Coastal modelling of a mega delta; Tide and river interactions

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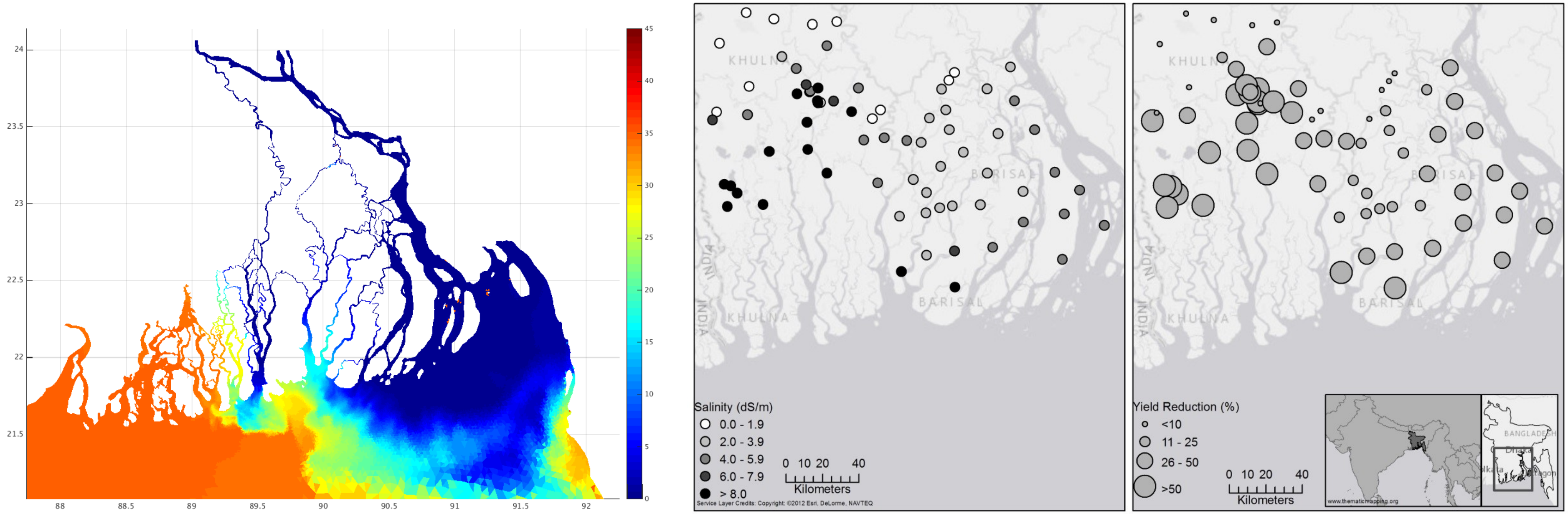
Motivation: What controls transport of salinity in a complex delta & estuarine system?

Context

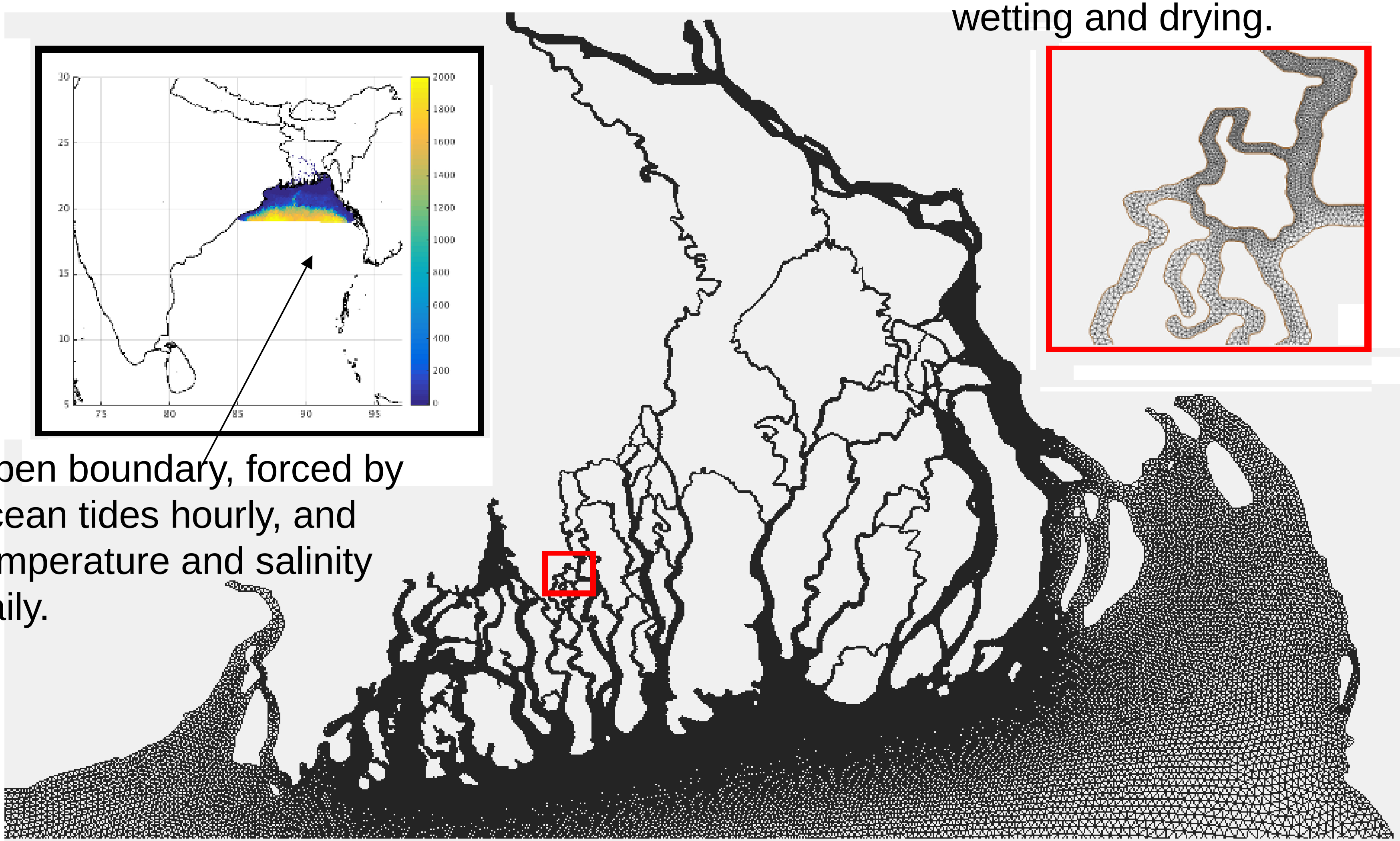
- High salinity values are observed in the south and west of the delta.
- This leads to reduced crop yields, impacting on the livelihoods of local people.
- Local river and tidal processes control the salinity on the delta



