Modelling the carbon cycle across the Arctic land-ocean continuum: a case study of the Southeastern Beaufort Sea

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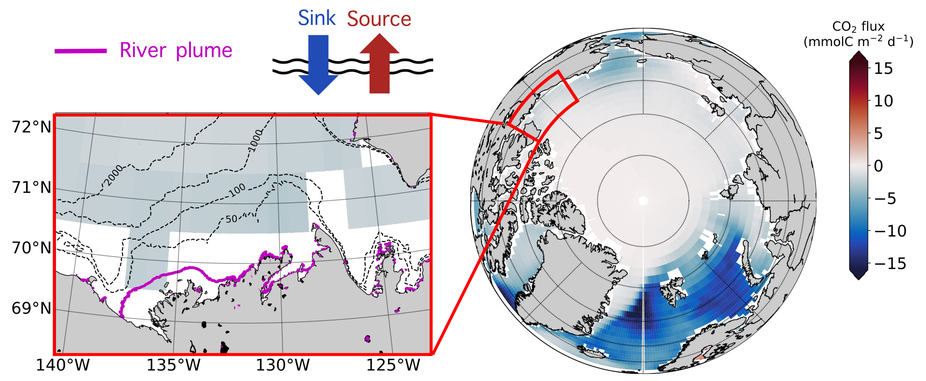
Background.

Five of the world's largest rivers discharge into the Arctic Ocean (AO), conveying large amounts of terrestrial matter into its coastal waters[1]. In the context of global warming and intensification of the hydrological cycle[2], the response of the coastal AO to changing biogeochemical river runoff remains highly uncertain. To better understand the impact of terrestrial dissolved carbon release (organic tDOC and inorganic tDIC) on AO air-sea CO_2 flux, we use a state-of-the-art ocean/sea-ice/biogeochemical model (ECCO-Darwin) specifically configured to simulate the dynamic Mackenzie Delta/Southeastern Beaufort Sea region (SBS; western AO).



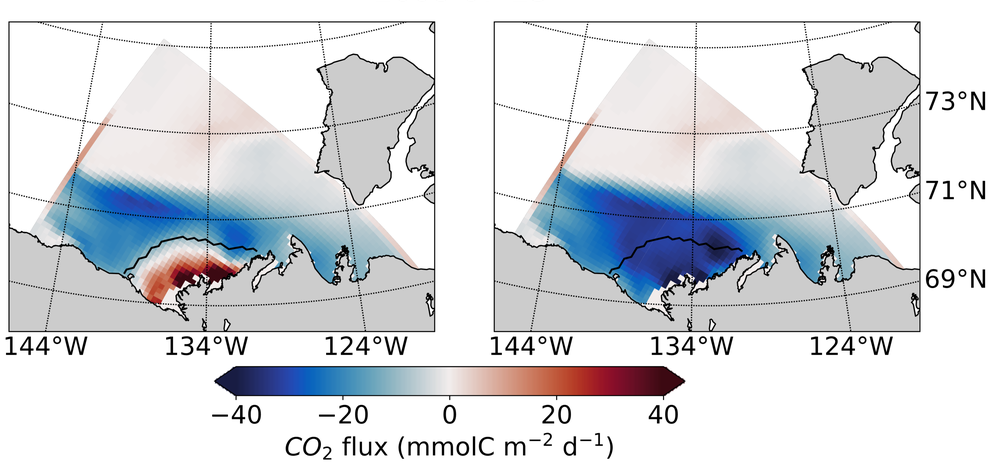


Figure 1. Net air-sea CO_2 flux simulated by ED-SBS on 23 July 2008 with (left panel) and without (right panel) tDIC/tAlk river runoff. Black solid lines indicate the Mackenzie plume region (S<27) (Adapted from Bertin et al. 2023).

THE ECCO-DARWIN SOUTHEASTERN BEAUFORT SEA MODEL (ED-SBS):

- Ocean/sea ice/biogeochemical **regional model** of the Mackenzie Shelf from 2000 to 2019
- Includes **daily interannual** Mackenzie **river runoff** of terrestrial Dissolved Organic and Inorganic Carbon (**tDOC and tDIC**)
- Simulates **semi-labile** and **semi-refractory DOC** pools with turnover rates of 1 month and 10 years, respectively (DOC_{sl} and DOC_{sr})

BIOGEOCHEMICALLY-INDUCED OUTGASSING IN THE RIVER PLUME REGION:

- Addition of **tDOC/tDIC river runoff promotes outgassing** of 0.13 TgC yr^{-1} in the river plume region (Fig.1 black solid line)
- **192 outgassing events** were identified (Fig.2 green dots) during the open-water season. Number decreases to 26 (1) without land-derived tDOC (tDIC)
- Years with **higher** (lower) **discharge** show **higher** (lower) air-sea CO_2 **outgassing**.

