Influence of rivers and coastal erosion on the Arctic Ocean carbon cycle using E3SM v2

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Abstract:

The hydrography and circulation in Arctic Ocean are significantly influences surrounding rivers, but the biogeochemical (BGC) inputs from rivers and coastal erosion have been missed by most previous climate models. Here three E3SM v2 G-case simulations with monthly climatology of carbon and nitrogen input from arctic rivers and coastal erosion are conducted to validate the physical and BGC model results with observations, and evaluate the influences of river and coastal erosion input on the arctic primary production and spatial distribution of other BGC tracers.

Introduction of E3SM v2 G-case simulations with coastal erosion discharge

In order to validate the E3SM v2 BGC with less uncertainties from atmospheric forcing, we evaluate the E3SM with JRA-55 forced G-case runs.

Initial conditions are from an OMIP2 style spin-up (with constant background vertical diffusion and salinity restoring timescale of 2 months). All currently use the standard resolution EC30to60E2r2 a) "normal" repeat year forcing with ocean-ice BGC for 200 years with pre-industrial atm CO2 b) 108 years of transient CO2 increase from 1850-1958 c) JRA-55 interannual forcing with historical CO2 from 1958 to 1986 (year 334).

Climatological monthly coastal erosion discharge (Figure 1, Terhaar et al., 2020) are included in the two sensitivity runs. Three 32-years (1986-2018, or model year 334 to 366) sensitivity simulations for coastal erosion effects in the Arctic Ocean are conducted following the model spin up:

1. **Case B:** Baseline with prescribed monthly river fluxes including N, C (inorganic 32%, organic 68% as in Terhaar et al., 2021) and no coastal erosion fluxes.
2. **Case S1:** CoastalErosion_90i_10o with same river runoff as Case B and coastal erosion fluxes of total annual N and C inputs from Terhaar et al. (2021), but dividing the fluxes into 90% inorganic N (C) and 10% organic N (C).
3. **Case S2:** CoastalErosion_10i_90o, same as Case S1 but dividing the fluxes into 10% inorganic N (C) and 90% organic N (C).

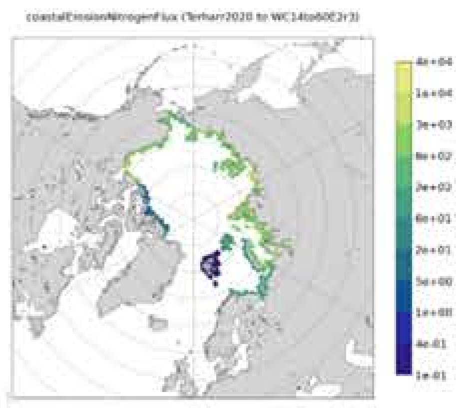
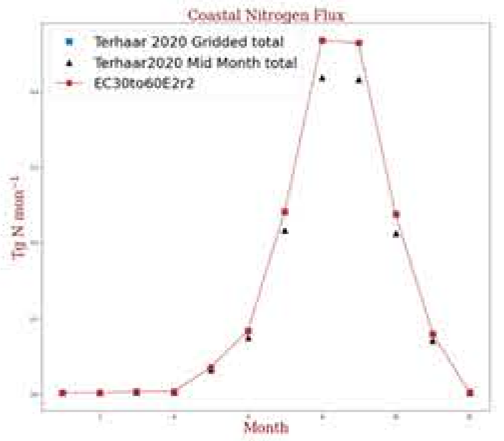


Figure 1: Location of coastal erosion discharge



Monthly arctic total coastal nitrogen flux

Results

1. **In the northern hemisphere, modeled sea ice area** is larger than remote sensing in every month, but the long-term declining trend is close to observations
2. **In the Canada Basin (Figure 2), modeled sea ice thickness (Figure 3)** is thicker than observed in summer, but close to observation in winter **Modeled temperature and salinity at 5m and 35m (Figure 4) match well with observations in August.**

