Variability and budgets of Dissolved Inorganic Carbon and Alkalinity over the north Indian Ocean using a high-resolution model

EGU24-12796 | OS3.1

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Introduction

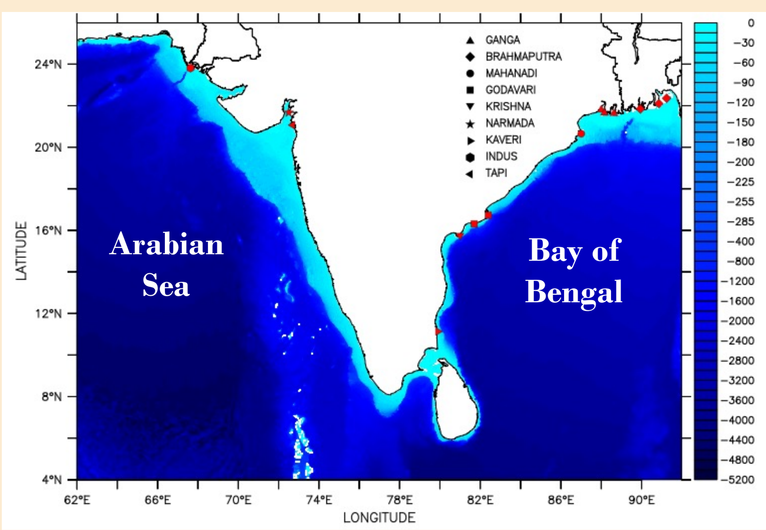


Figure 1: Study Area

- To understand the north Indian Ocean carbon cycle, it is important to study the distinctive processes controlling the dissolved inorganic carbon (DIC) and alkalinity (ALK) concentrations.
- This region has sparse in-situ biogeochemical observations and thus quantifying the DIC and ALK budgets using the MITgcm-DIC model provides a comprehensive understanding.
- The high spatial resolution (1/20°) allows us to look into the well-resolved coastline of the Indian subcontinent. The model is setup using climatological initial and boundary conditions.