Snapshot of modelled river salinity (left) and observations of soil salinity (centre) and crop yield reduction (right)

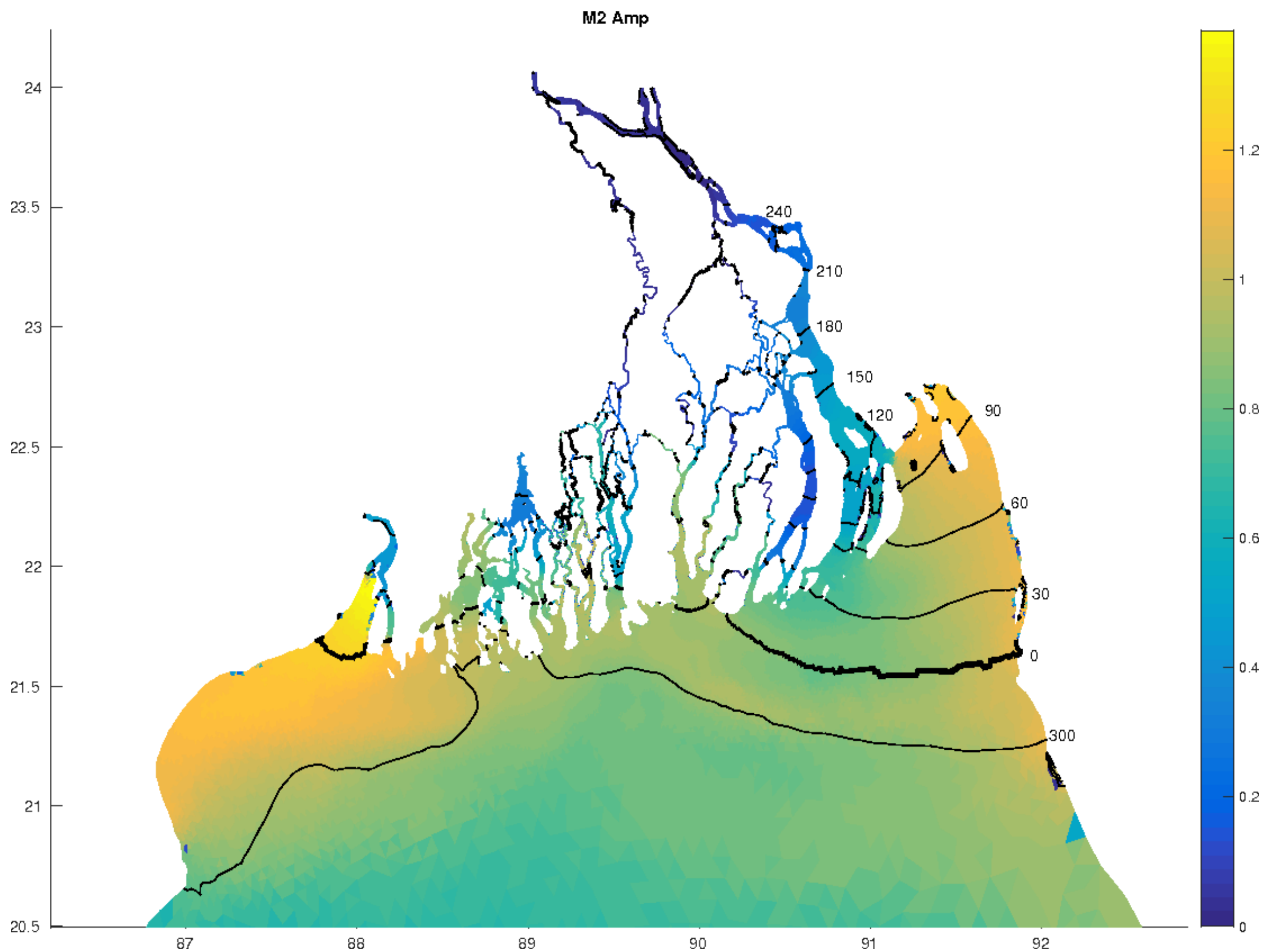
Approach

30 arc-second GEBCO bathymetry. Model permits wetting and drying.



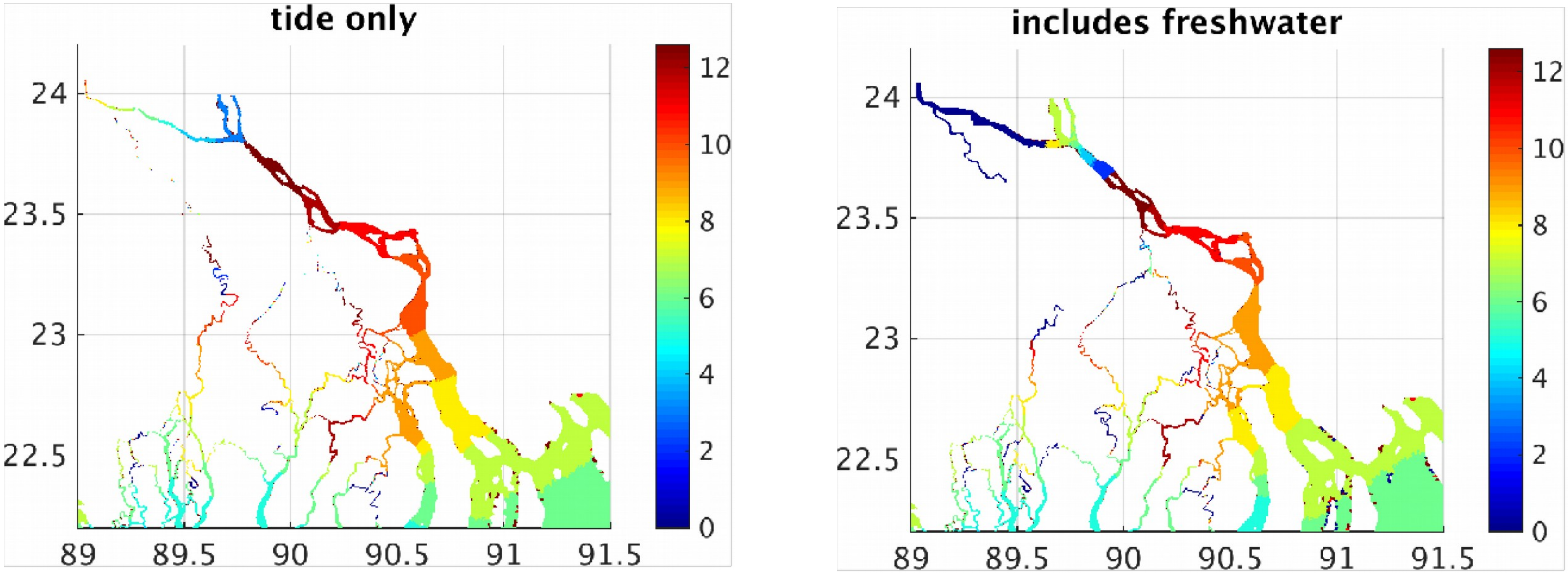
Open boundary, forced by ocean tides hourly, and temperature and salinity daily.