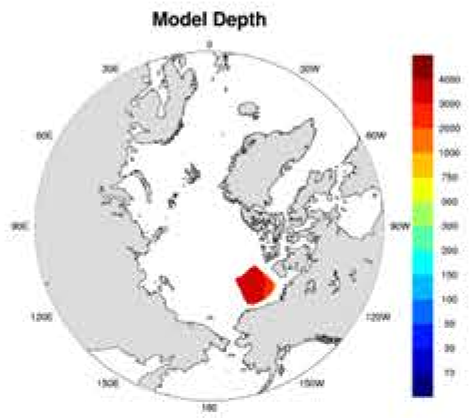


Figure 2: The red area for model validation

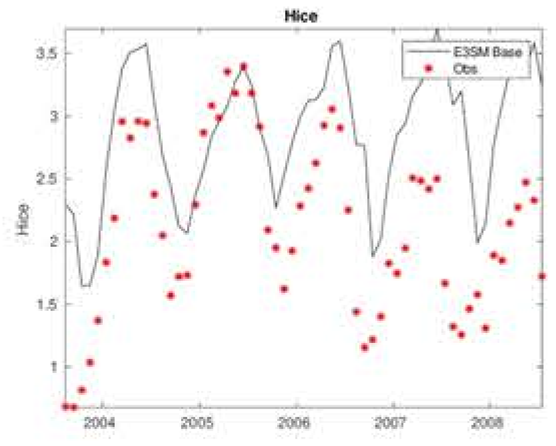


Figure 3: Monthly mean ice thickness of E3SM case B and the mean of three upward looking sonar observations.

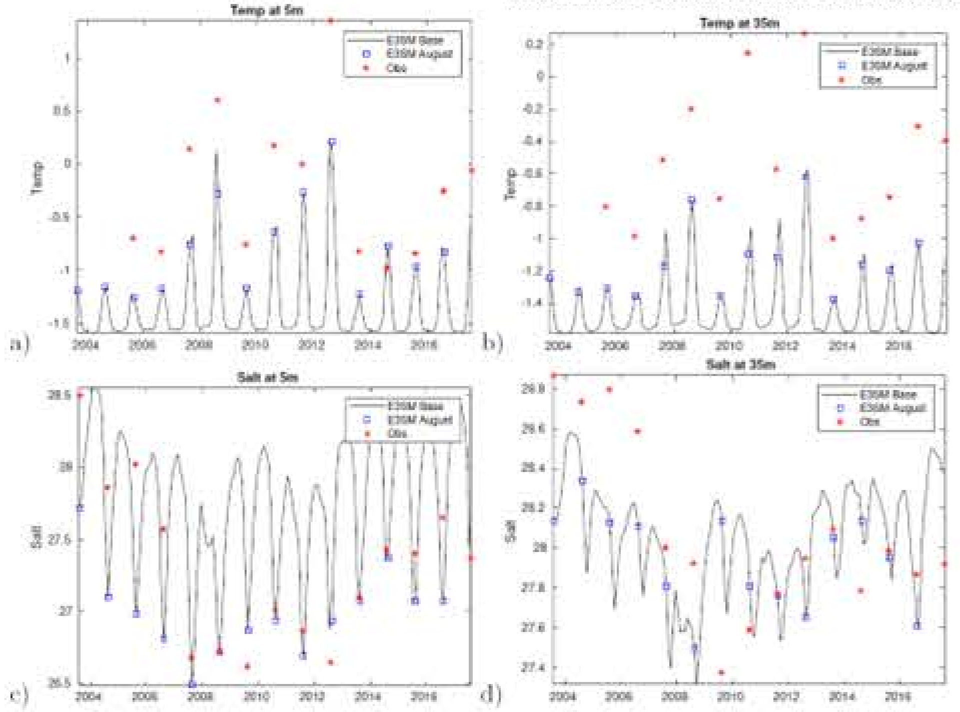


Figure 4: The validation of temperature at a) 5m and b) 35m; salinity at c) 5m and d) 35m. Observations are the August mean, blue square is model August mean.

3. Nutrients

3.1 NO3 model bias NO3 is less than half of WOA observations in the Atlantic Ocean and Bering Sea, which reduced the contribution of NO3 inflow into the Arctic Ocean. But in the Canada Basin, model shows low nitrate, close to observation.

