An Asymmetric Change in Circulation and Nitrate Transport Around the Bay of Bengal

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1. MOTIVATION

The Bay of Bengal is a dynamic region that experiences seasonally reversing monsoon winds and currents. Key circulation features include the East India Coastal Current (EICC), which flows poleward from December to May and equatorward from July to October, and the Sri Lanka Dome (SLD), a cyclonic eddy that forms off the east coast of Sri Lanka during the Summer Monsoon with a paired anticyclonic eddy (AE). The region is of key socio-economic and ecological interest due to the enormous amounts of riverine runoff and nutrients that enter the Bay on an annual basis. As such, **it is essential that we understand how the Bay of Bengal will respond to future anthropogenic climate change.**

2. MODEL DESCRIPTION

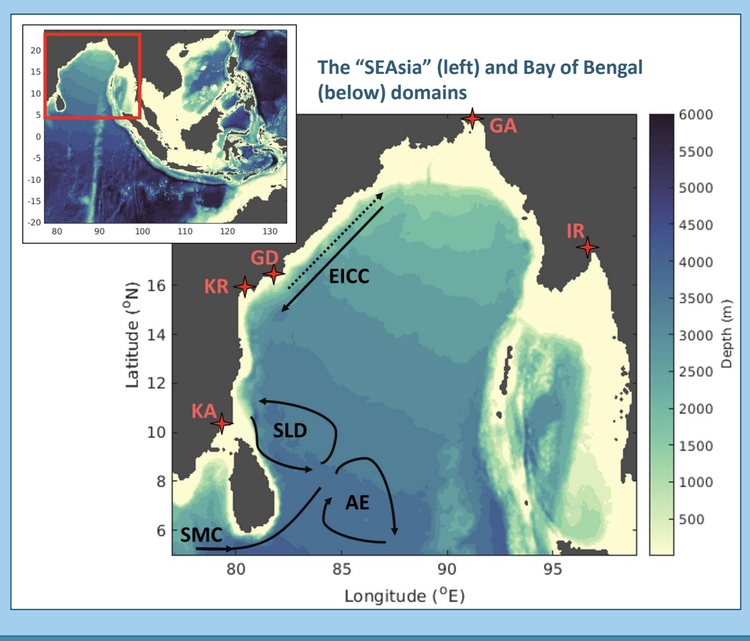
The SEAsia model is a tide-enabled, coupled physics-biogeochemistry (**NEMO-ERSEM**) model that covers much of the Indian Ocean. We focused on the Bay of Bengal region (right figure; key rivers are marked by the red stars, and the main seasonal currents are marked by black arrows).

Model specs:

- Resolution: 1/12th degree (~9km)
- Length of run: 80 years (1980 to 2060)
- GlobalNEWS2 rivers.
- HADGEM2 atmospheric forcing (CMIP5).
- Ocean forcing is ¼ degree Global NEMO-MEDUSA
- 20 year spin up period (1960-1980).
- 75 vertical levels (hybrid σ-z* coordinates)

We compared **Past (1990-2010)** and **Future (2040-2060)** time periods during the **Summer Monsoon (JJAS)** and **Fall Inter-monsoon (ON)** seasons. All F-P difference plots are to the 90% confidence limit, and values below that limit have been removed (i.e. difference = 0).

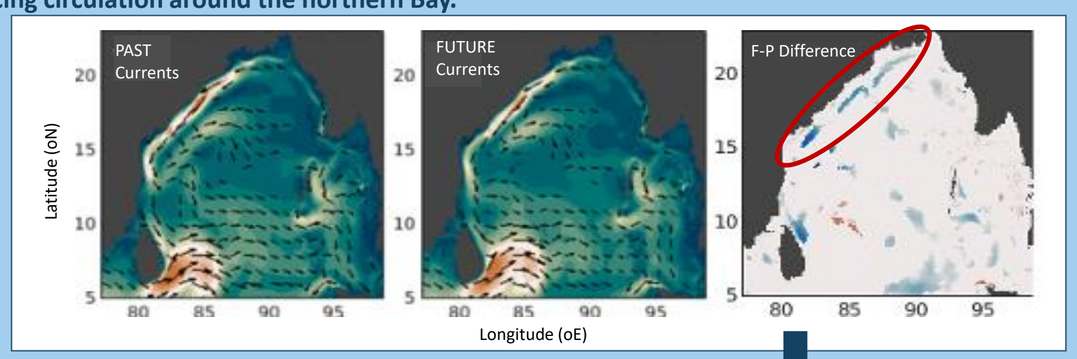
The "SEAsia" (left) and Bay of Bengal (below) domains



