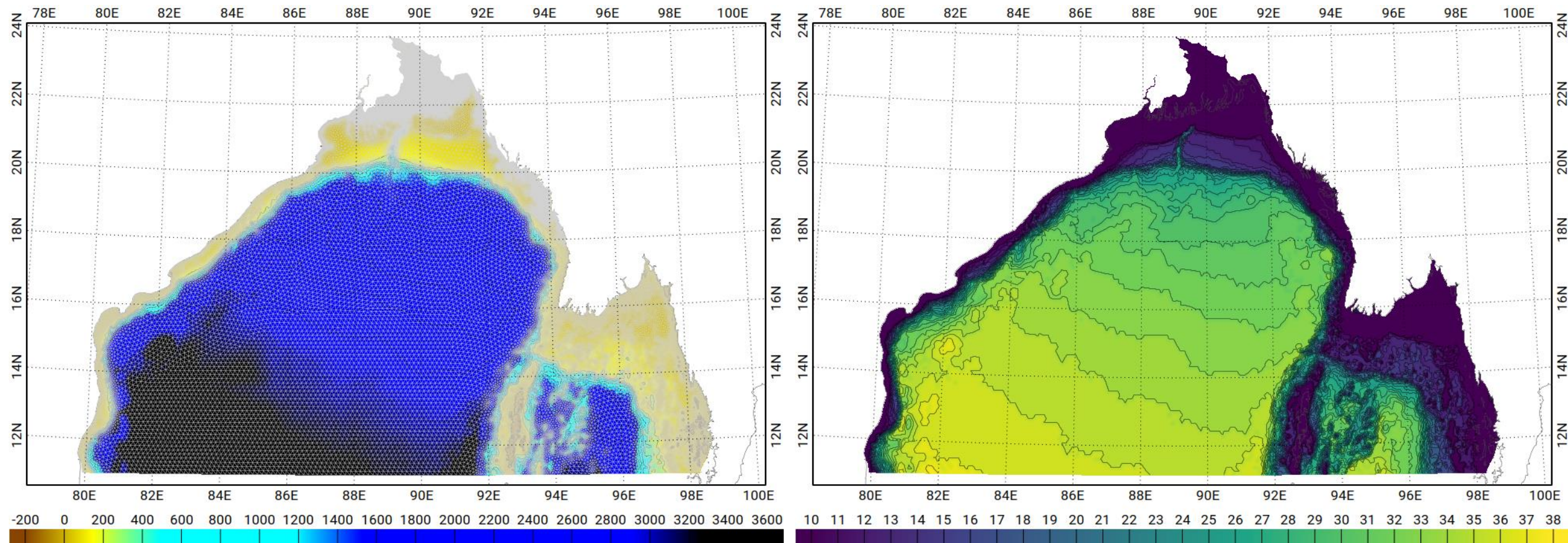
Densely populated: more than 150M people

Low topography: typically less than 3m above mean sea level

Macrotidal: typical tidal range above 4m

Sharp salinity front under the influence of various processes : high-frequency tides, seasonal variations of the river flow, extreme events (cyclones), sea level rise
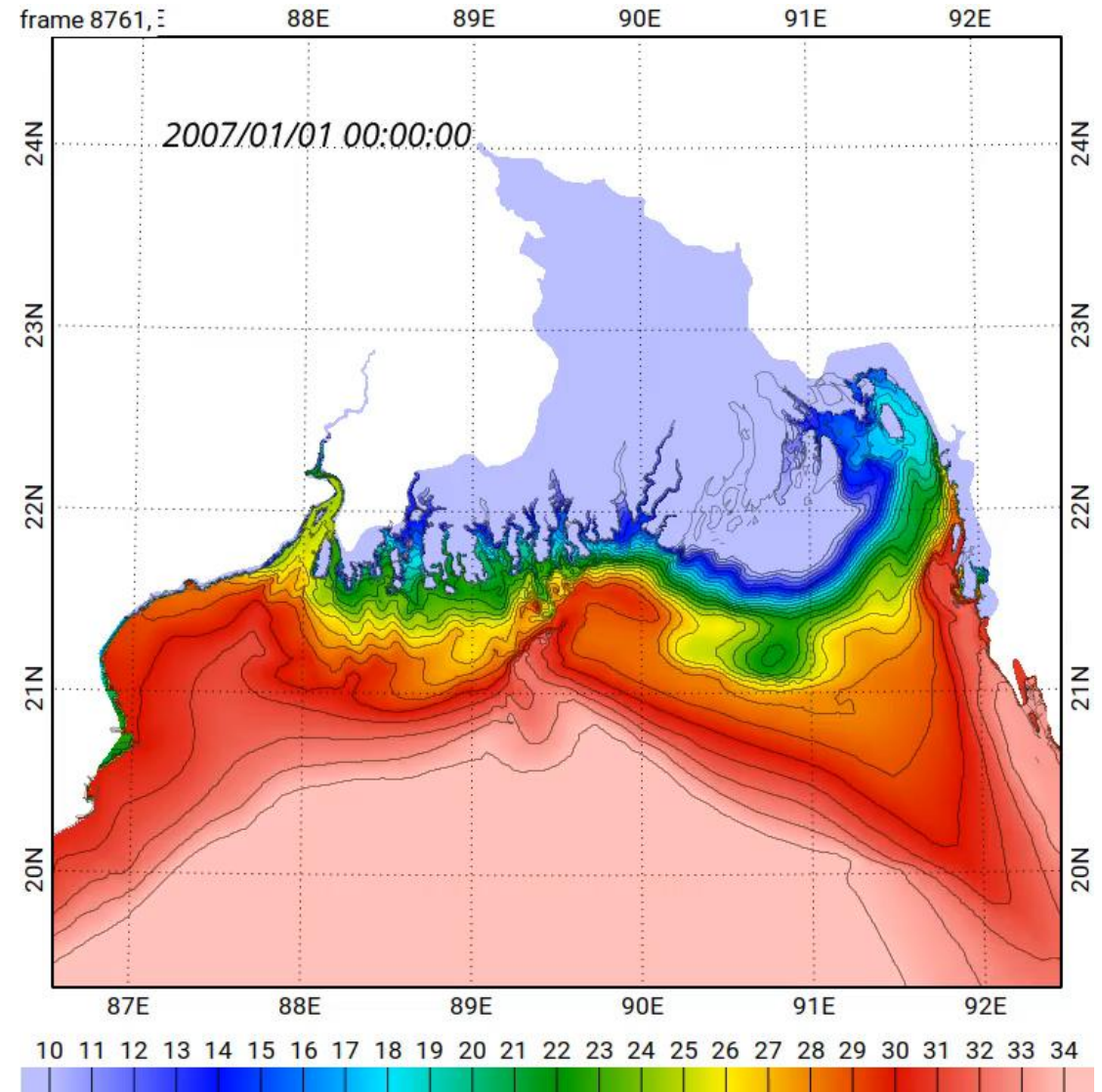
Bay of Bengal configuration (SCHISM)

Bathymetry and horizontal grid
600 000 nodes, 1.1 million elements
15km deep ocean to 250m nearshore

1-year simulation
~30 000hCPU

Number of vertical levels
deep 38 => shallow 10

Bay of Bengal configuration (SCHISM)

Evolution from previous 2D configuration (Krien et al., 2016, 2017; Tazkia et al., 2017; Khan et al., 2020, 2021, 2022)

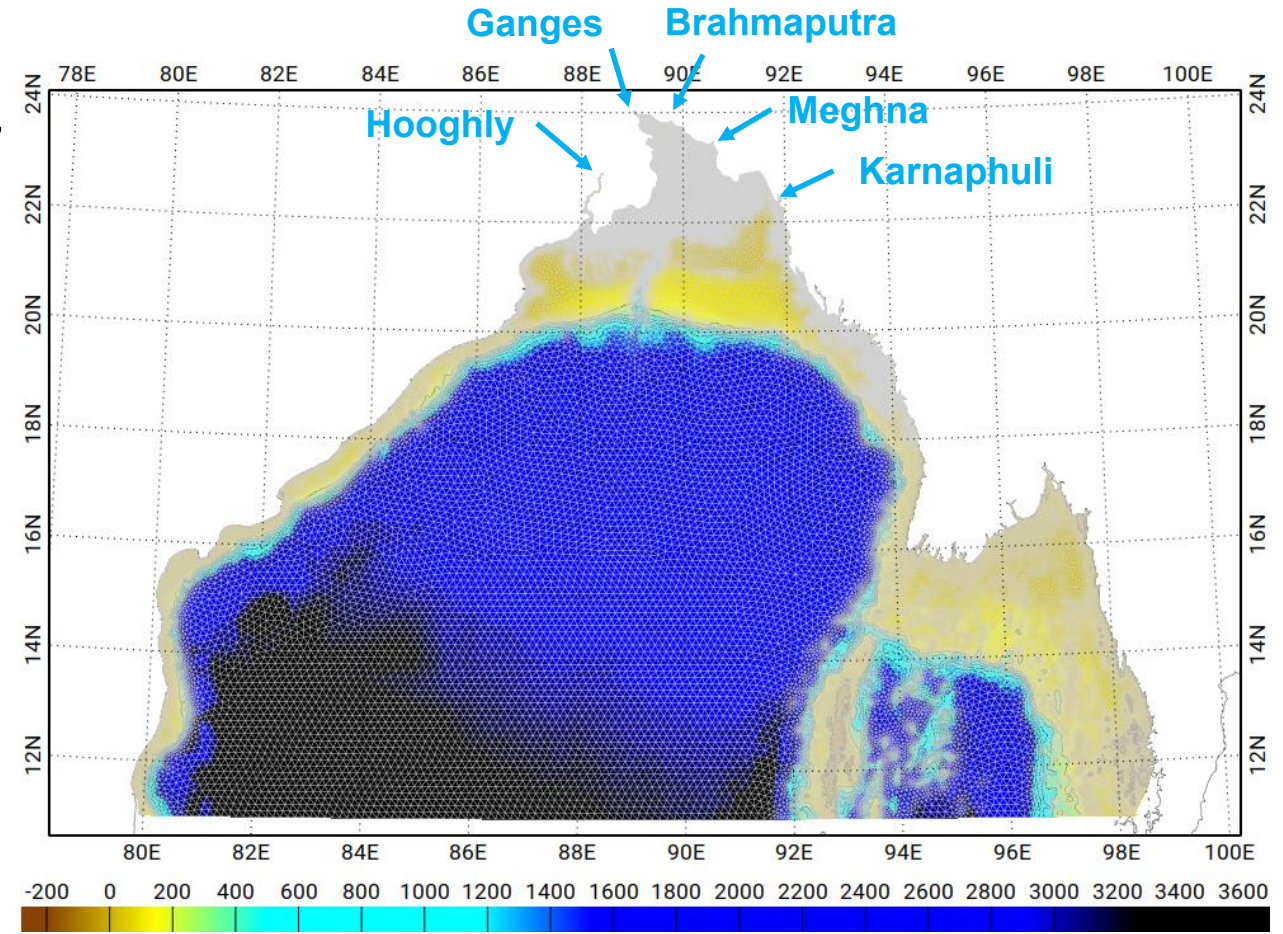Fine bottom friction tuning derived from J. Khan PhD

Atmospheric forcing: DRAKKAR forcing set 5.2

Large scale OBC forcing: GLORYS reanalysis 12V1

Tides : FES2022 elevations and currents

River discharges:
- climatology for Hooghly and Karnaphuli
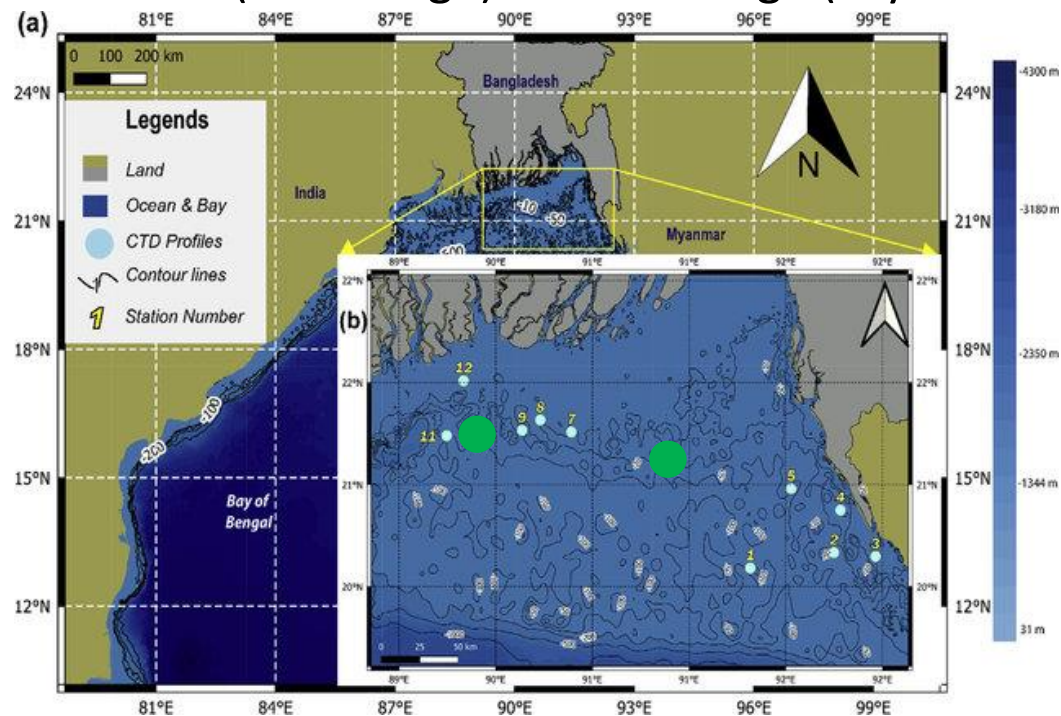- daily for Meghna, Ganges and Brahmaputra