Controlling processes: tide



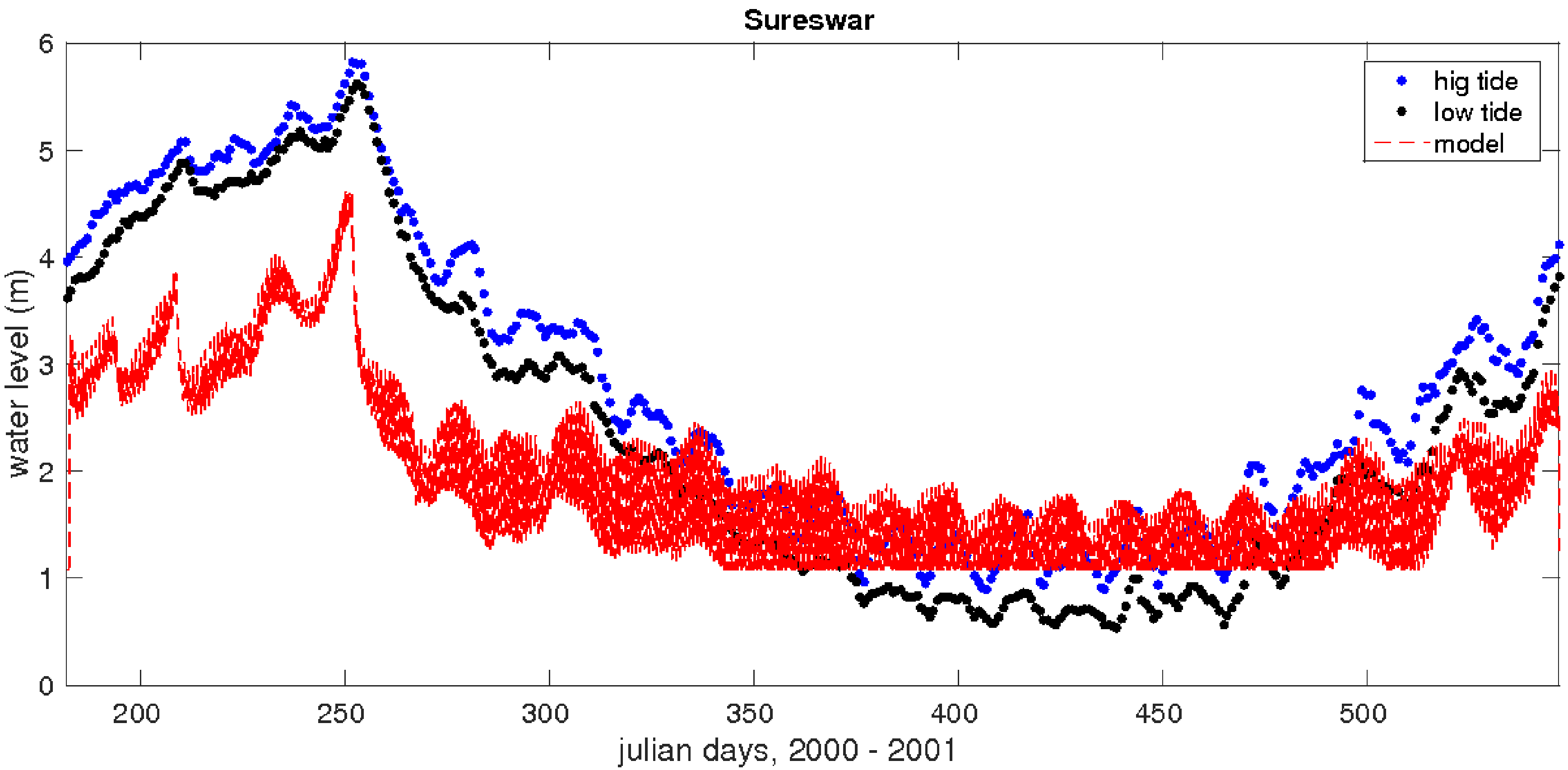
- Diurnal tide, with range around 3m.
- Two hotspots of amplified semidiurnal tides to the NW and NE corners
- Tide penetrates over 2 degrees north inland
- There is significant interannual variability, related to the monsoon.

Tidal penetration in-land



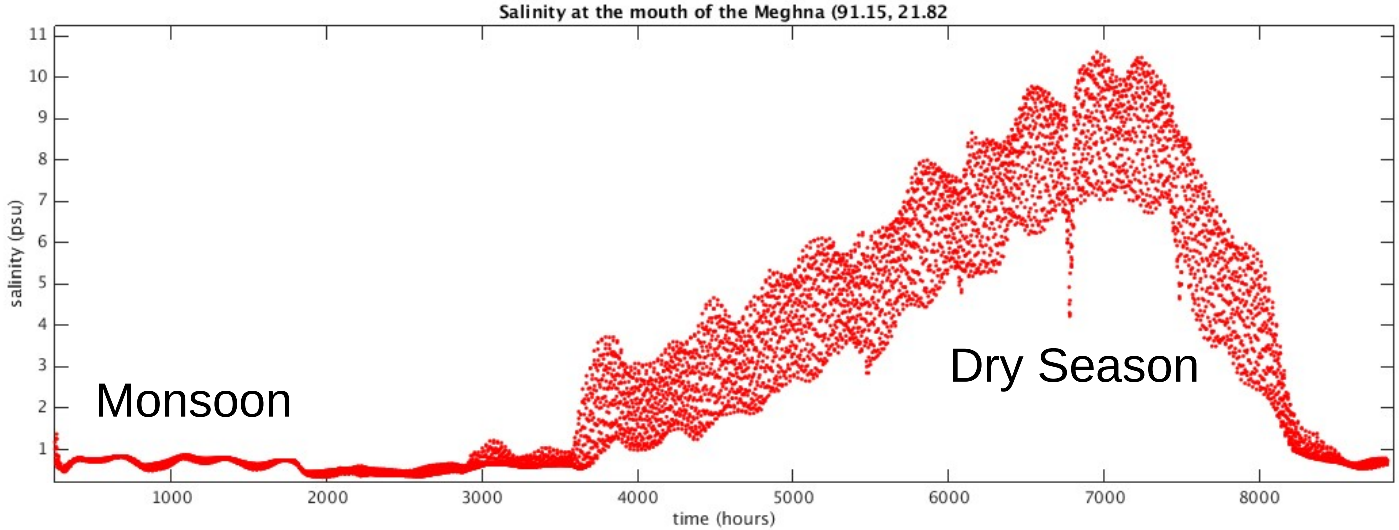
- Time taken for high tide (starting at shelf-break 200m water depth) takes to penetrate in-land.
- Left panel shows a model with tide-only, right panel includes river discharge.
- When river discharge is included, speed of tidal wave penetration is retarded.