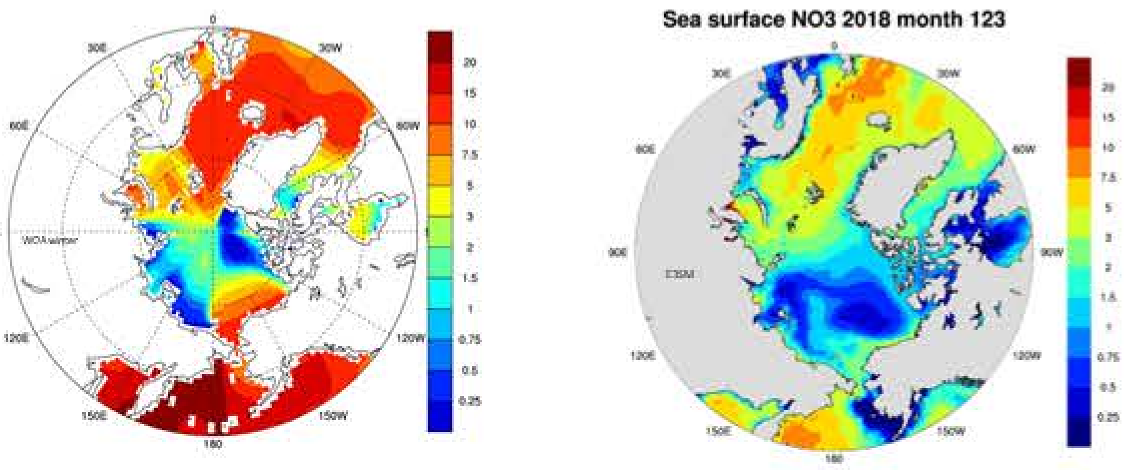


Figure 5: Nitrate in winter: left) WOA climatology; right) model average of Jan-Mar, in 2018

3.2 In the Canada Basin region (Figure 2), the E3SM modeled NO3 and Chl match well with observations at 5m and 35m from 2004-2018.

Surface and subsurface averaged NO3 in the CB are comparable to observations.

Surface and subsurface averaged Chl in the CB are comparable to observations.

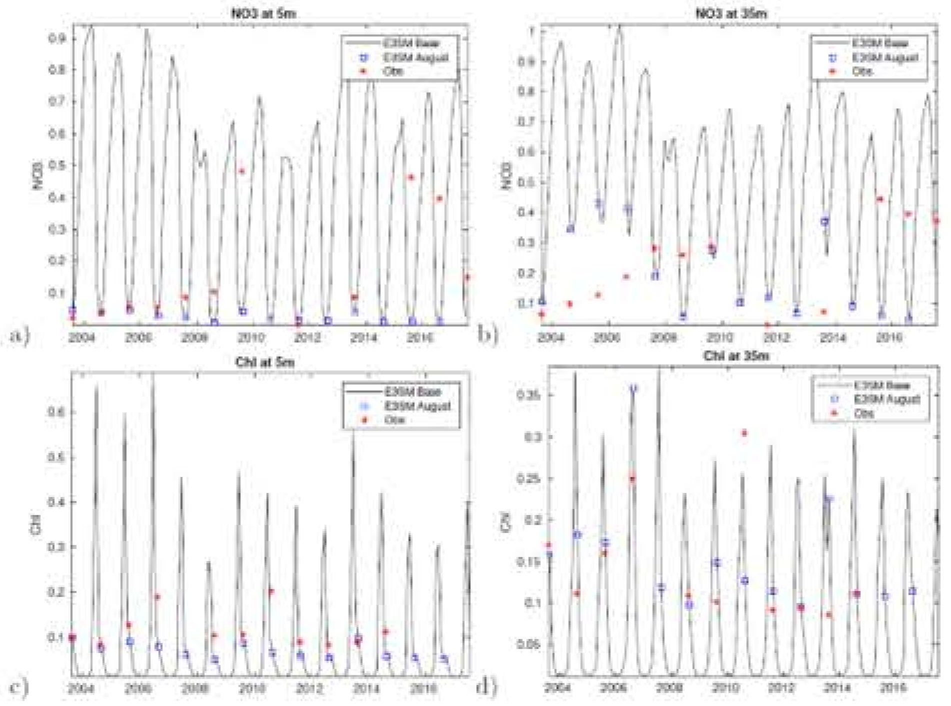


Figure 6: The validation of NO$_3$ at a) 5m and b) 35m; Chl-a at c) 5m and d) 35m in the CB. Observations are the August mean, blue square is model August mean.

4. Coastal erosion effects

4.1 DIC in the Arctic are higher in the spring (Apr-Jun) than summer (Jul-Sep) (Figure 7). The coastal erosion fluxes of nitrate, DIC/DOC have combined effects of increased DIC in the sea surface basin wide, but highest in the Russian coast and transpolar drift regions. Case S2 shows more increase than Case S1. In the summer the effects are much smaller and spatially even due to biological consumption.