1-year spinup, simulation over 2006-2007

A bit of "large scale" validation

Comparison with salinity profiles measured in 2020 (Masud-Ul-Alam et al., 2020) in the northern Bay of Bengal

2006 model vs 2020 data: identification of similar tidal conditions (tidal range) and discharge (dry season)
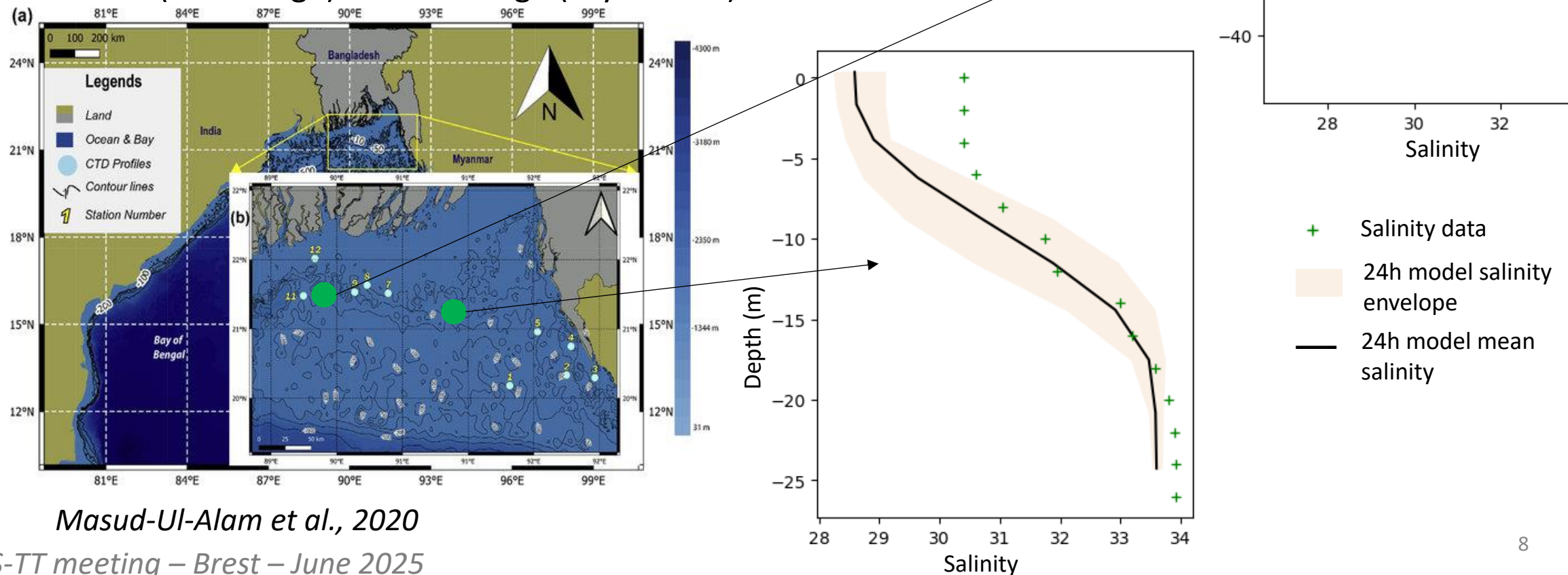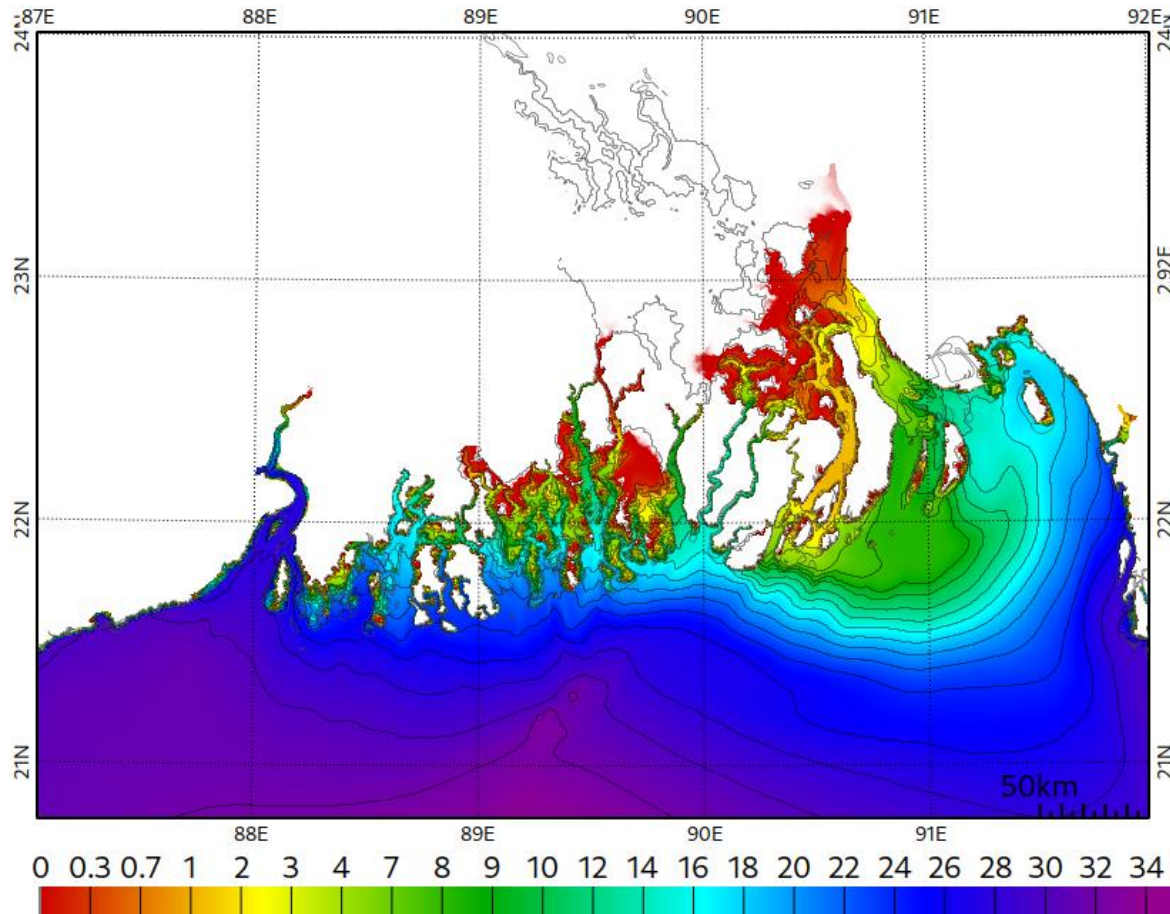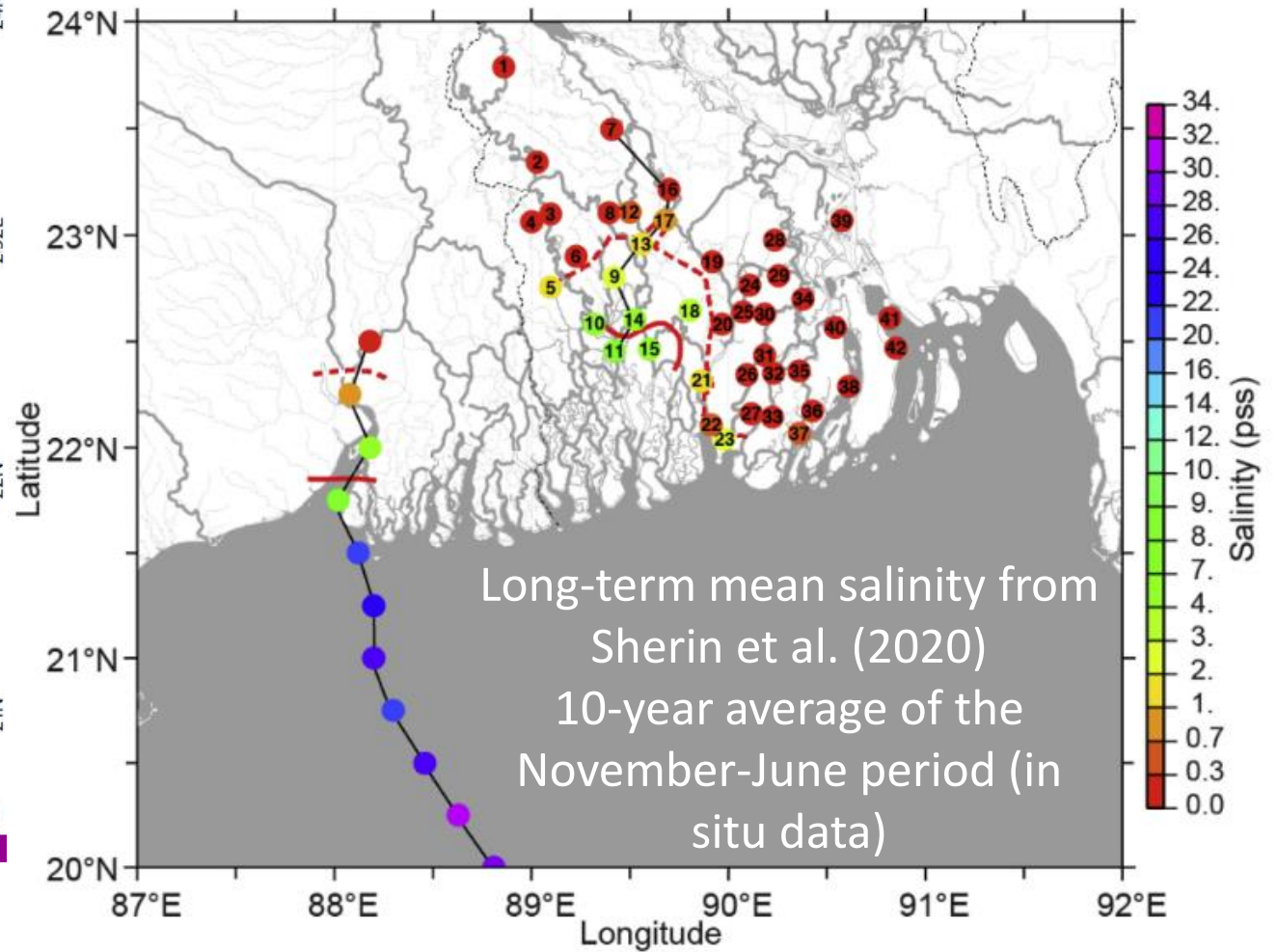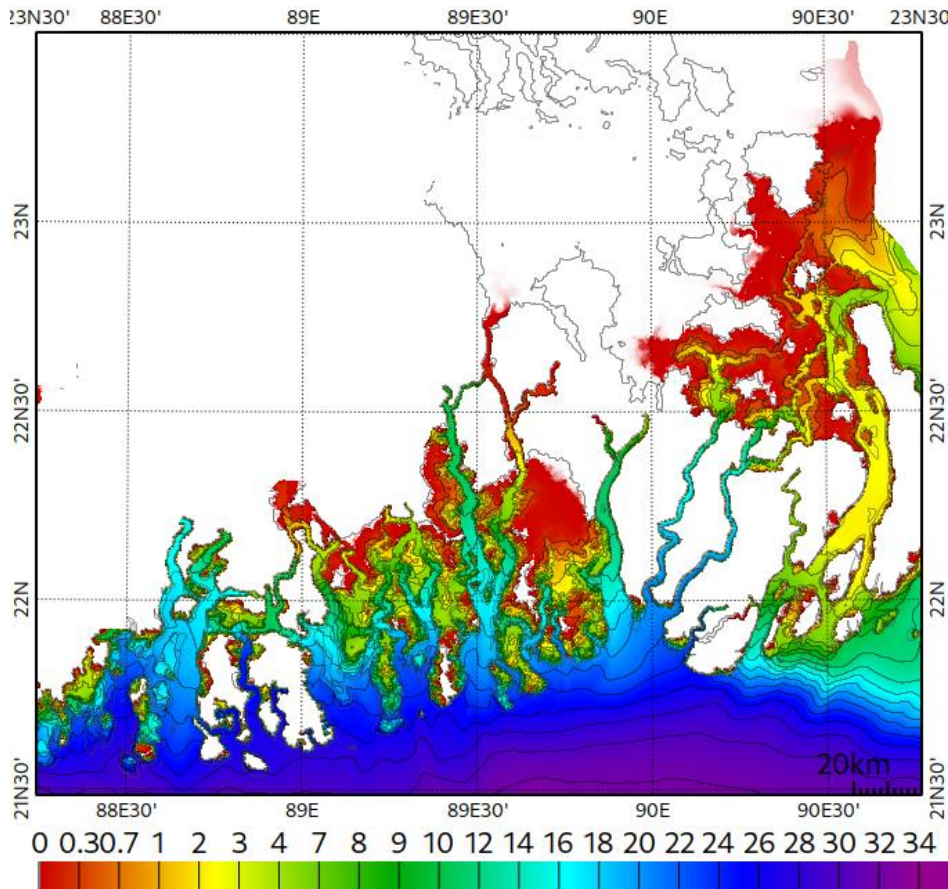