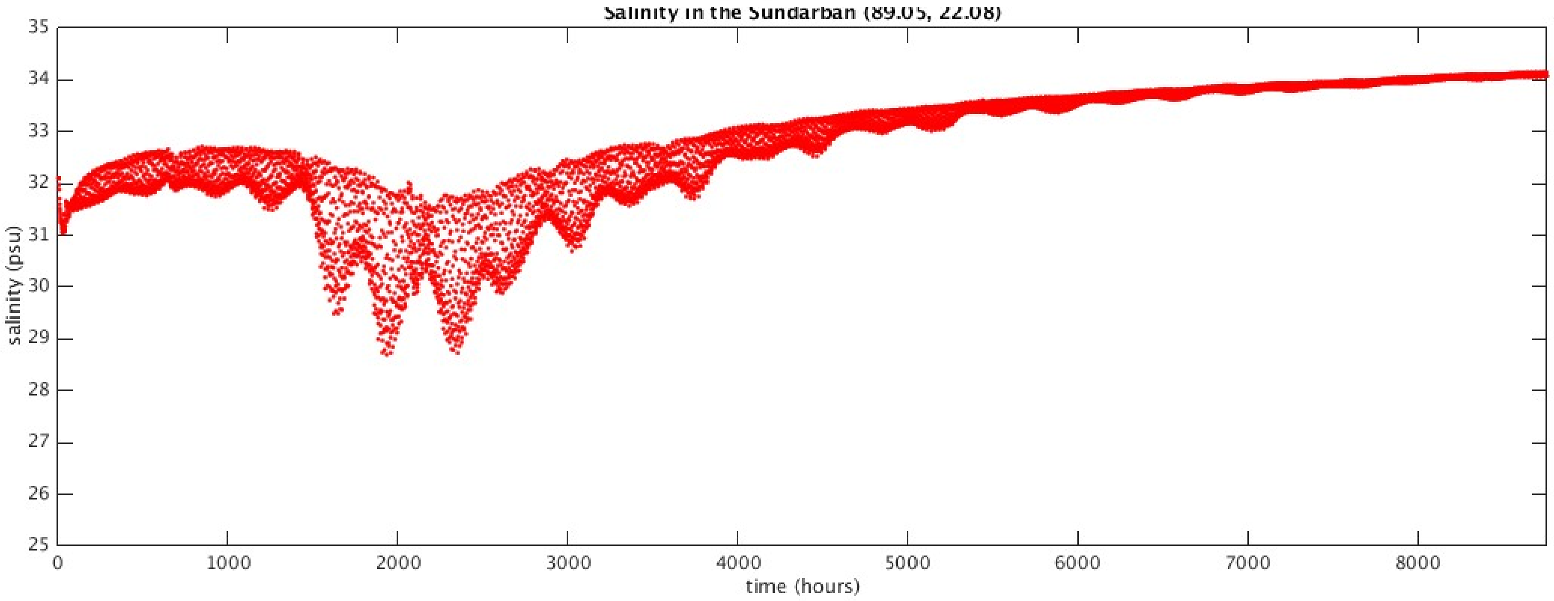
Controlling processes: river



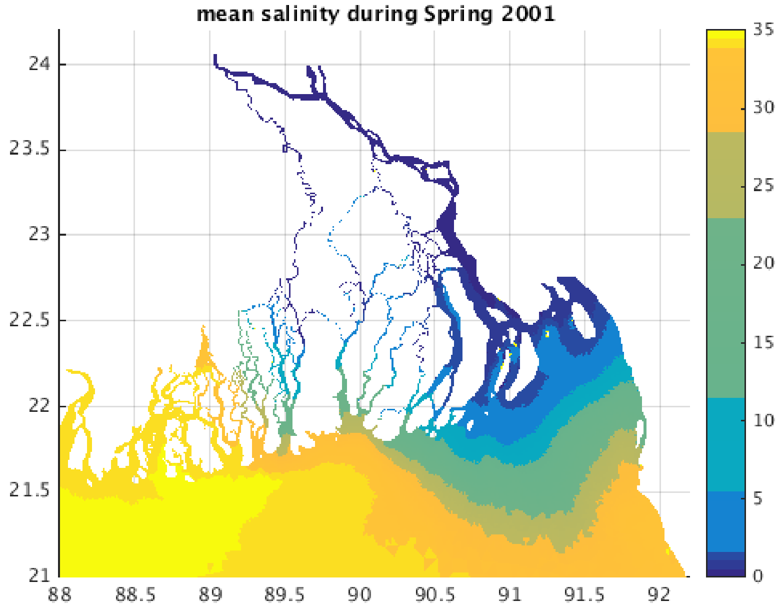
- Extra water volume associated with river discharge can raise water levels by over 3m in places.
- The extra discharge also suppresses the tide, reducing the amplitude.