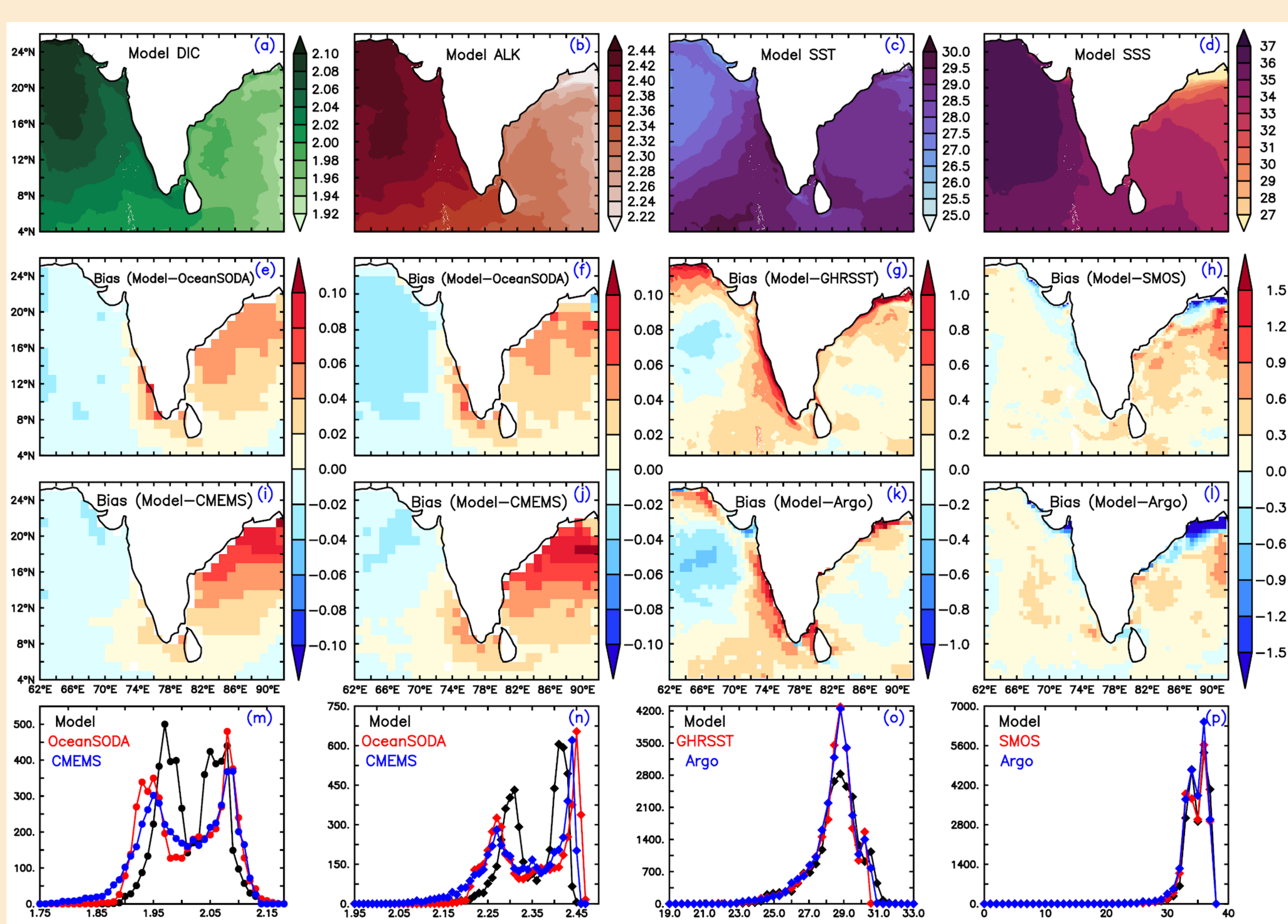
Methodology

We employ the MITgcm model (*Marshall et al., 1997*) coupled with the DIC package (*Dutkiewicz et al., 2005*). The equations for calculating the surface DIC and ALK budgets are described in *Lauderdale et al., (2016)* and are as follows:

$$\frac{\partial C_T}{\partial t} = -\nabla.(\vec{u}C_T) + \nabla.(\kappa\nabla C_T) - R_{C_T:P}S_{bio} - S_{CaCO_3} - \frac{F_w\overline{C_T}}{\rho_{fw}h} - \frac{F_{CO_2}}{h} \quad (1)$$

$$\frac{\partial A_T}{\partial t} = -\nabla.(\vec{u}A_T) + \nabla.(\kappa\nabla A_T) - R_{N:P}S_{bio} - 2S_{CaCO_3} - \frac{F_w\overline{A_T}}{\rho_{fw}h} \quad (2)$$

Validation



- The Arabian Sea is a high evaporation basin whereas the Bay of Bengal is a freshwater basin. Due to this peculiarity, we observe a bimodal distribution for surface DIC, ALK and SSS, which is well captured by the model.
- Model DIC and ALK are validated with the OceanSODA and Global Ocean Surface Carbon from Copernicus Marine Service. Model SST and SSS are validated with GHRSST and SMOS SSS.

Figure 2: Annual mean of surface DIC and ALK (mol/m³), SST (°C) and SSS (psu) (first row). The second and third row represents annual bias between model variables and observations. The fourth row depicts the histogram of each variable.