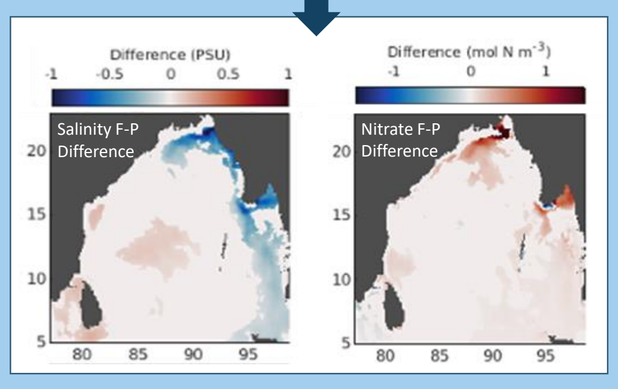
3. AN ASYMETRIC CHANGE IN CIRCULATION

3.1 NORTH (SUMMER MONSOON)

Past vs Future current comparisons during the Summer Monsoon show a weakening in the EICC, reducing circulation around the northern Bay.



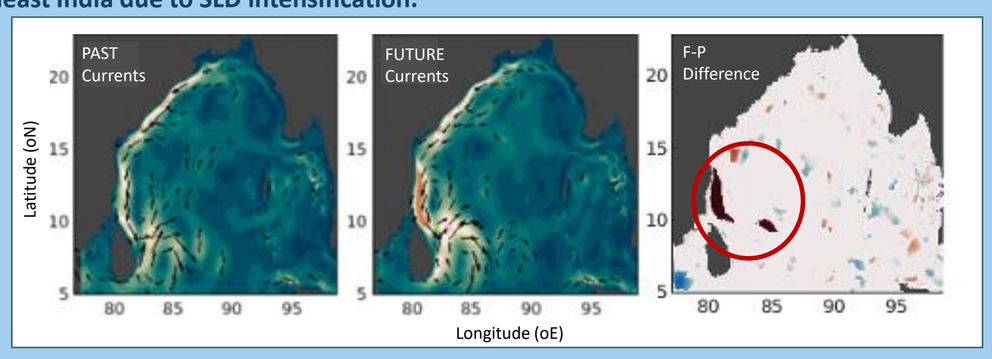
This weakening is further seen in the Past to Future salinity difference, with the north/north-eastern Bay exhibiting maximum freshening, further reducing the the horizontal density gradient and leading to positive feedback whereby the current weakens further.



Maximum nitrate increases are strongly consistent with areas of freshening, suggesting increased riverine nitrate runoff into the Bay.

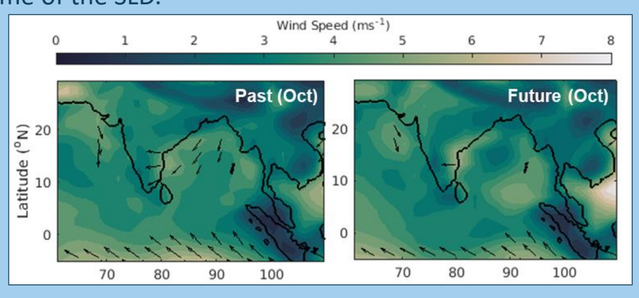
3.2 SOUTH (FALL INTER-MONSOON)

Past vs Future changes during the Fall Inter-monsoon show an strengthened coastal current along southeast India due to SLD intensification.

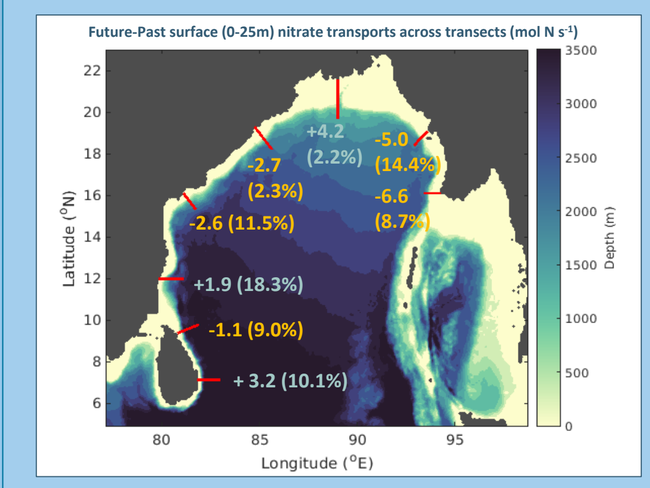


This is due a lengthening of the Summer Monsoon and consequently a delayed onset Winter Monsoon. As the SLD is sustained by the Summer Monsoon, any variations to the longevity of the Summer Monsoon would be reflected in the residence time of the SLD.

The SLD is expected to dissipate in September with the Summer Monsoon retreat. However, future north-westerly winds during October have decreased across the Bay, suggesting the system is still transitioning from Summer to Winter conditions.