Masud-Ul-Alam et al., 2020

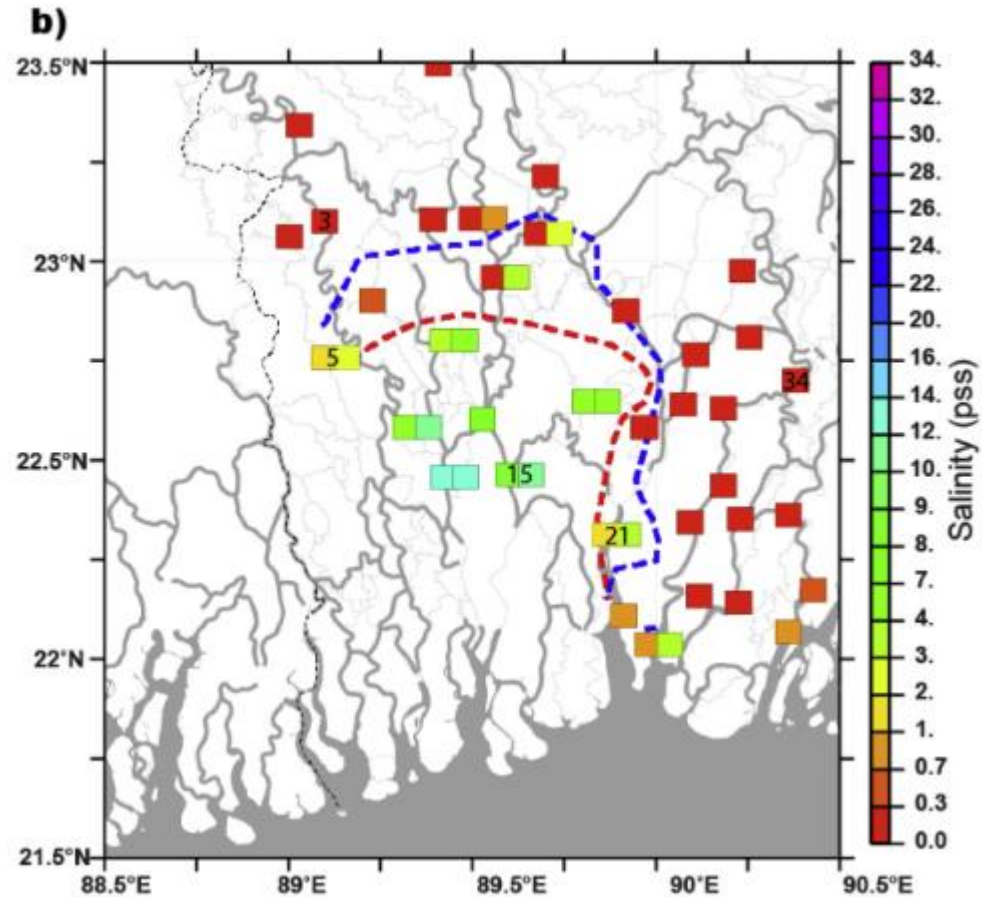# A bit of "large scale" validation

Comparison with salinity profiles measured in 2020 (Masud-Ul-Alam et al., 2020) in the northern Bay of Bengal

2006 model vs 2020 data: identification of similar tidal conditions (tidal range) and discharge (dry season)

Masud-Ul-Alam et al., 2020

+ Salinity data

24h model salinity envelope

24h model mean salinity

A bit of "large scale" validation

Modelled salinity average
November 2006 - June 2007

Long-term mean salinity from Sherin et al. (2020)
10-year average of the November-June period (in situ data)

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9

A bit of "large scale" validation

Modelled salinity average - April 2007

Salinity climatology in April from Sherin et al. (2020)

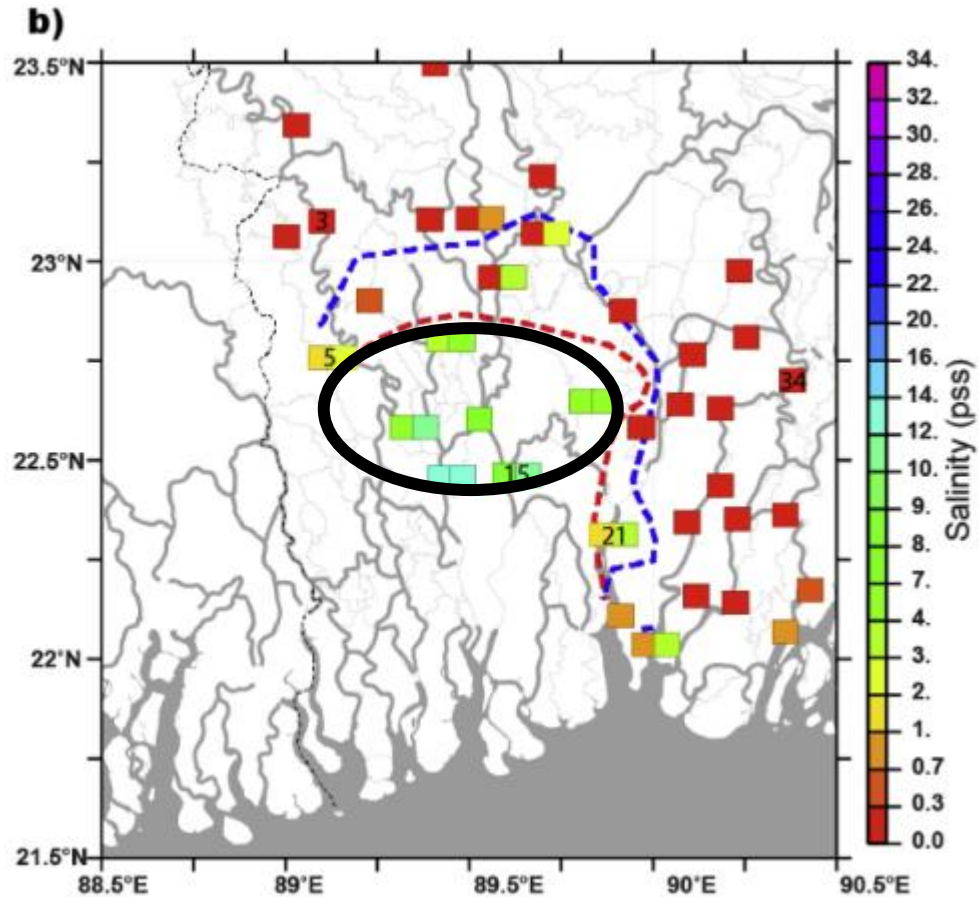Good overall representation of the salinity

A bit of "large scale" validation
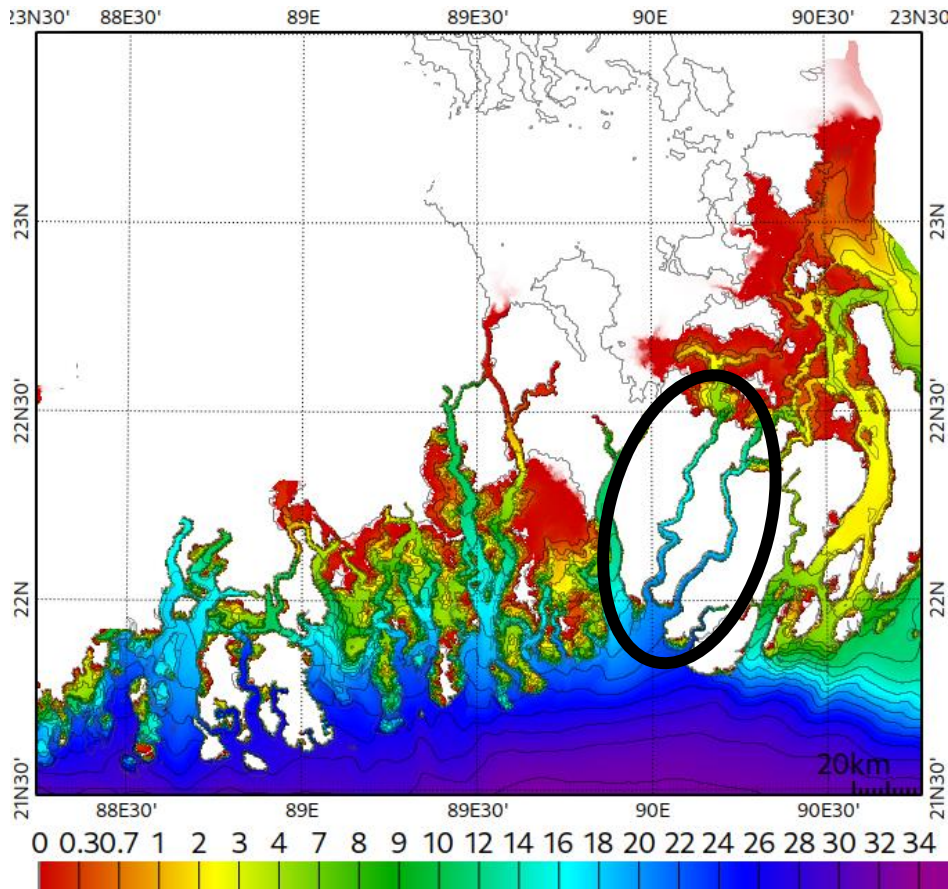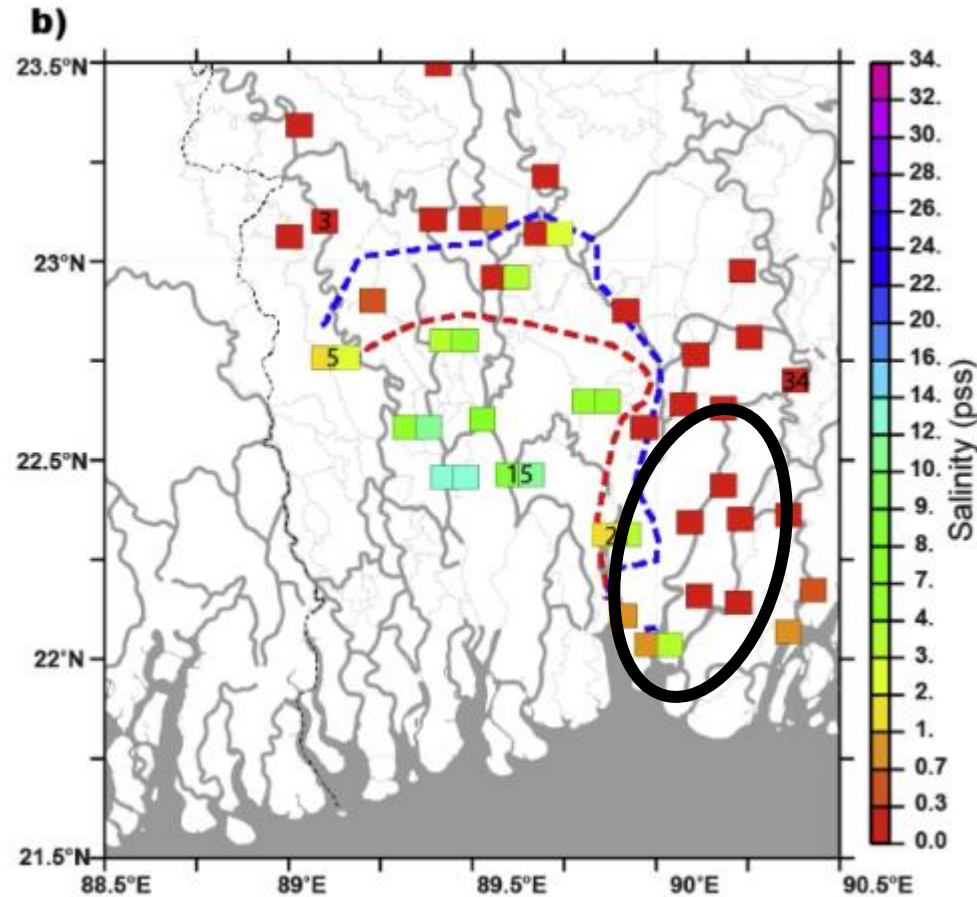
Modelled salinity average - April 2007

Salinity climatology in April from Sherin et al. (2020)

Good overall representation of the salinity

Overestimation of salinity intrusion in the Payra and Bishkhali rivers

A bit of "large scale" validation

Comparison with salinity measurements over 10 years (Sherin et al., 2020)
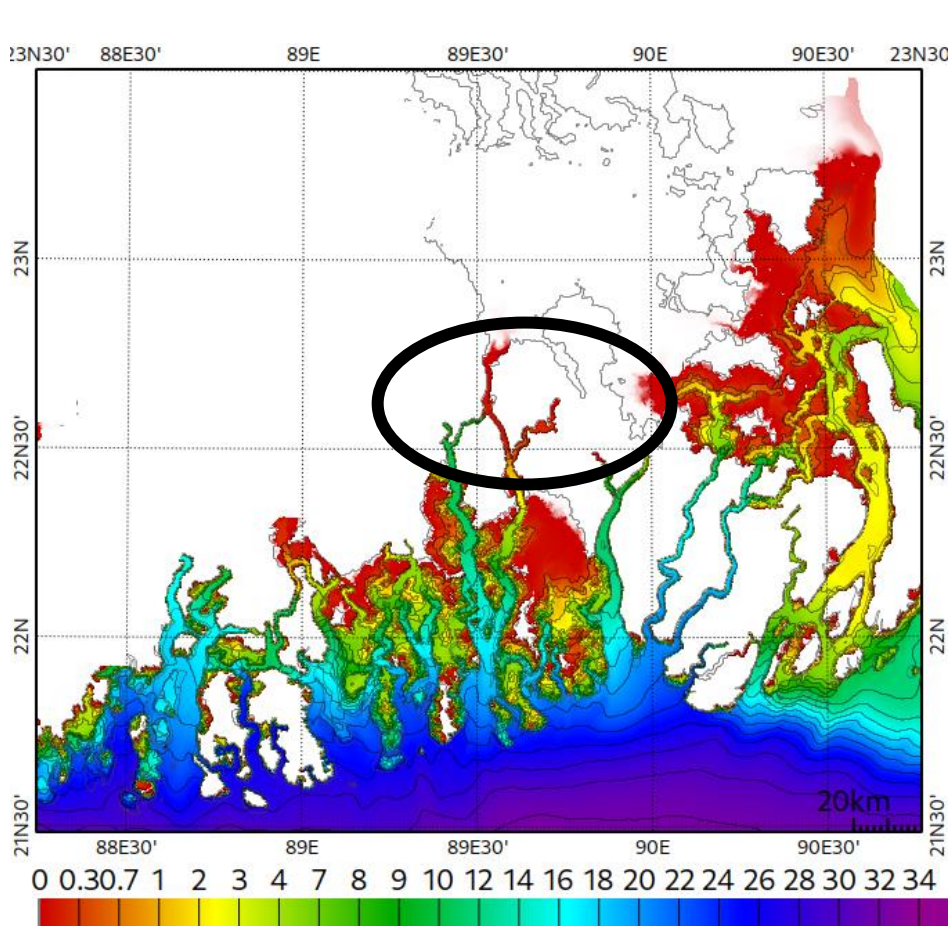
Modelled salinity average - April 2007