Budget analysis

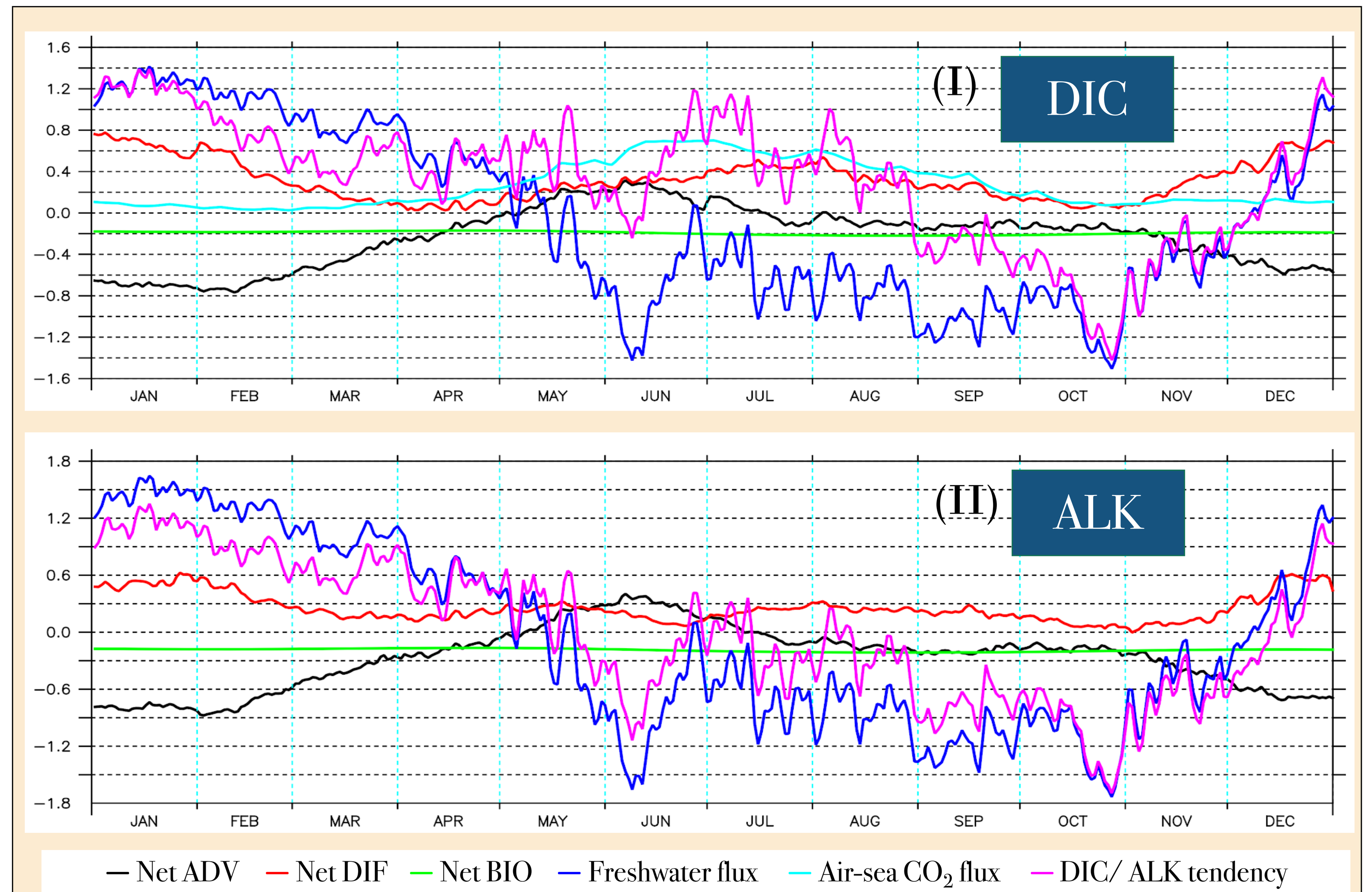


Figure 3: Surface budgets (area averaged) of (I) DIC (mol C/m³) and (II) ALK mol eq/m³)