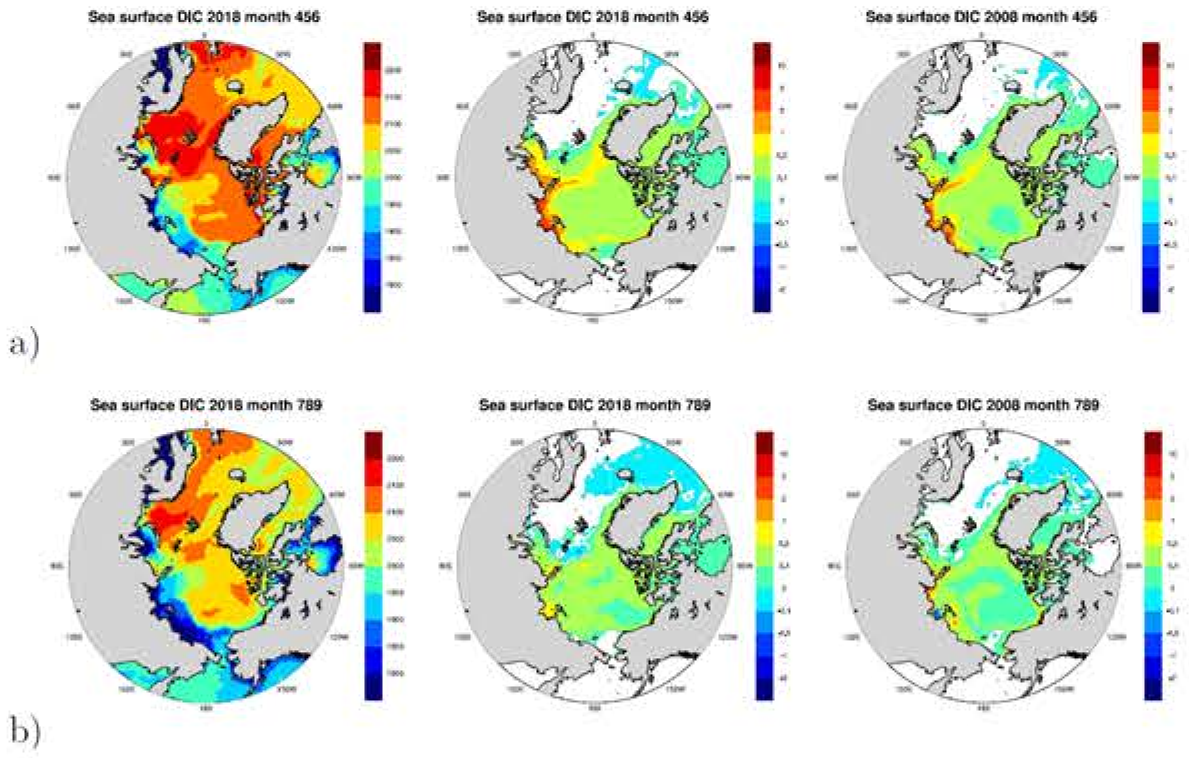


Figure 7: The three columns are DIC of case B, case S2-B, case S1-B. a) in April to June, and b) in July to September

4.2 Sea surface NO$_3$ in the Arctic are higher in the spring (Apr-Jun) than summer (Jul-Sep) (Figure 8). The coastal erosion fluxes of nitrate, DIC/DOC have combined effects of increased NO$_3$ in the sea surface basin wide, also highest in the Russian coast and transpolar drift regions in spring. Case S2 shows more increase than Case S1. In the summer the effects are much smaller and spatially even due to biological consumption.