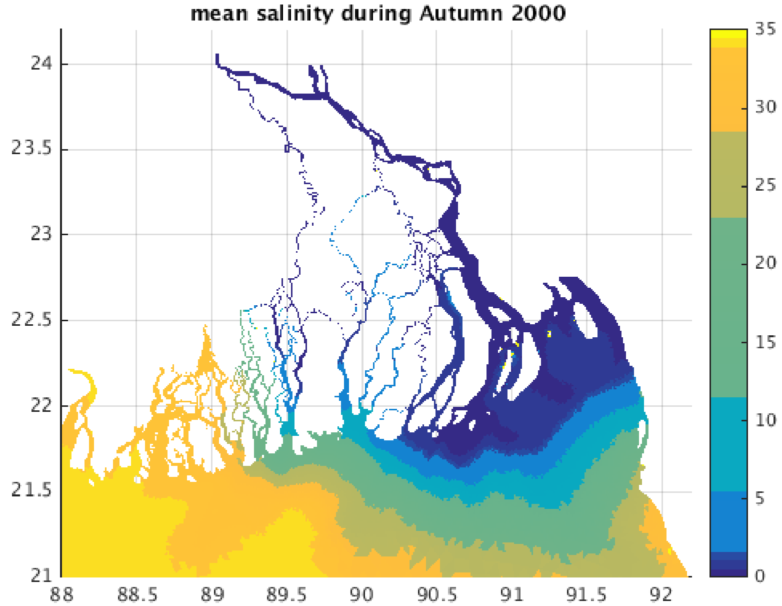
Impact of river / tide on salinity





Timescales of variability: seasonal

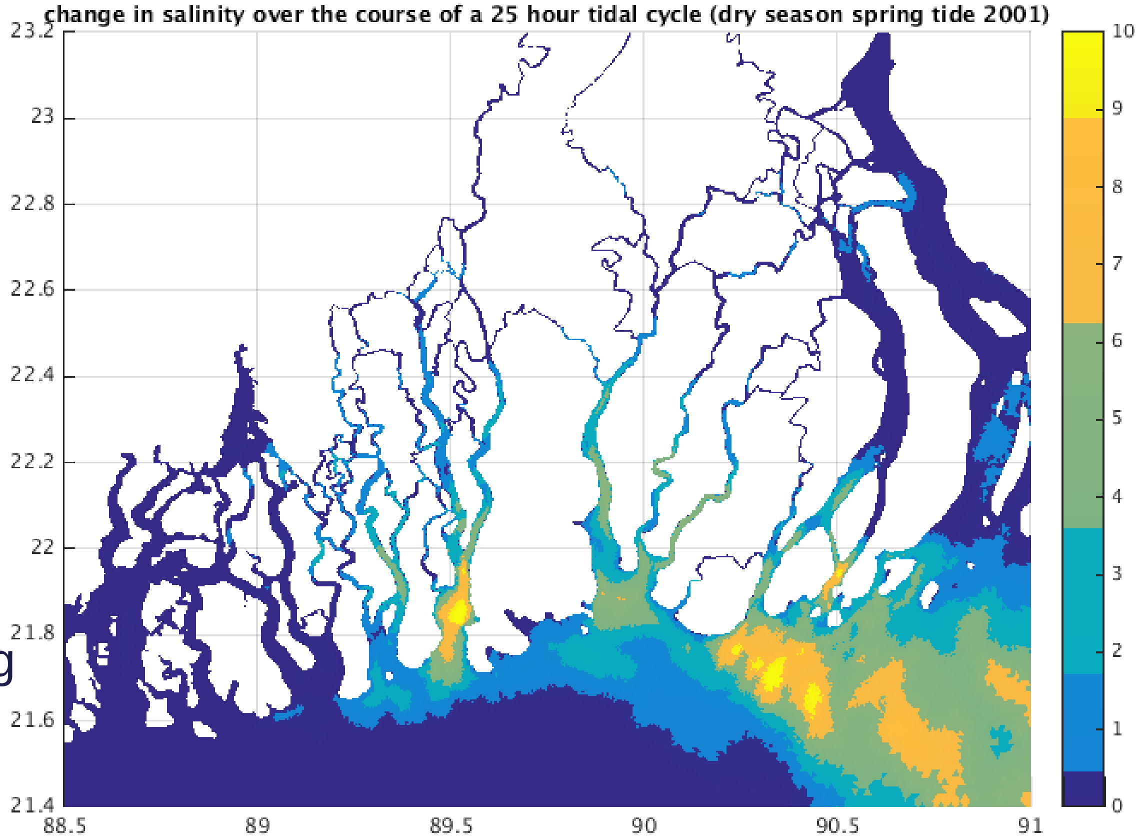




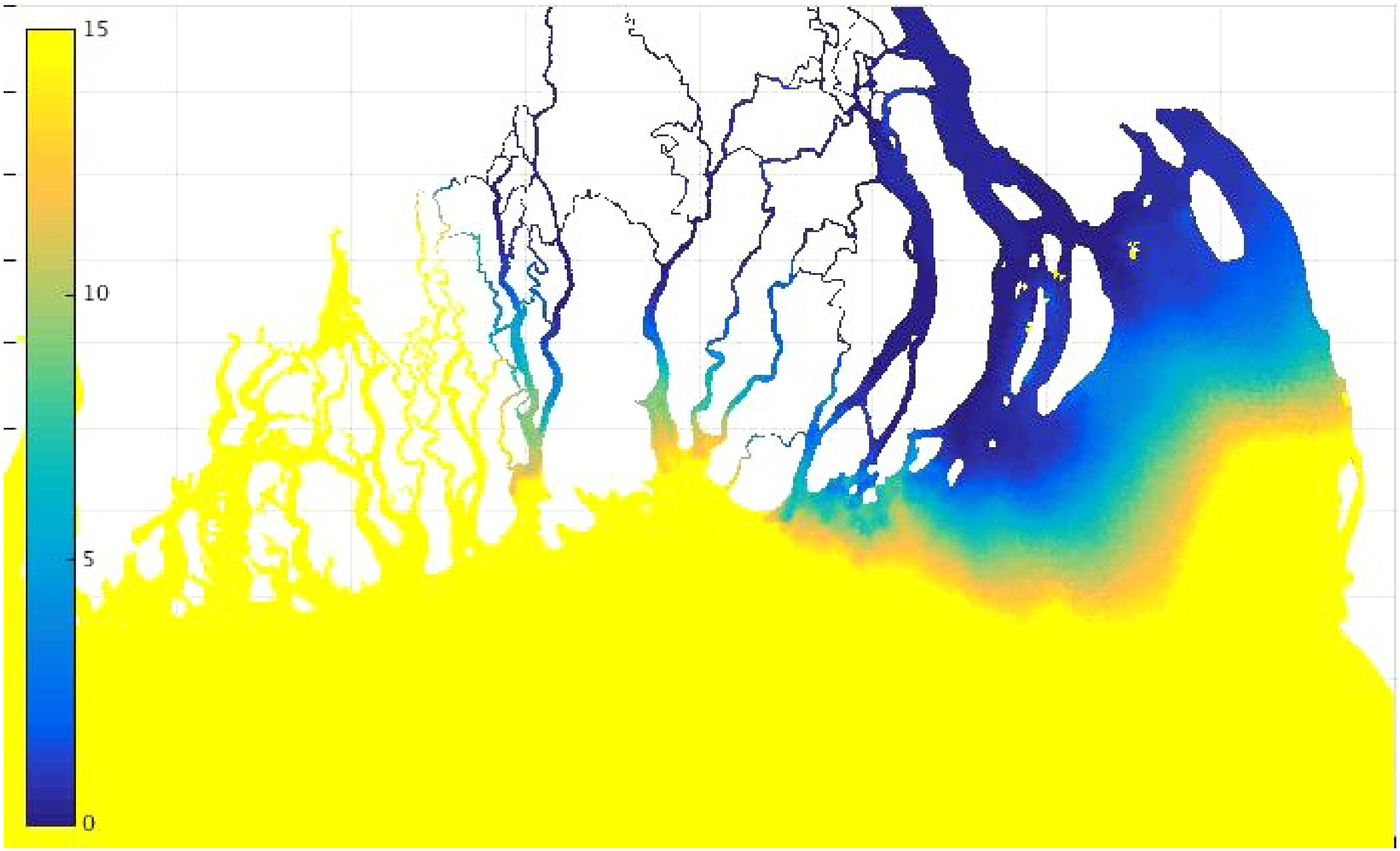
- During the dry season there is increased salt penetration into the river channels.
- In the monsoon, increased river discharge flushes the river distributary system, and creates a large freshwater plume offshore.
- The annual salinity difference at any one site can be greater than 10 psu.