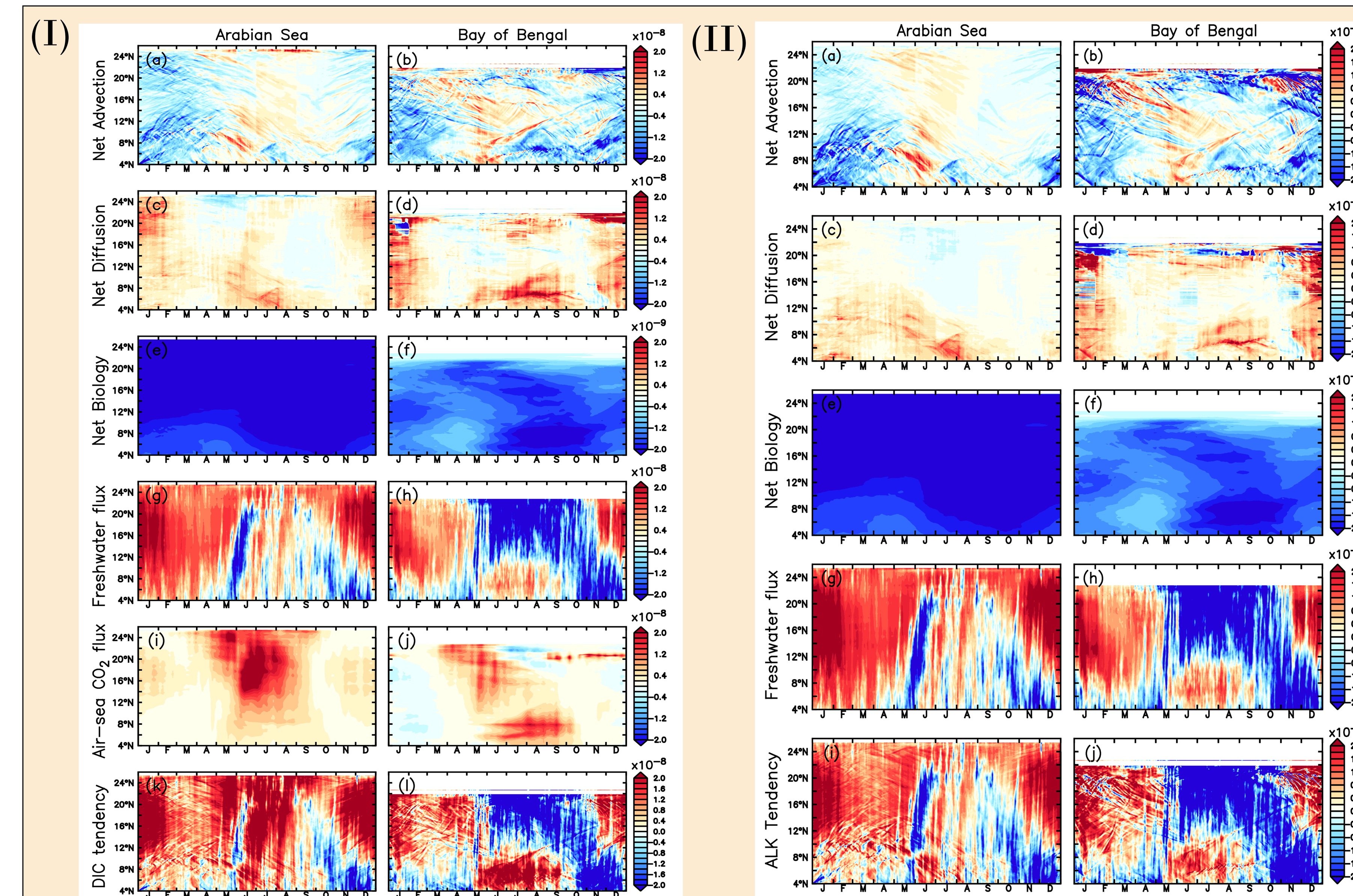


Figure 5: Surface tendency terms of (I) DIC (mol C/m³) and (II) ALK (mol eq/m³) as a function of latitude