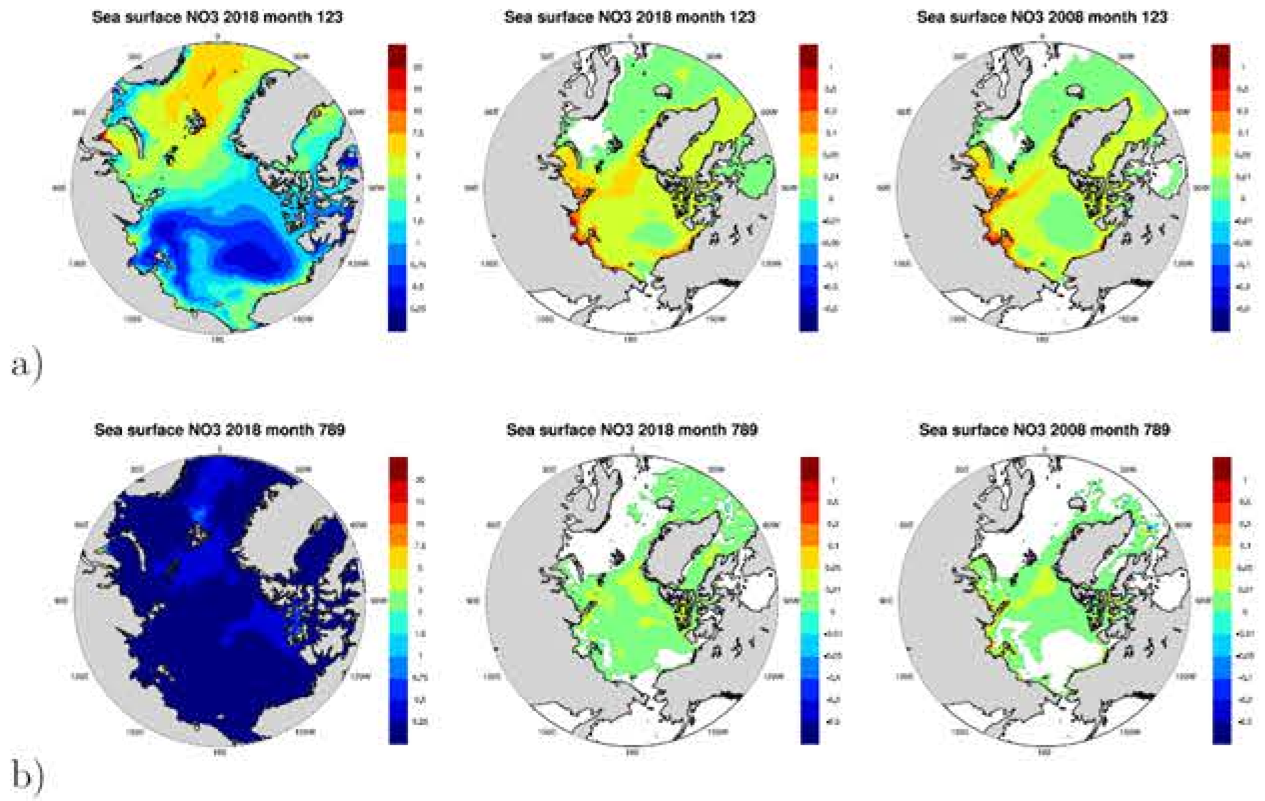


Figure 8: The three columns are NO$_3$ of case B, case S2-B, case S1-B. a) in Jan-Mar, and b) in July to September

4.3 Ocean Primary Production (PP) in the Arctic in 2018 in the basin region are lower than coastal regions, but all are much lower than the Atlantic Ocean (Figure 9). The coastal erosion fluxes of nitrate, DIC/DOC have combined effects of increased PP basin wide, also highest in the Russian coast, transpolar drift regions and Alaska coastal regions. Case S1 shows slightly more increase than Case S2.

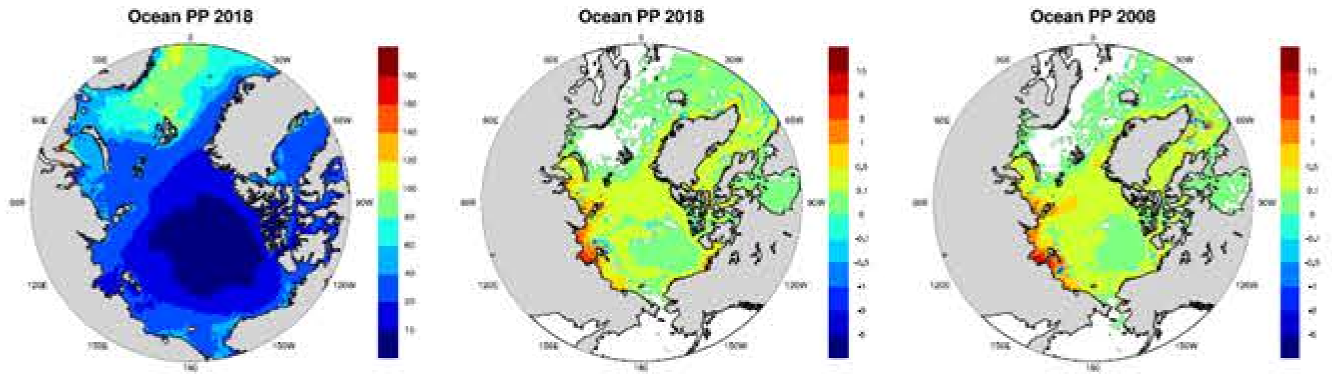


Figure 9: The three columns are PP of case B, case S2-B, case S1-B in 2018

4.4 The POC-to-sediment fluxes in the Arctic in 2018 are very low and spatially even in winter, but high in the coastal seas in summer (Figure 10). The coastal erosion fluxes of nitrate, DIC/DOC have combined effects of increased POC-to-sediment fluxes basin wide, highest in the Russian coast and Alaska coastal regions. Case S1 shows slightly more increase than Case S2.