Salinity climatology in April from Sherin et al. (2020)

Good overall representation of the salinity

Overestimation of salinity intrusion in the Payra and Bishkhali rivers

Underestimation of salinity intrusion in the central part of the delta

A bit of "large scale" validation
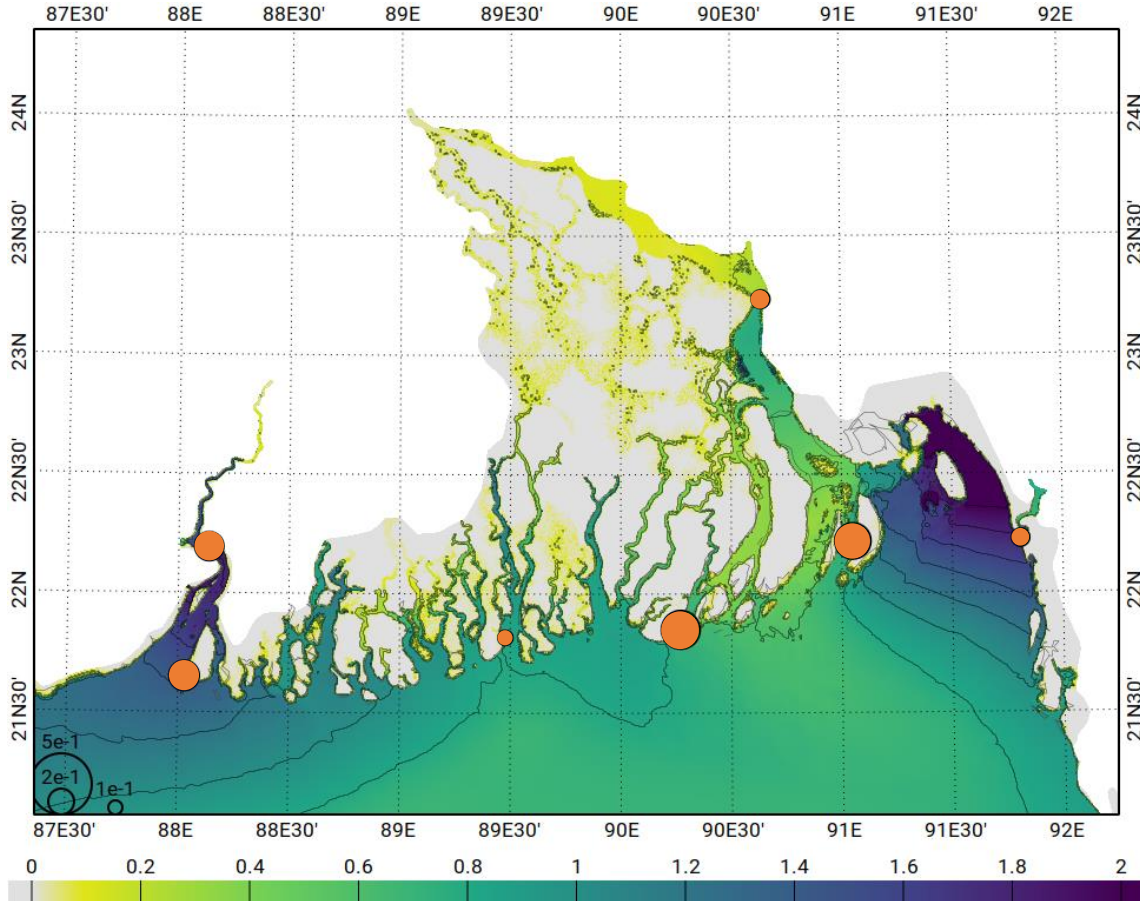
M2 tide (m) - 1-year simulation
Circle size proportional to the complex error

Complex errors: 10 to 30 cm

Amplitude errors: 0.4 to 18 cm

Not so bad...
What happens if we add new inland data?
(Testut et al., 2024)
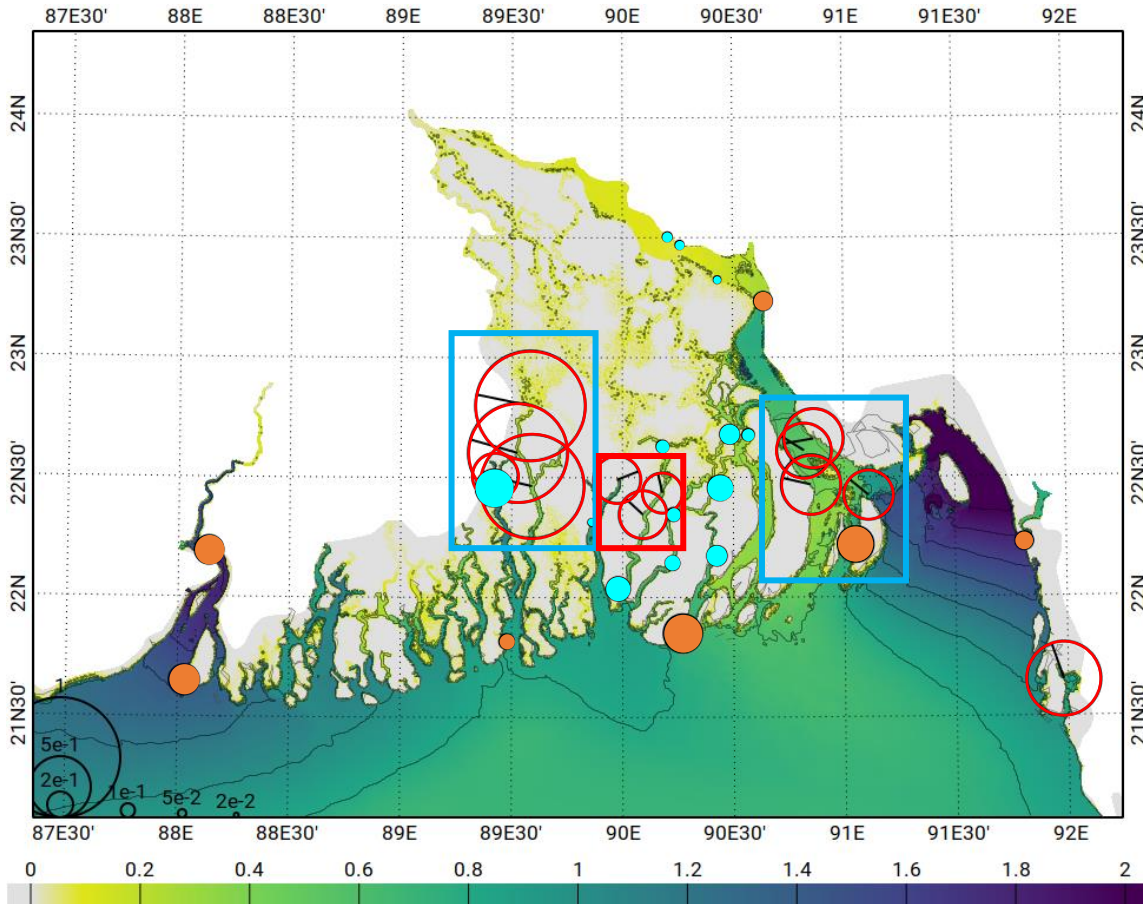
A bit of "large scale" validation
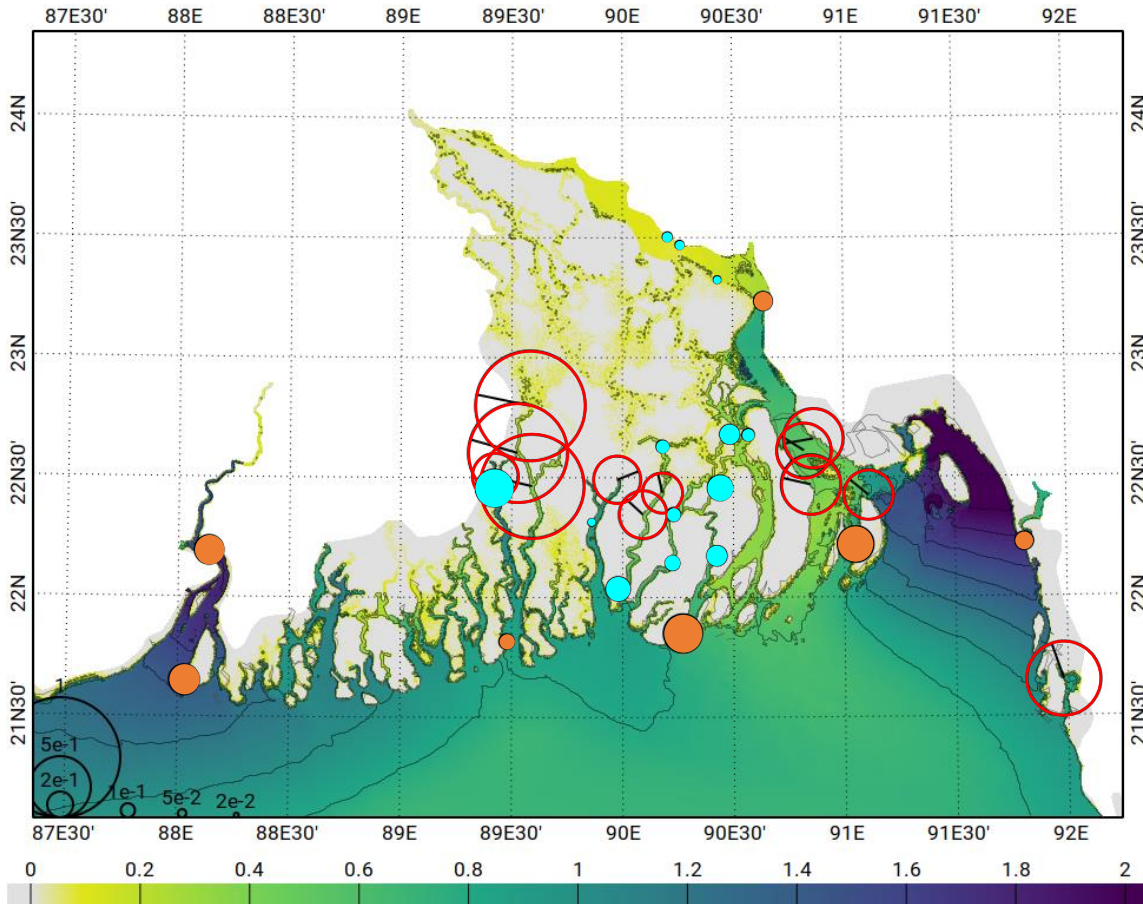
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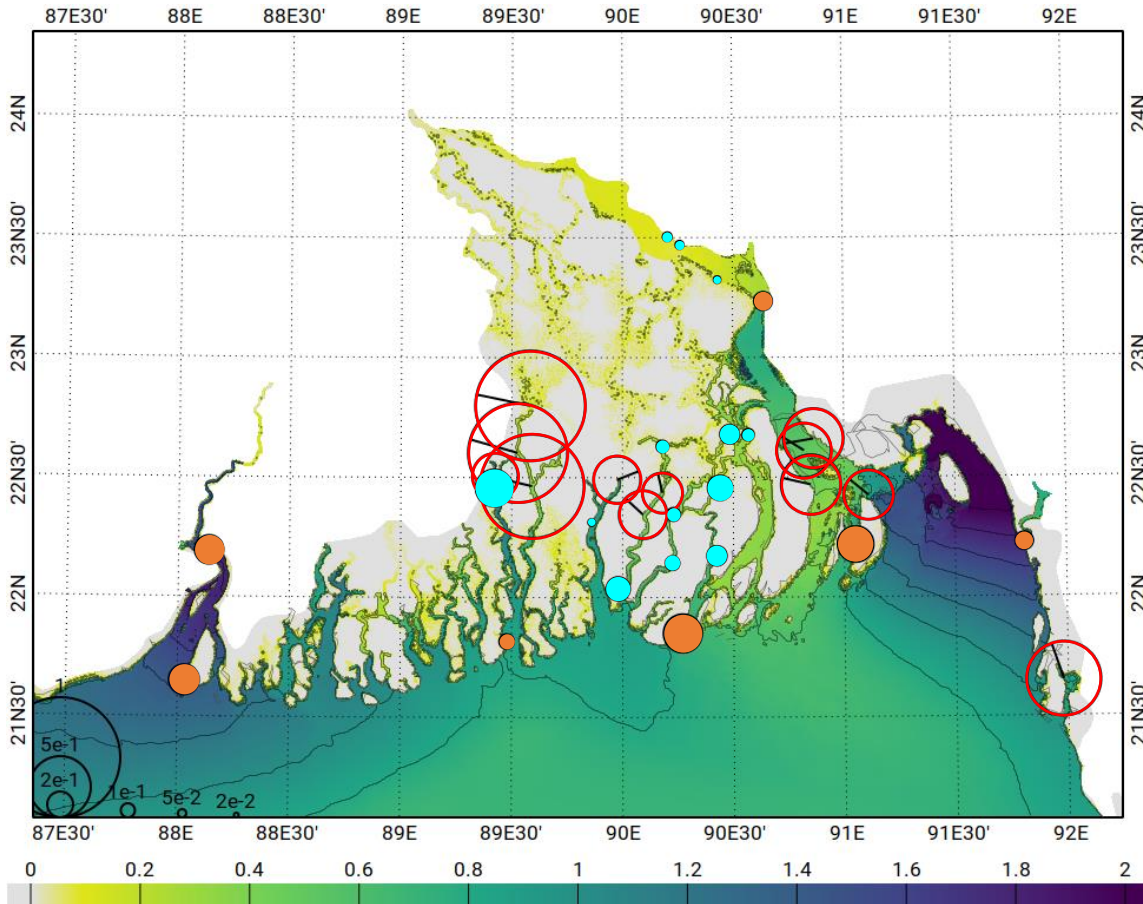
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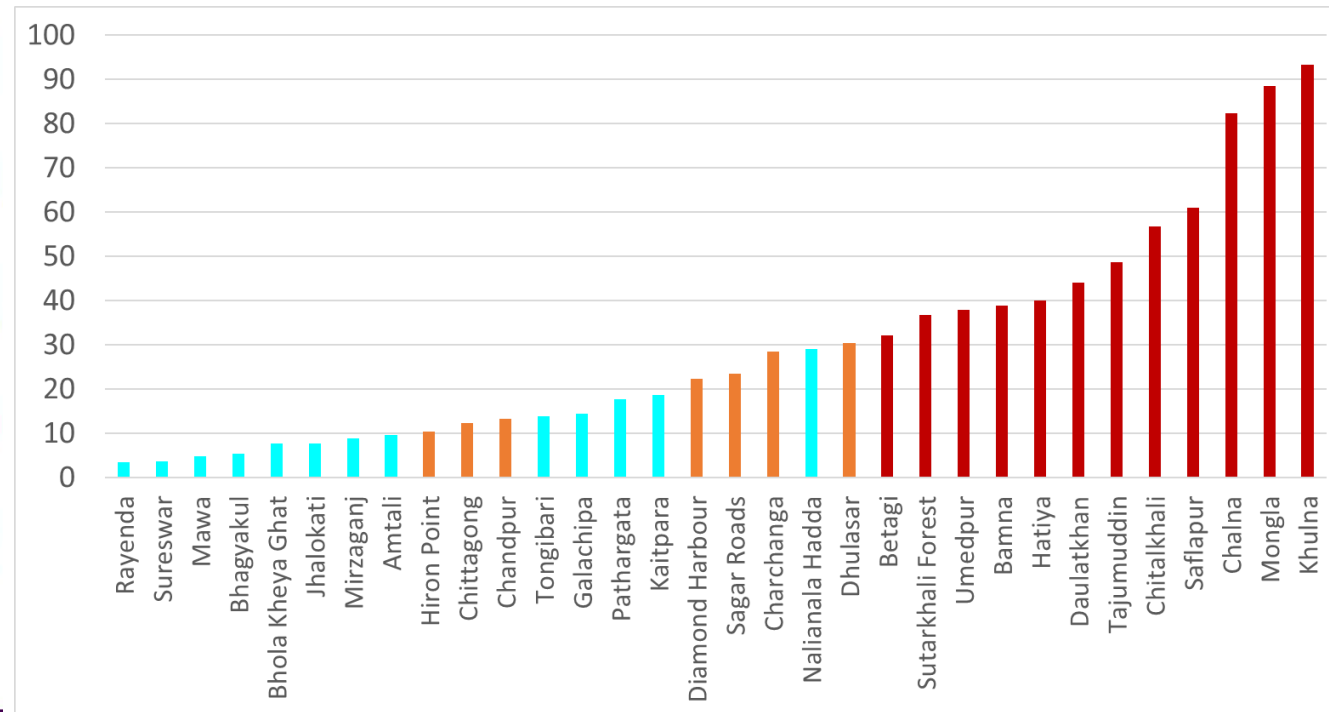
M2 complex error (cm)