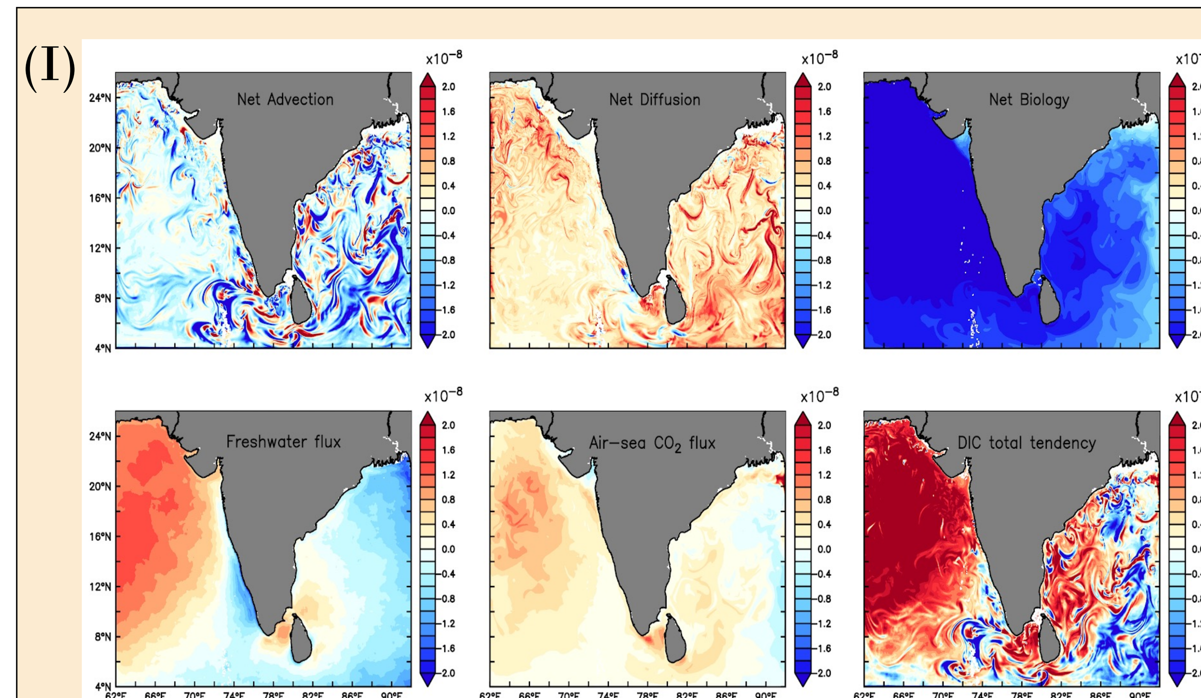
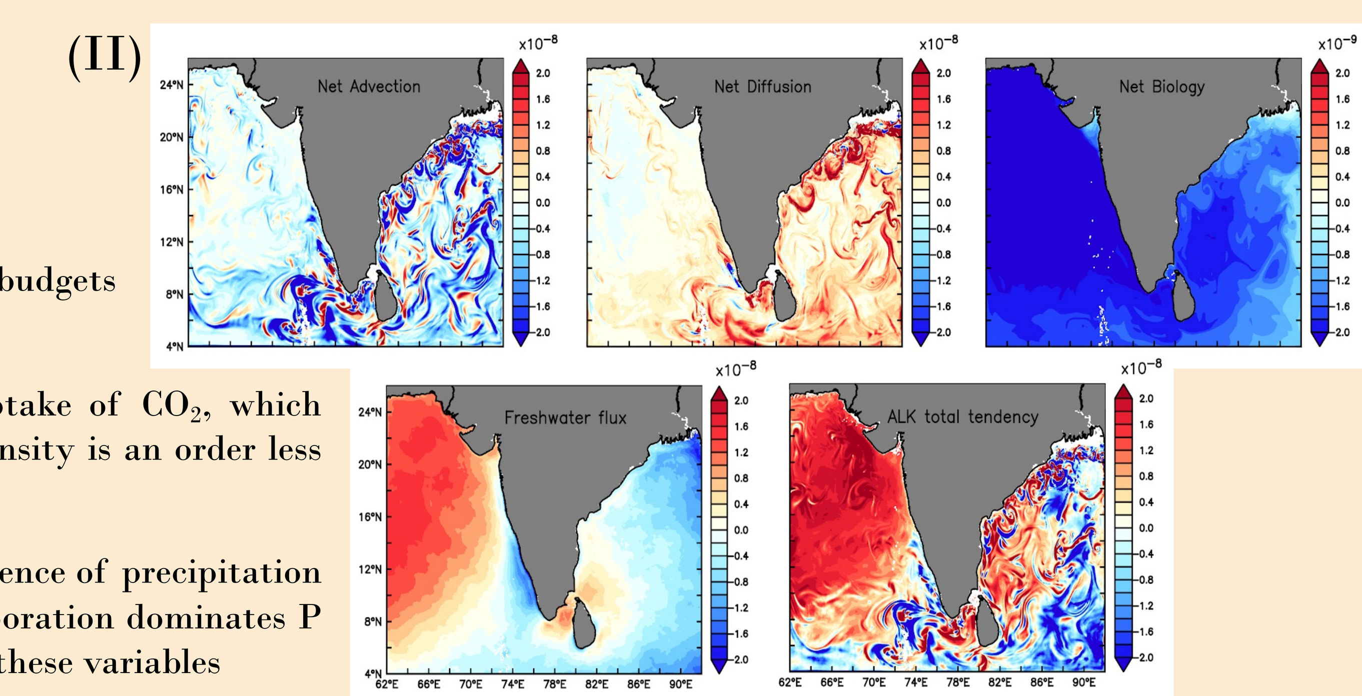
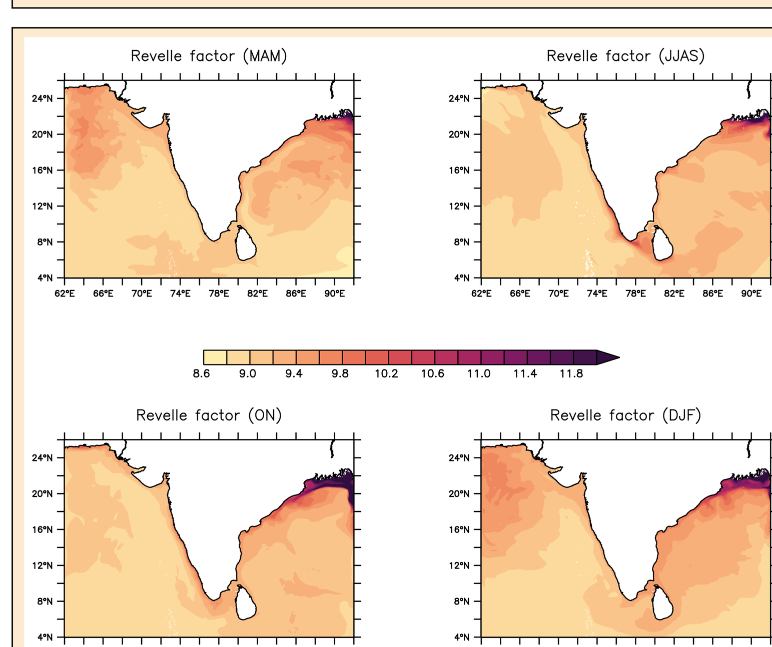


Figure 4: Annual climatology of surface tendency terms of (I) DIC (mol C/m³) and (II) ALK (mol eq/m³)



- The advective and diffusive terms of the budgets counterbalance each other.
- The biological production leads to a continuous uptake of CO_2, which leads to a reduction in surface DIC, however its intensity is an order less compared to other processes.
- The dilution of ALK or DIC is attributed to the influence of precipitation (P) and river runoff (R), whereas regions where evaporation dominates P and R, leading to an increase in the concentration of these variables



Revelle Factor (seasonal climatology)

$$\frac{\Delta(P_{CO_2})/(P_{CO_2})}{\Delta(DIC)/(DIC)}$$

Conclusions

- The influence of freshwater flux on the concentrations of surface DIC and ALK is evident and it dominates their budgets compared to the other tendency terms.
- The surface waters of the Arabian Sea have a high DIC concentration majorly due to air-sea interaction and high evaporation over precipitation. The Bay of Bengal observes lower DIC/ALK concentrations due to freshwater (P+R) induced dilution.
- The low Revelle factor indicates the high buffering capacity to absorb atmospheric CO_2 in the north Indian Ocean. However, the head-bay yields a high Revelle factor due to the dilution of DIC concentration by river discharge from the Ganga and Brahmaputra.