Timescales of variability: tidal

- Over the course 12.5 hours, the tidal excursion can alter the local salinity by up to 10psu.
- The distance of movement of the fresh/salt water front can be 10s of km
- The distance of tidal excursion can change over the spring/neap cycle
- Depending on whether it is during dry season, or a monsoon, the tide will penetrate further into the delta



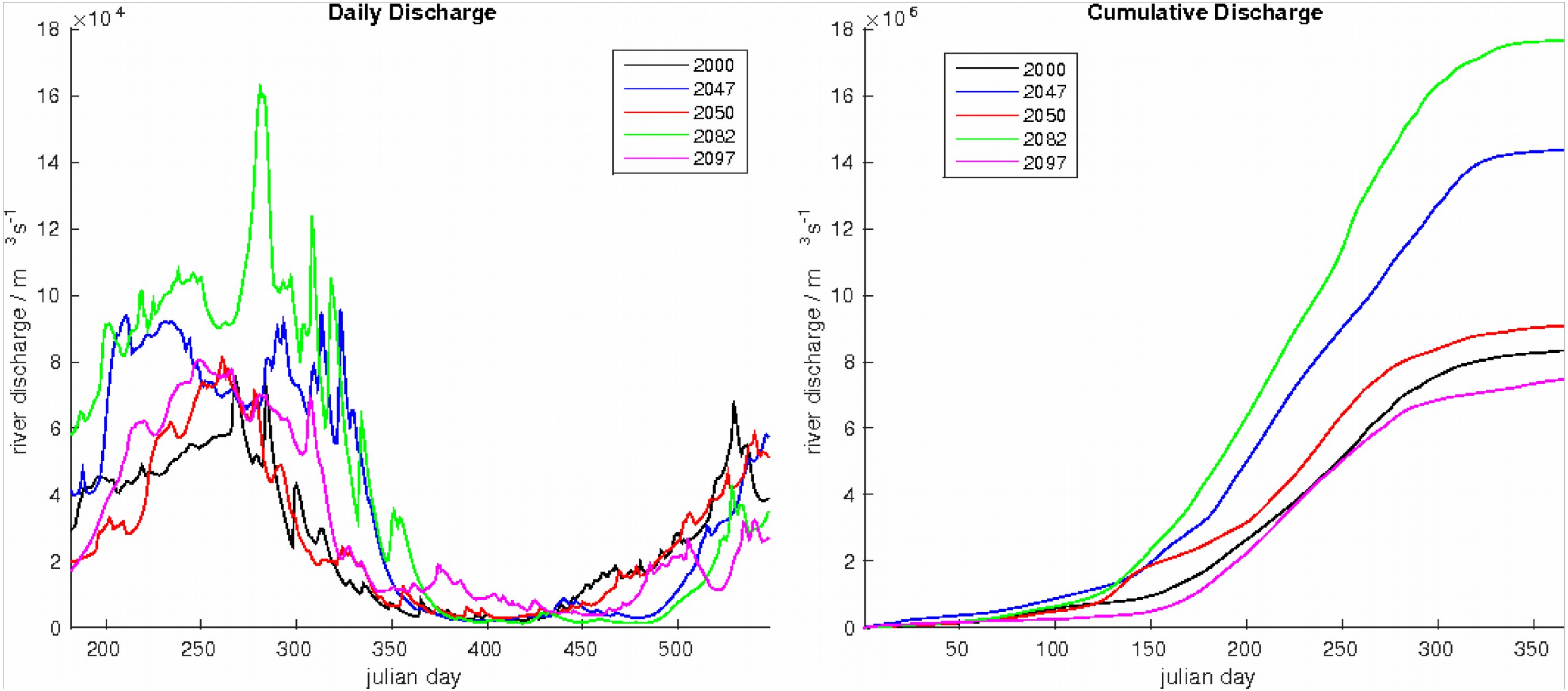
Movie of salinity



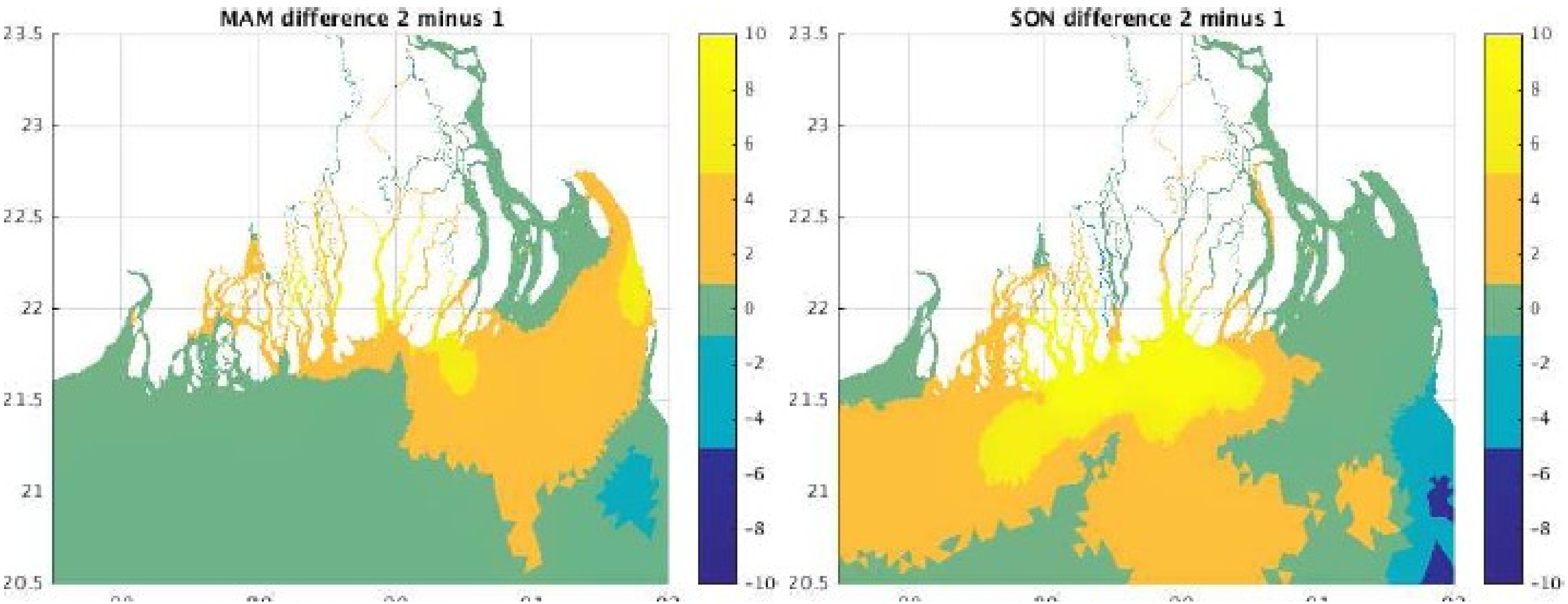
Future salinity: scenario projections

Scenario	Description	Climate & management	MSLR (cm)	Year	Discharge (m3)
Historic	historic	historic	0.0	1998 – 1999	9,054,014