A bit of "large scale" validation

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Underestimation of M2 amplitude
Overestimation of M2 amplitude

Looking more into detail
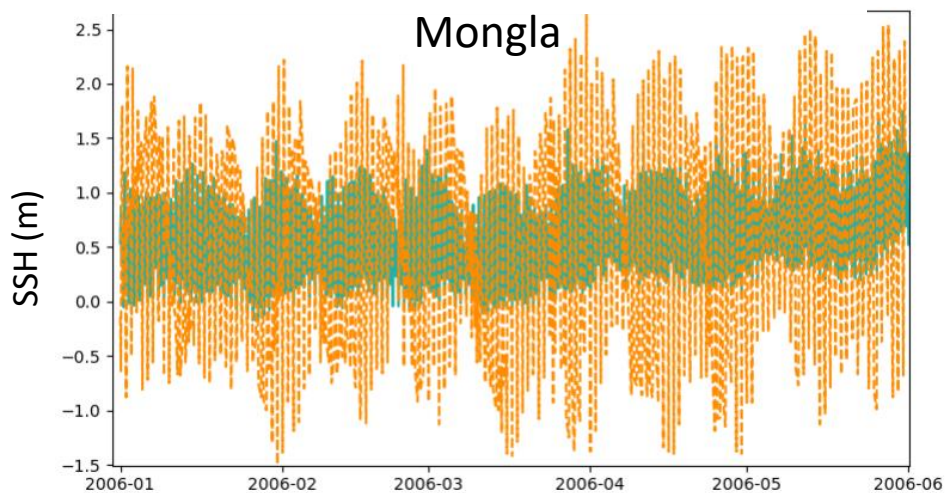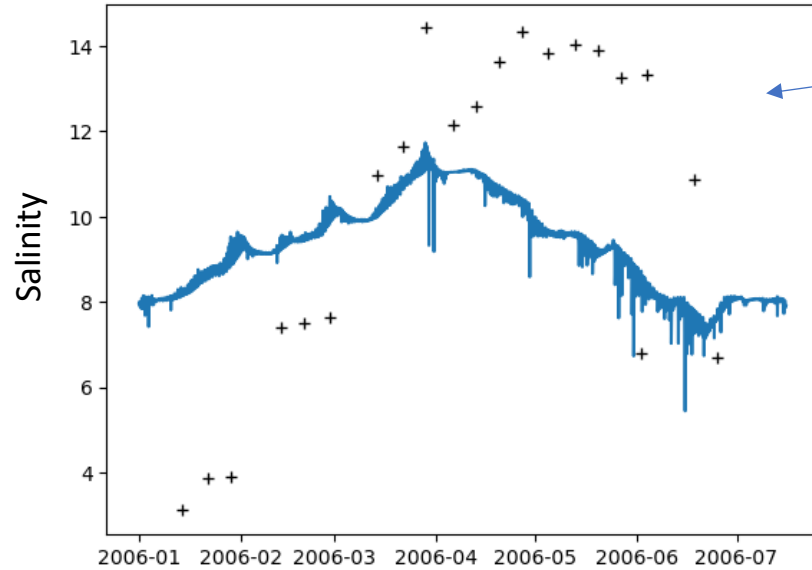
Mongla

+ Salinity data (Sherin et al., 2020)

— Model surface salinity

- - SSH data (Testut et al., 2024)

— Model SSH

Looking more into detail

Umedpur

Pathargata

Mongla

+ Salinity data (Sherin et al., 2020)

— Model surface salinity

- - SSH data (Testut et al., 2024)

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Looking more into detail

Umedpur

Pathargata

Mongla

Tajumuddin

+ Salinity data (Sherin et al., 2020)

— Model surface salinity

- - SSH data (Testut et al., 2024)