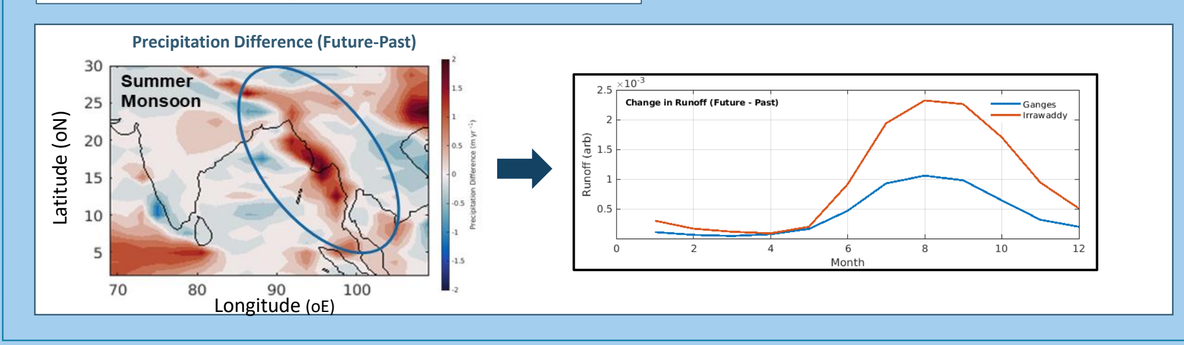


4.1 SUMMER MONSOON NITRATE TRANSPORT

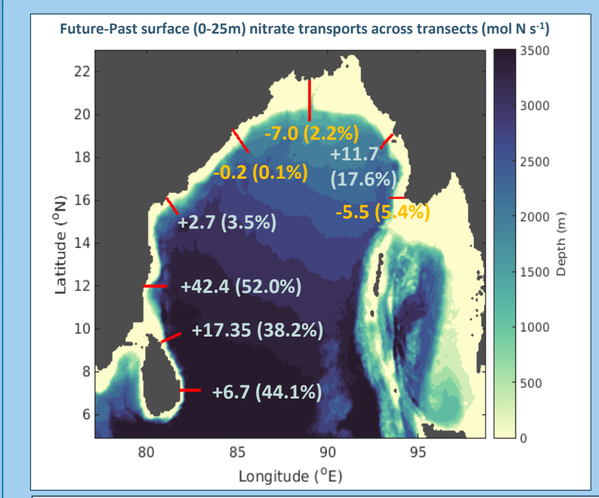


Weakened circulation leads to reduced nitrate transports, especially in the northeast. This is counter-intuitive considering the increase in riverine runoff from the Ganges and Irrawaddy rivers, due to increased precipitation (see graph below).

Future currents become inefficient at flushing this excess riverine nutrients from the northern Bay and could lead to eutrophication, stagnation, and phosphate/silicate limitation due to changes in nutrient stoichiometry.

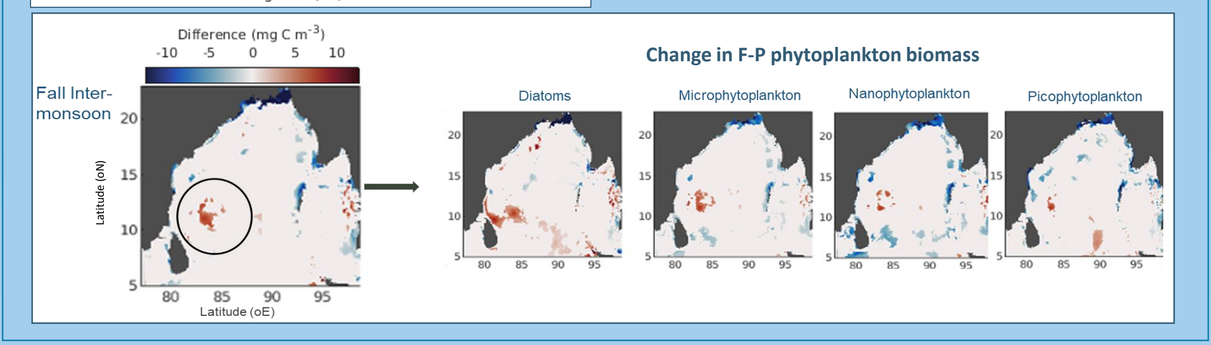


4.2 FALL INTER-MONSOON NITRATE TRANSPORT



Coastal currents from a prolonged SLD significantly increase nitrate transports, despite the reduced currents in the north.

Transported nutrients promote localised diatom blooms along the south-eastern Indian coast, whereas upwelling supports phytoplankton blooms further offshore. While advantageous to local fisheries, more nutrients leads to an increase risk of eutrophication, especially near river mouths.



5. CONCLUSIONS

Results from a coupled physics-ecosystem model suggest that from 1990 to 2060, **the northern Bay of Bengal will see a reduced circulation during the Summer Monsoon that restricts nitrate transport, despite the higher riverine runoff**. Conversely**, in the southern Bay, a prolonged SLD leads to strengthened coastal currents during the Fall Inter-monsoon, resulting in an intensified nitrate transport and localised phytoplankton blooms**. These results highlight the need for more rigorous ecosystem modelling in the region.

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