1	Baseline	Q0 + Business as Usual	0.0	2000 – 2001	9,928,407
2	Mid century	Q0 + Business as Usual	31.96	2047 – 2048	13,979,424
3	Mid century	Q8 + Less Sustainable	27.06	2050 – 2051	10,011,085
4	End century	Q8 + Less Sustainable	58.77	2082 - 2083	16,517,208
5	End century	Q0 + Business as Usual	59.01	2097 - 2098	10,978,254

Future salinity: scenario projections



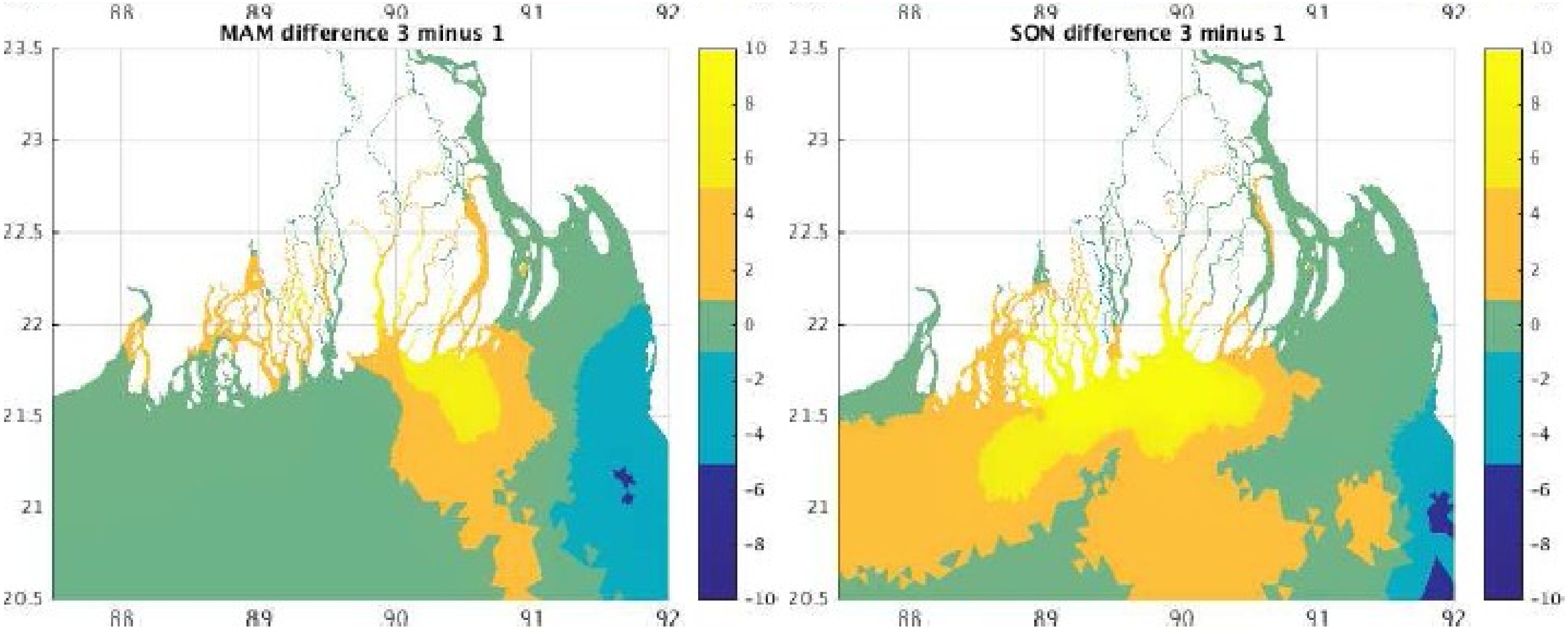
Future salinities: projections under climate change.



- Future difference in salinity (compared to historic base-line). Left March-April-May, Right September-October-November.

- Scenario 2 = 'mid century, wet'