— Model SSH

Tides (M2) seasonality

Model difference = 20 cm vs

~10cm

Observed
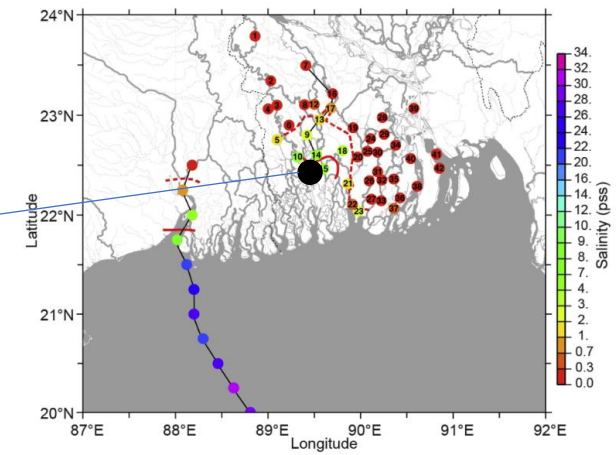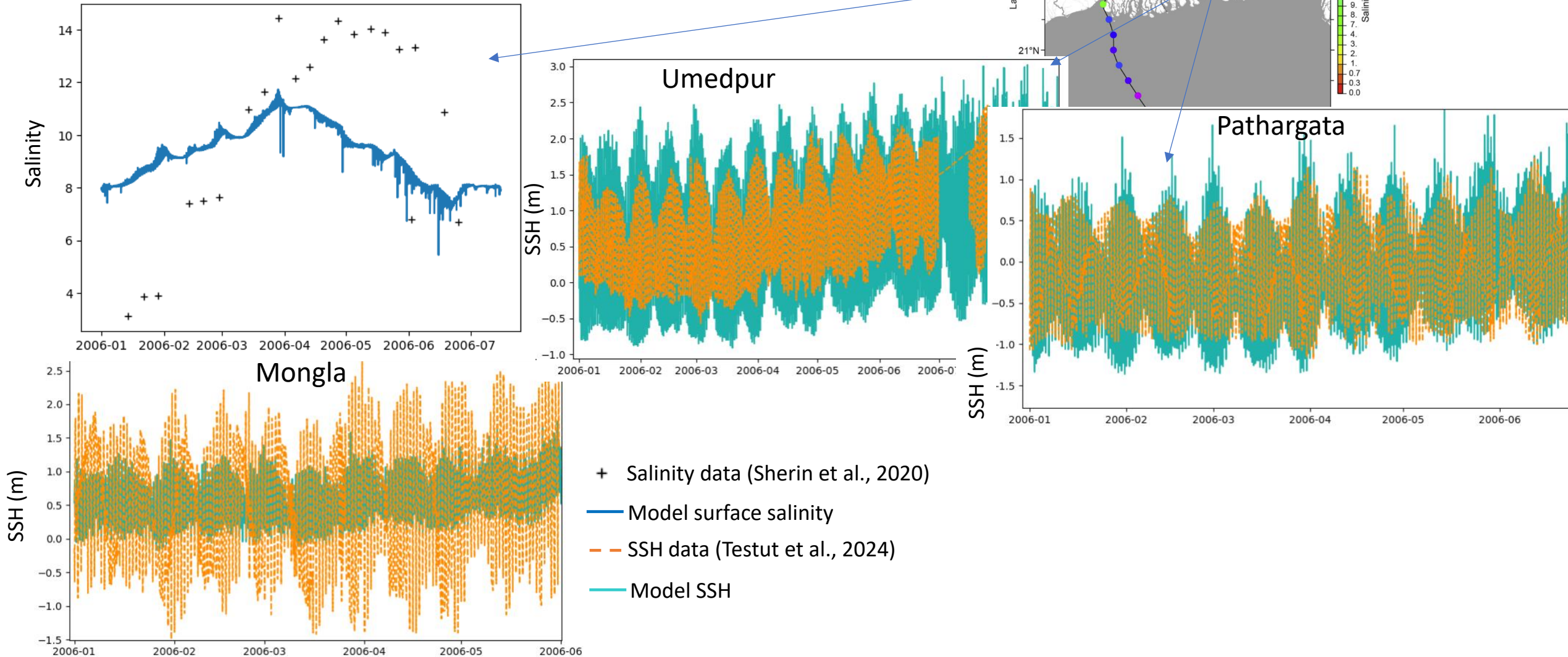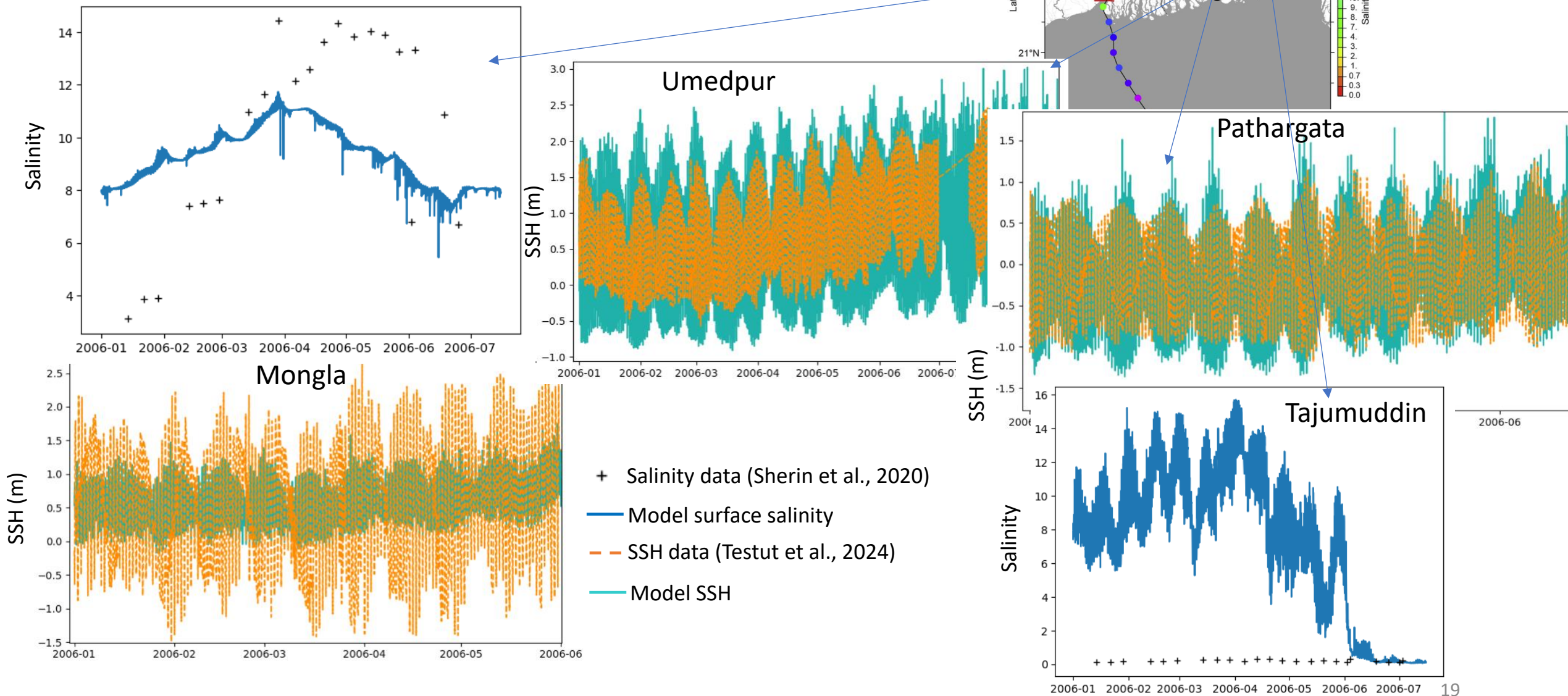
Modelled M2 tide (m) - 1-year simulation
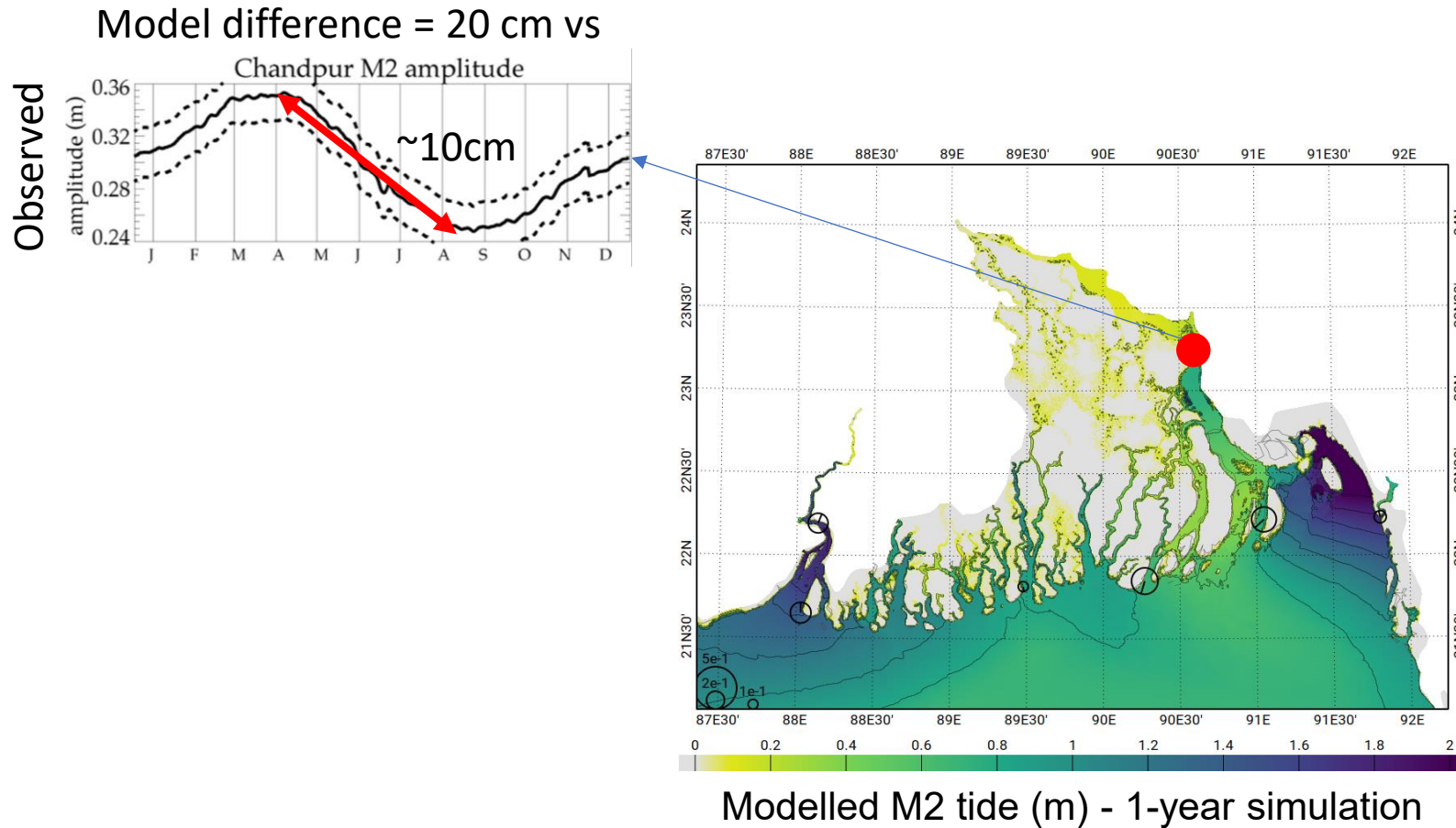
Tazkia et al., 2017
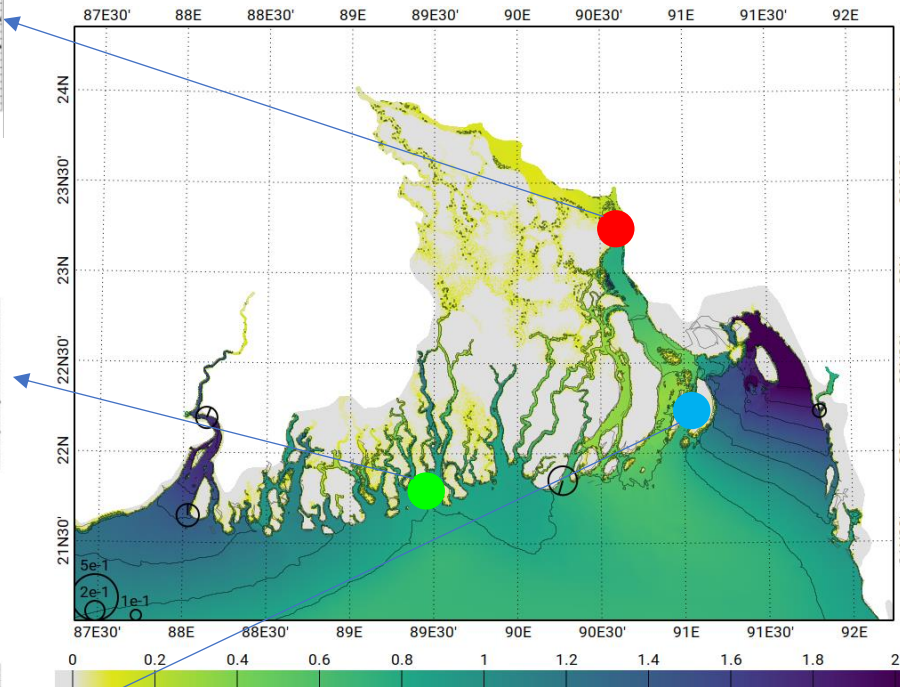
Tides (M2) seasonality

Model difference = 20 cm vs
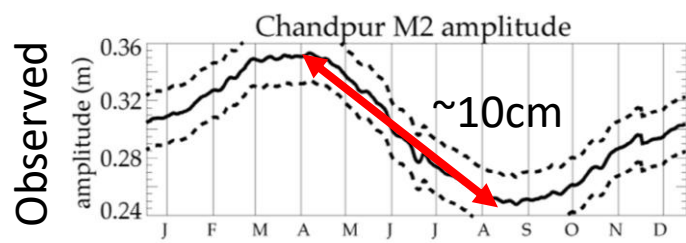
Model difference = 9 cm vs

Modelled M2 tide (m) - 1-year simulation

Tazkia et al., 2017

Tides (M2) seasonality

Model difference = 20 cm vs

Observed

Model difference = 9 cm vs

Observed

Model difference = 11 cm vs

Observed
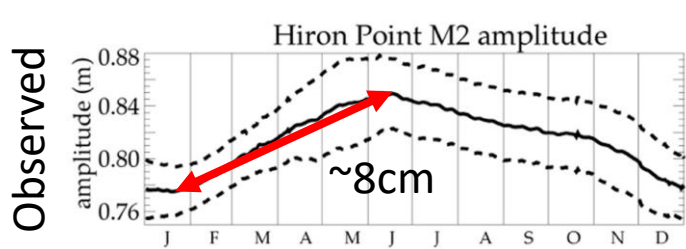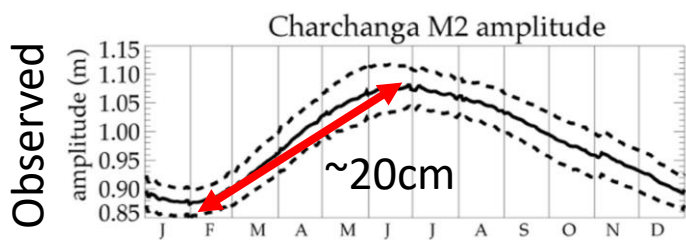
Tazkia et al., 2017

Modelled M2 tide (m) - 1-year simulation
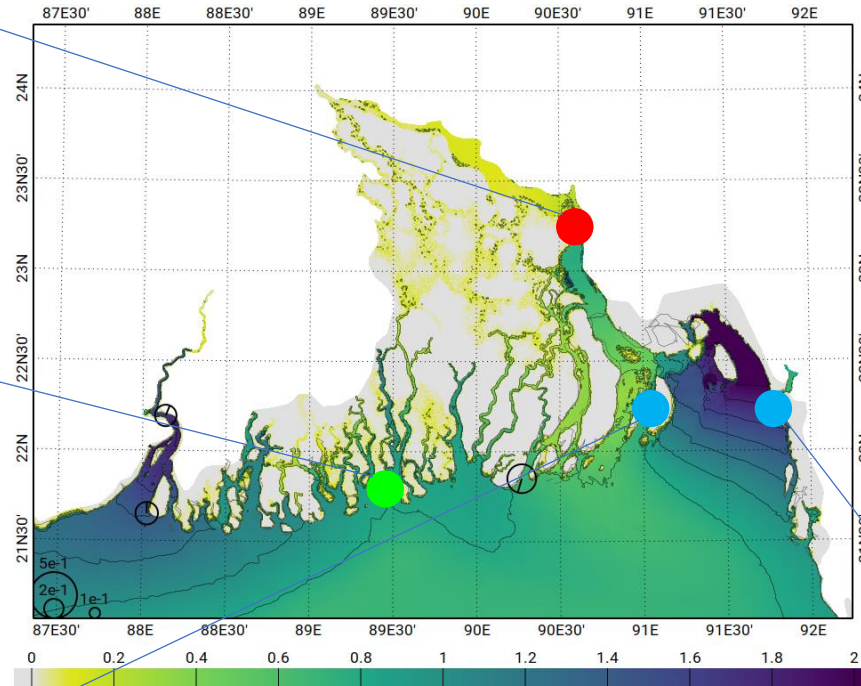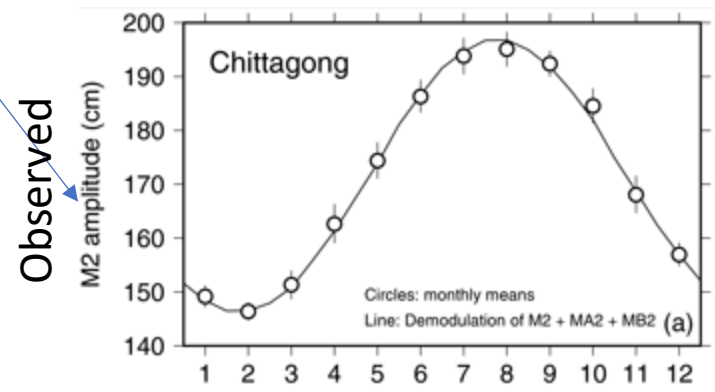
Tides (M2) seasonality