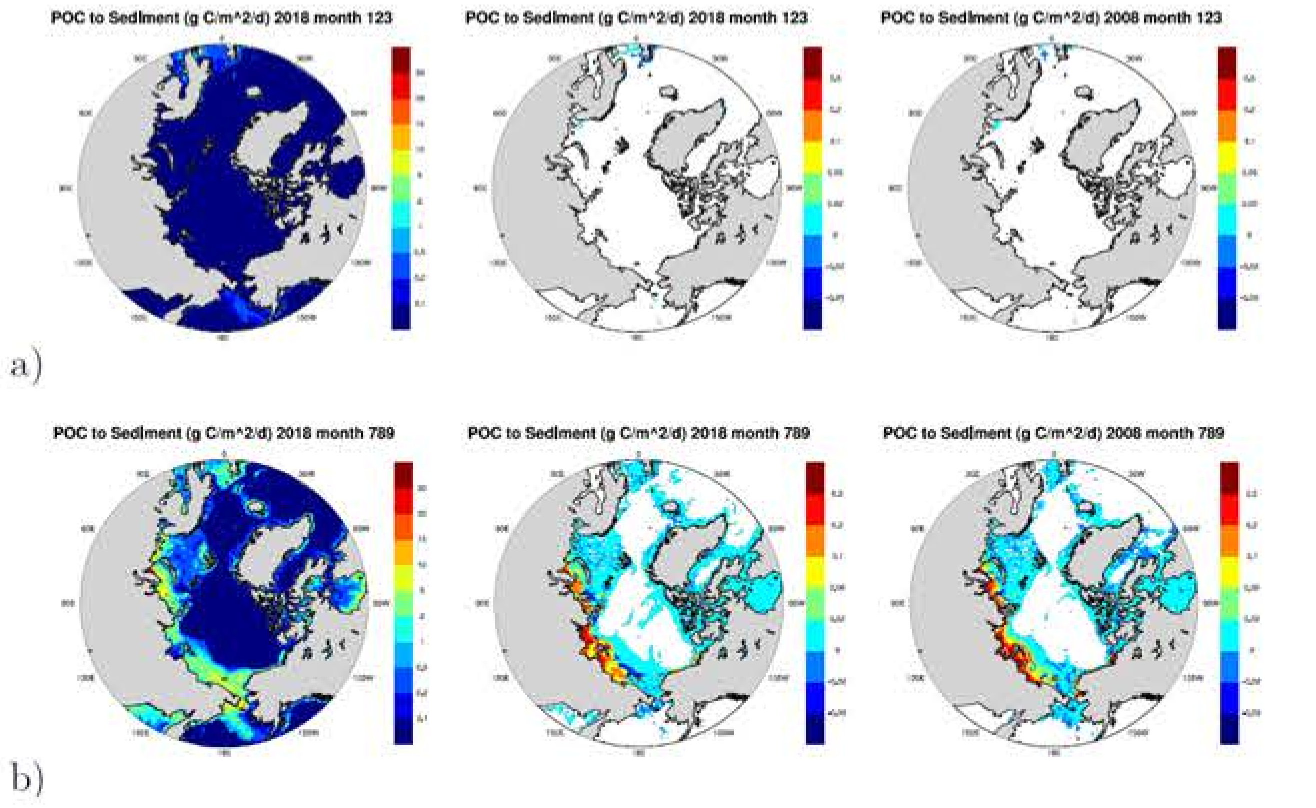


Figure 10: The three columns are POC-to-sediment fluxes of case B, case S2-B, case S1-B. a) In Jan-Mar, and b) in July to September

Summary:

Validation of the E3SM v2 G-cases of observations revealed some ocean and sea ice model bias in the northern hemisphere, but generally match well with observations in the Canada Basin. that need urgent improvement work. Coastal erosion fluxes of N, DIC/DOC have effects of increased surface DIC, NO3, PP and POC-to-sediment fluxes basin wide, but the highest increases are in the Russian coastal seas, transpolar region and Alaska coastal regions.