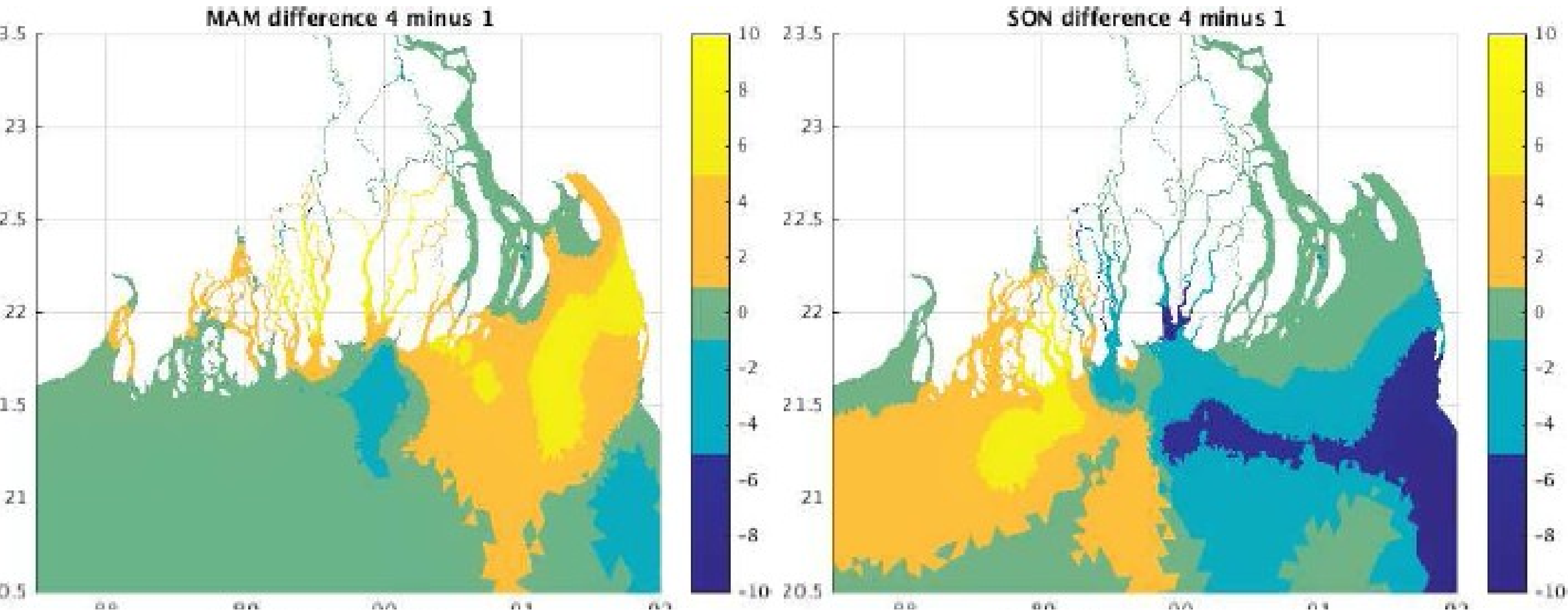
Future salinities: projections under climate change.



Future difference in salinity (compared to historic base-line). Left March-April-May, Right September-October-November

Scenario 3 = 'mid century, dry'

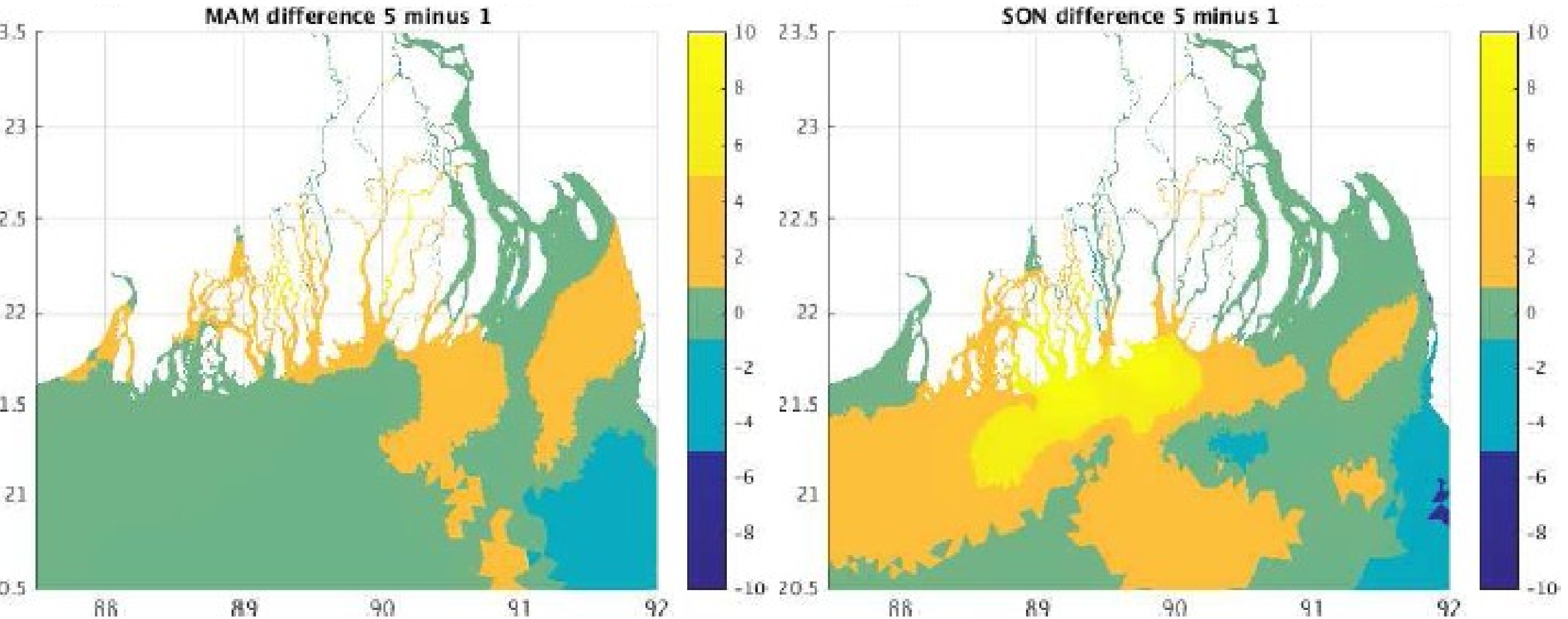
Future salinities: projections under climate change.



Future difference in salinity (compared to historic base-line). Left March-April-May, Right September-October-November

Scenario 4 = 'end century, wet'

Future salinities: projections under climate change.



Future difference in salinity (compared to historic base-line). Left March-April-May, Right September-October-November

Scenario 5 = 'end century, dry'

Future salinities: projections under climate change.

- In future projections, increased mean sea level is combined with altered river discharge under RCP climate scenarios.
- Sea level at the open ocean remains largely unchanged, with a slight freshening projected
- A range of possible river discharge futures were used, though the trend in the mean conditions was for a ‘wetter’ climate by the end of the century.
- Higher sea levels drive larger salinities, particularly at the South and West of the delta. There is also stronger seasonal variability, with drier dry seasons, and wetter monsoon seasons. This makes the extremes more severe, which will impact planting and rice production.

Conclusion

- Using an unstructured mesh model we can capture a range of space scales on the Ganges Brahmaputra Meghna delta: from ocean to coast.
- The transport and mixing in the delta is controlled by a combination of river and tidal processes.
- In the short term (hours to days) tidal processes control the freshwater plume. While on a seasonal timescale, the monsoon cycle is dominant.
- River discharge alters total water level as well as salinity, and can suppress the tidal amplitude
- In future projections, sea level rise overrides increased river flow, leading to increased salinity in the Bangladesh delta.