Model difference = 20 cm vs

~10cm

Model difference = 9 cm vs

~8cm

Model difference = 11 cm vs

~20cm

Tazkia et al., 2017

Modelled M2 tide (m) - 1-year simulation
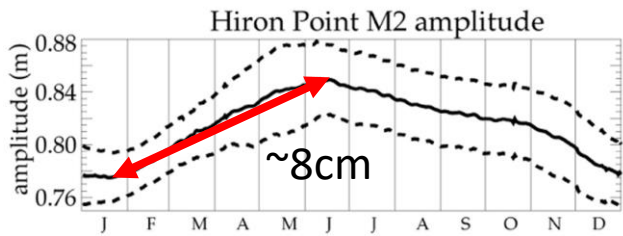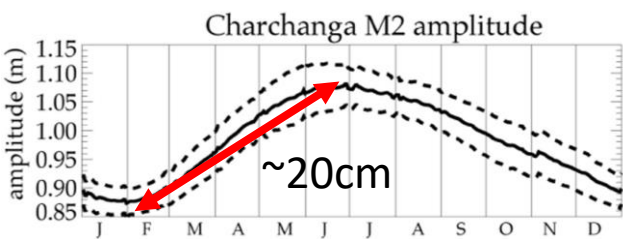
Chittagong - Model difference = 22 cm
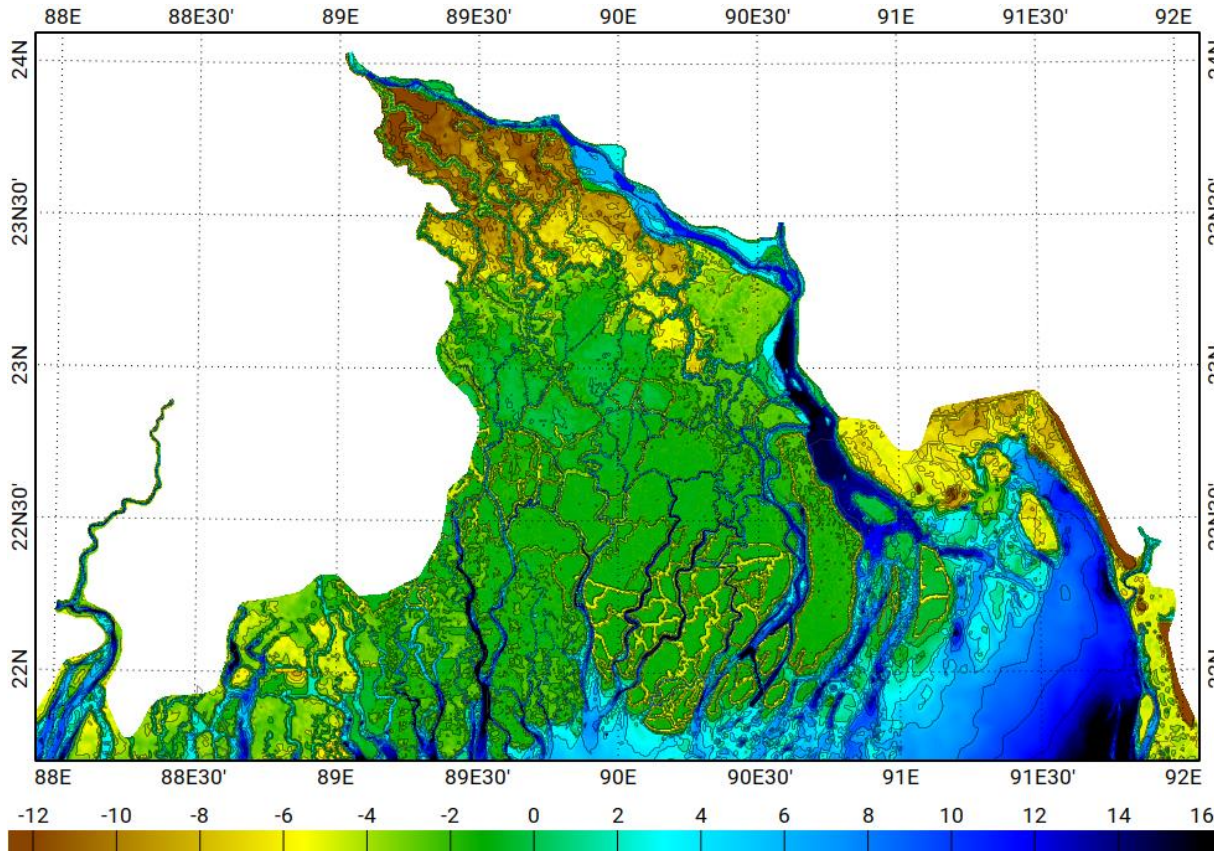

wet – dry
M2 amp (m)
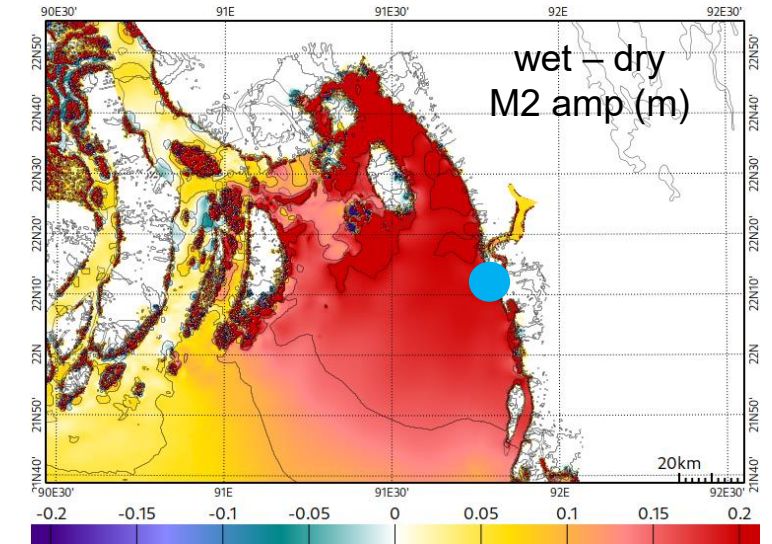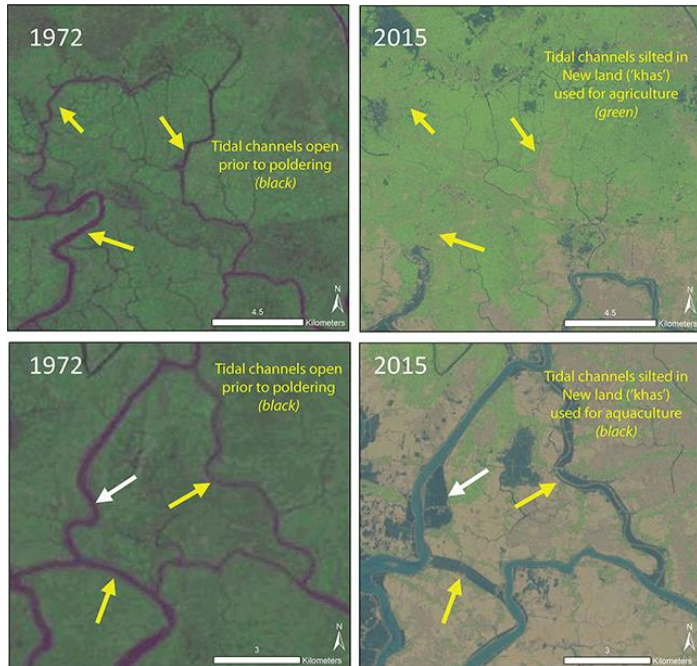
vs 49cm !!

Ray et al., 2022

Challenges of a "megadelta-scale" configuration
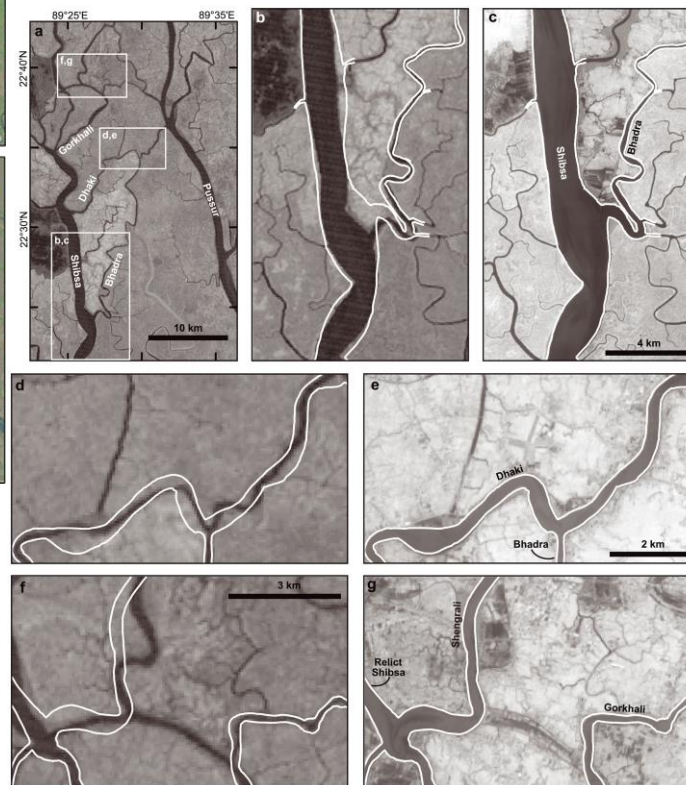

Bathymetry of the Bengal delta (m)

Complex network of interconnected channels

Dynamic system, due to both natural and anthropogenic impact (Wilson et al., 2017)

Challenges of a "megadelta-scale" configuration

Wilson et al., 2017

Bain et al., 2019

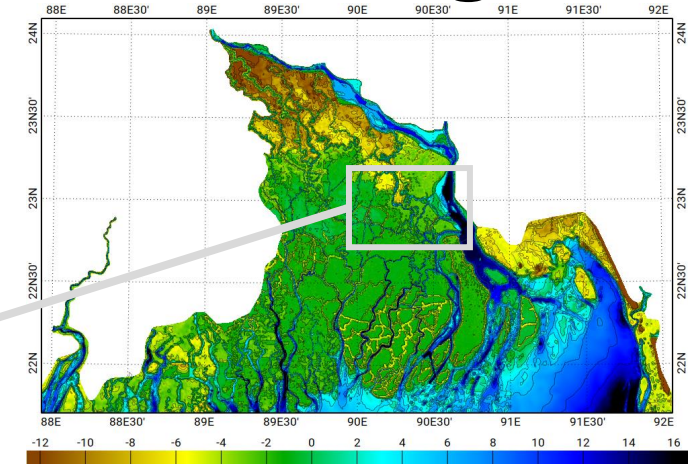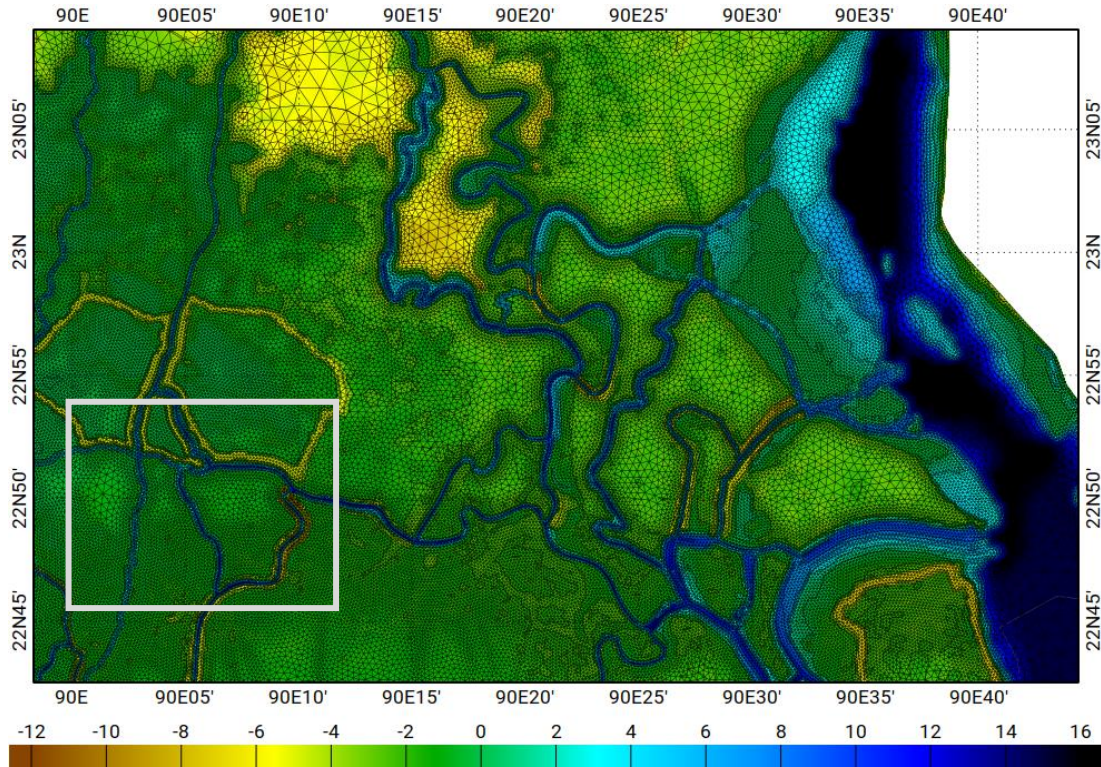Complex network of interconnected channels