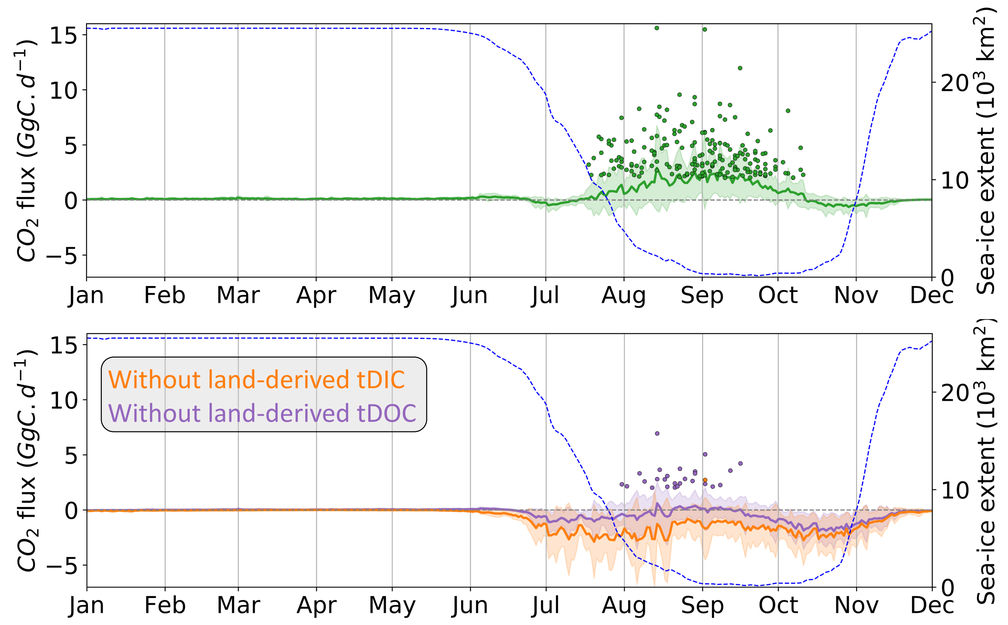


Figure 2. 2000–2019 daily net CO_2 flux (GgC d^{-1}) simulated in the plume region by ED-SBS (green solid line) and by ED-SBS without tDOC river runoff (purple solid line) and without tDIC/tAlk" runoff (orange solid line). Green, purple and orange dots show the net CO_2 flux driven by individual outgassing events. The simulated sea ice extent (10^3 km^2) is overlaid (blue dashed line) (Adapted from Bertin et al. 2023).

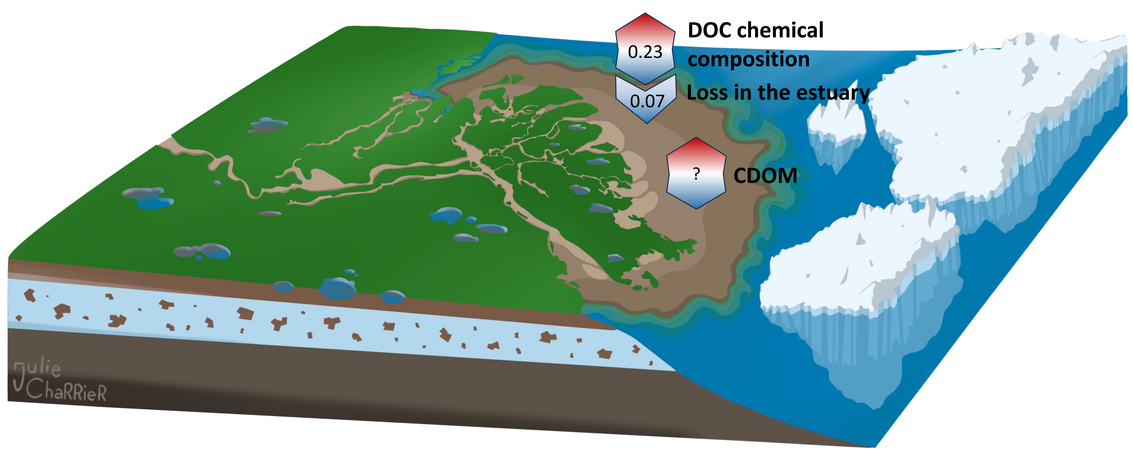


Figure 3. Schematic of the Mackenzie River Shelf showing processes affecting modeling of carbon cycling in Arctic river plumes and their estimated contribution to local air-sea CO_2 fluxes (results extracted from Bertin et al. *submitted to PPP; In Prep*)

CARBON CYCLE MODELLING IN ARCTIC COASTAL PERIPHERIES:

- **tDOC bioavailability** (DOC_{sl} vs. DOC_{sr}) results in variability of net CO_2 fluxes, leading to the **SBS being either source or sink** of atmospheric carbon (Fig.3).
- **Loss of DOC** in the **estuary** (presumably by flocculation) results in **decreased outgassing** as high as 0.13 TgC yr^{-1}.
- Including **CDOM** may lead to **later** phytoplankton **bloom**, less productive waters and potentially **decreased outgassing.**

Take home message.

- During the 2000–2019 period, the Mackenzie River plume induces a net CO_2 outgassing (0.13 ± 0.10 TgC yr^{-1}), resulting from tDIC and tDOC
- Year-to-year variability in river discharge is an important driver of the capacity of the coastal Arctic Ocean to uptake or release atmospheric CO_2.
- Riverine DOC chemical composition and lifetime rather than the quantity of tDOC exported from the river largely modulate Mackenzie River plume air-sea CO_2 fluxes.
- Estuarine processes such as flocculation or CDOM light attenuation may decrease the outgassing estimates.

References

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