Dynamic system, due to both natural and anthropogenic impact (Wilson et al., 2017)
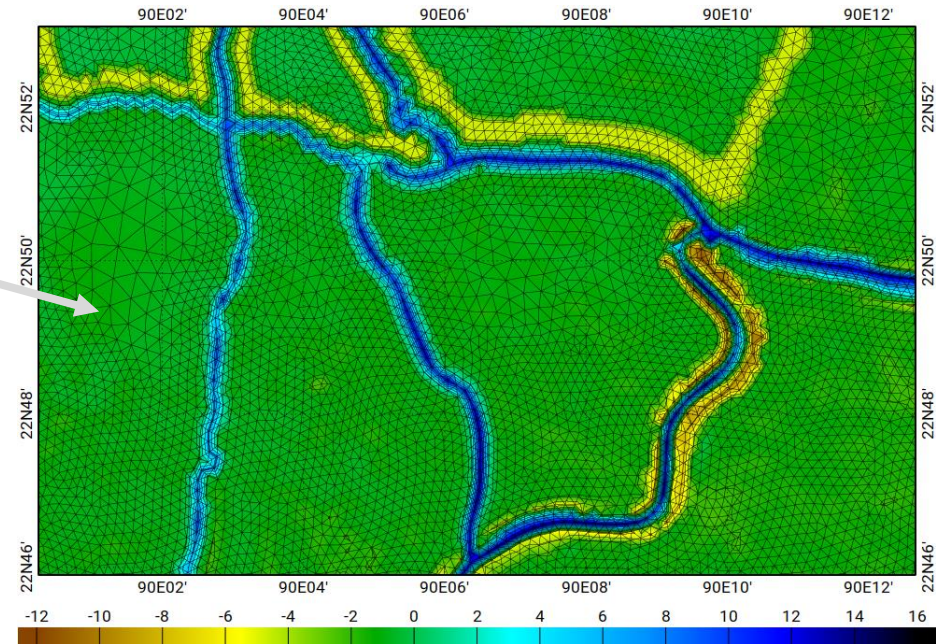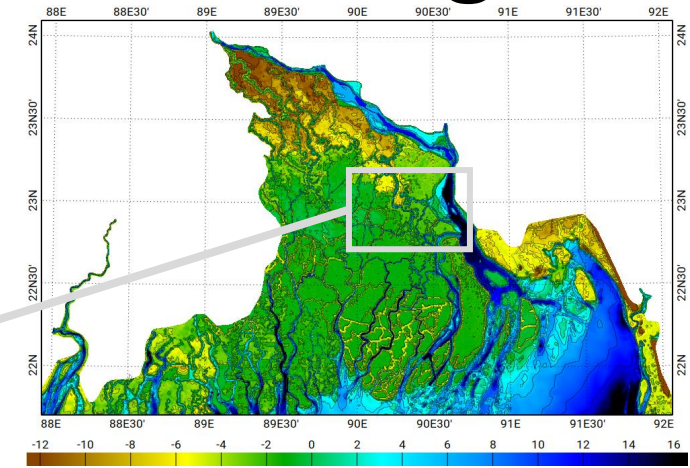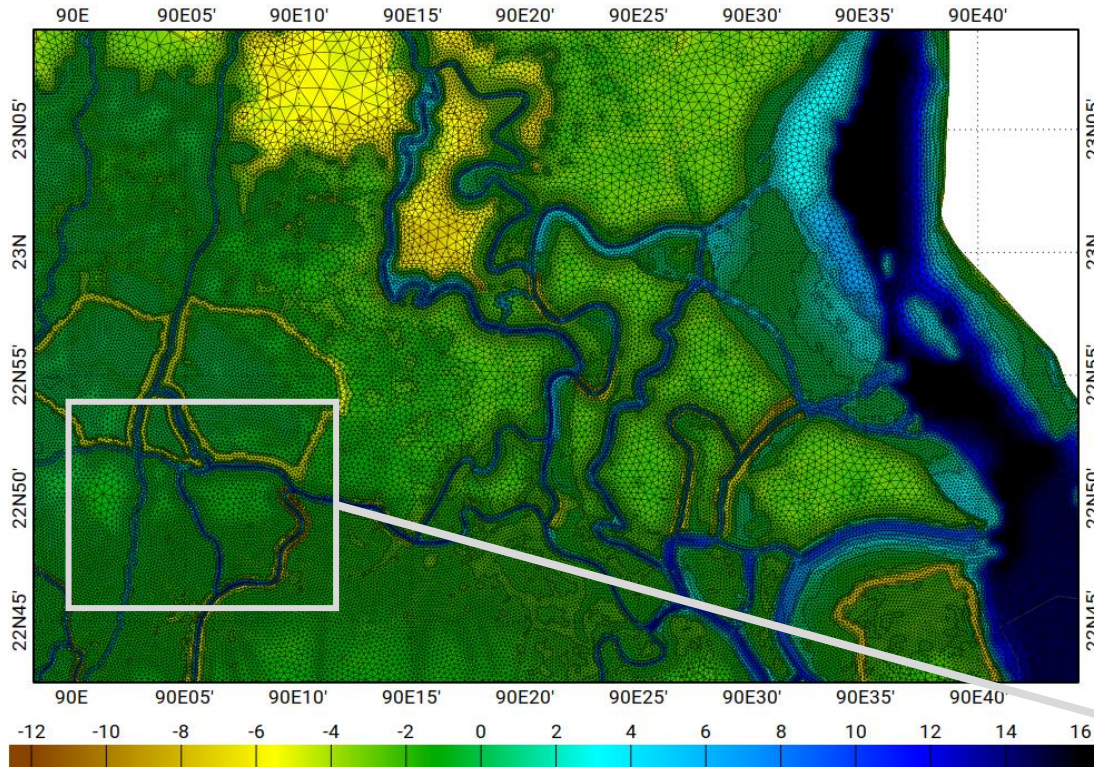=> morphodynamic system
=> human polderization, channel scouring and/or widening (Bain et al., 2019)

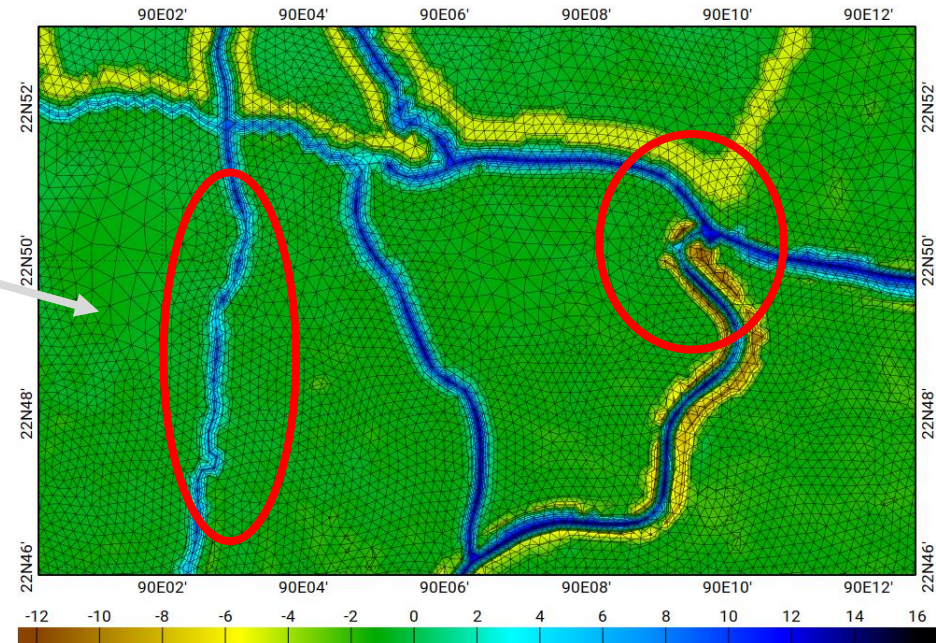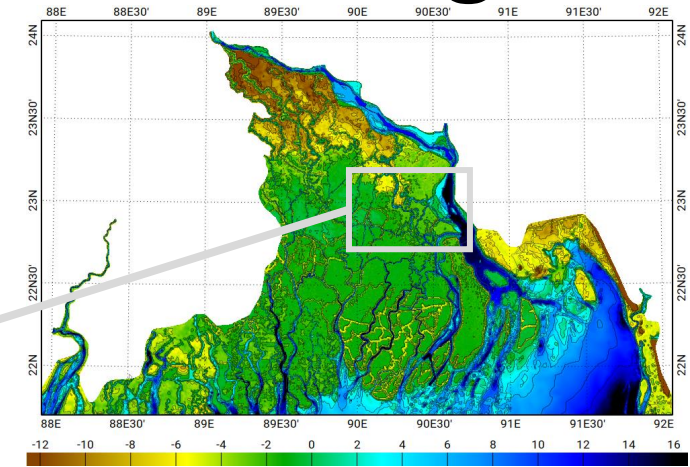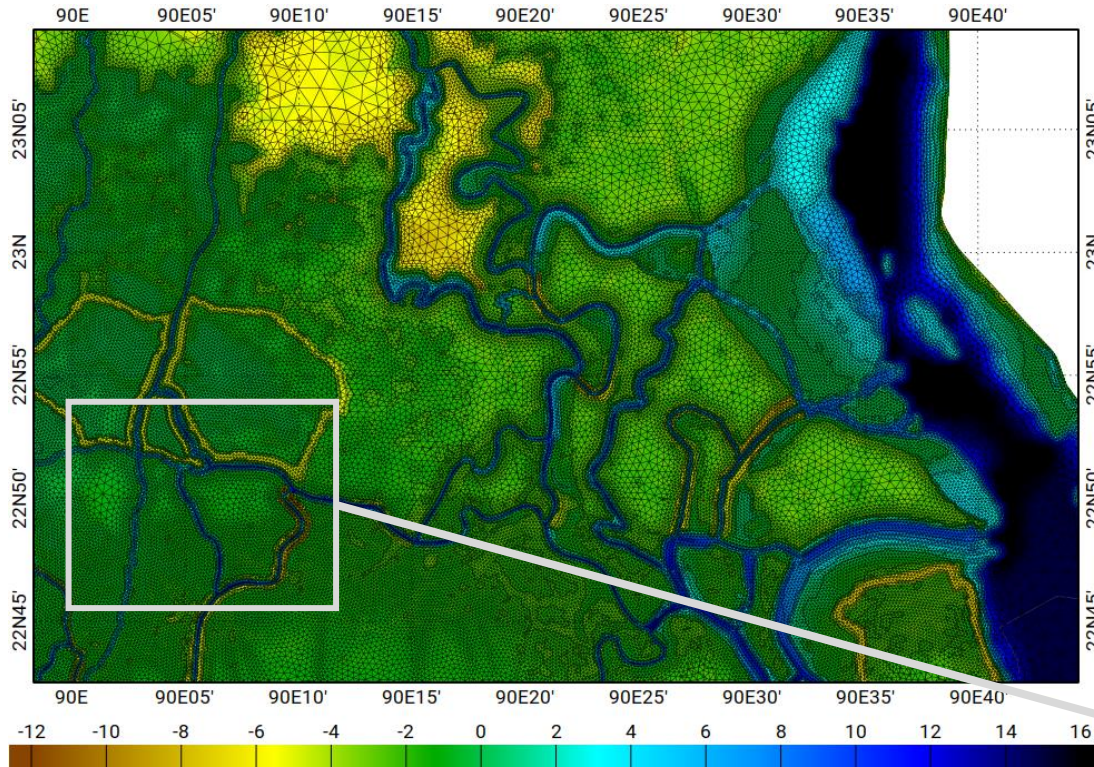How to properly mesh and represent this complex environment?

Challenges of a "megadelta-scale" configuration

Challenges of a "megadelta-scale" configuration
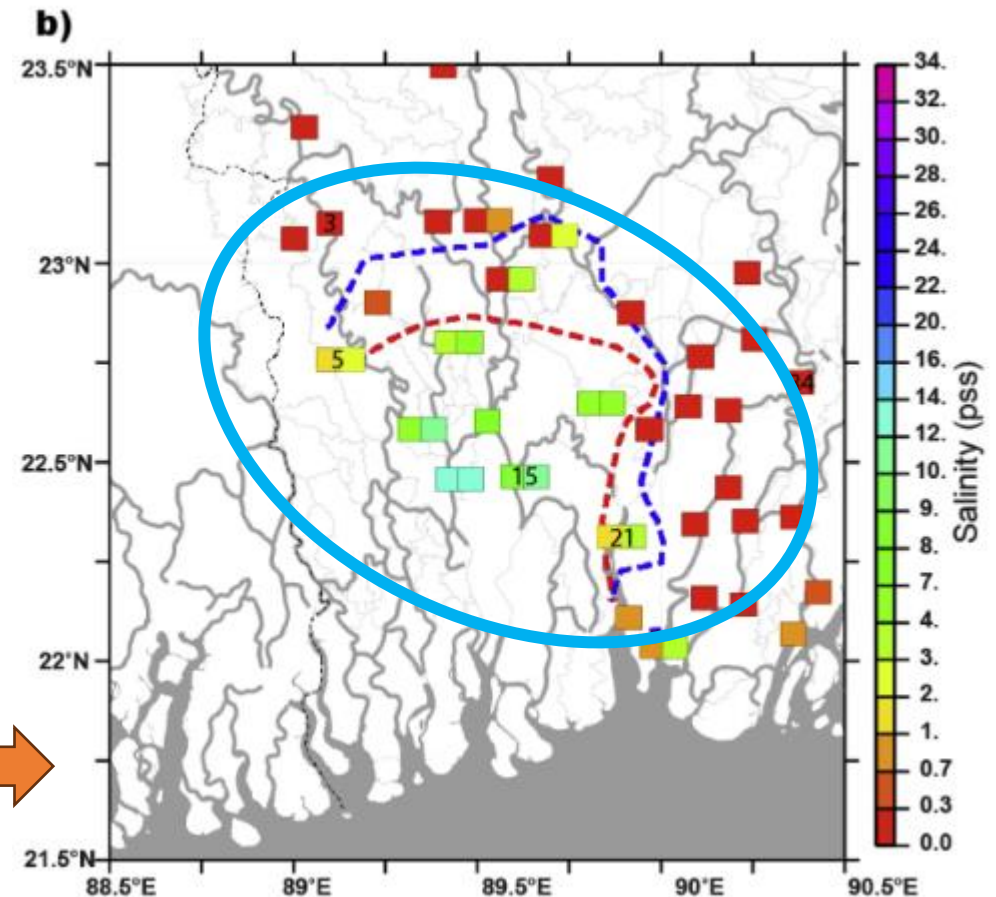
Challenges of a "megadelta-scale" configuration

Ongoing work…

- Better representation of tides and the M2 seasonal modulation
  - Better distributaries connectivity
  - Bathymetry
  - Turbulence tuning
  - Vertical grid
  - River discharge
  - …

- Switch to 2DH in very shallow regions (Zhang et al., 2022)

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- Switch to 2DH in very shallow regions (Zhang et al., 2022)

- Investigate the 2006-2007 shift in salinity (Sherin et al., 2020)

Thank you!