

Ayub Regehr¹, Mohamed Ahmed², Nick Decker¹, Kristina Brown¹, Zou Zou Kuzyk¹, & Tim Papakyriakou¹

¹Centre for Earth Observation Science, University of Manitoba, Winnipeg, MB & ²Esri Canada, Calgary, AB

1. Background

Atmospheric CO₂ concentrations have increased drastically since the pre-industrial era. As a result, the uptake in CO₂ by oceans is also increasing (Fig. 1). The ocean is a major global CO₂ sink [1].

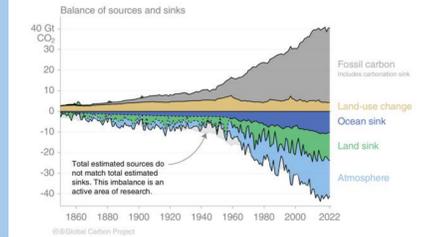


Fig. 1: Balance of CO₂ sources and sinks since 1850 [1].

The flux of CO₂ between the ocean and land is controlled by the partial pressure of CO₂ in seawater, or pCO₂, which varies depending on water properties [2]. Arctic and sub-Arctic regions uptake more CO₂ than other regions due to their cold waters and low salinities [3].

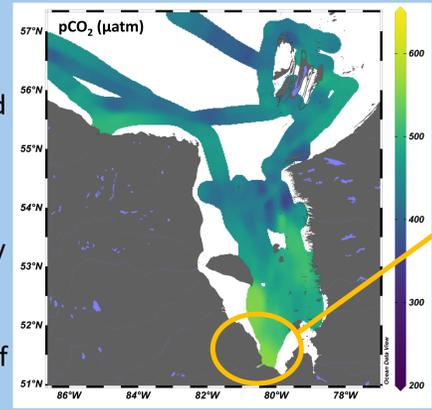


Fig. 2: The RV William Kennedy cruise track in James Bay showing pCO₂ measurements in µatm. Credit: Nick Decker

2. Objectives

- Use knowledge of pCO₂ drivers and an artificial neural network machine learning system to:
 - Estimate pCO₂ distribution and variability spatially and temporally in James Bay
 - Provide a detailed CO₂ flux estimate for James Bay to quantify the source/sink status for the region
- Use results to assess the role of river inflow on the CO₂ flux in James Bay

3. Methodology & Preliminary Results

We will be using various environmental predictor variables to build a machine learning model to estimate pCO₂ in James Bay from 2021 – 2023 based on observational ship data. The model will output monthly pCO₂ maps which will be used to calculate CO₂ fluxes for the region and determine the CO₂ source/sink status.

Predictor Variables

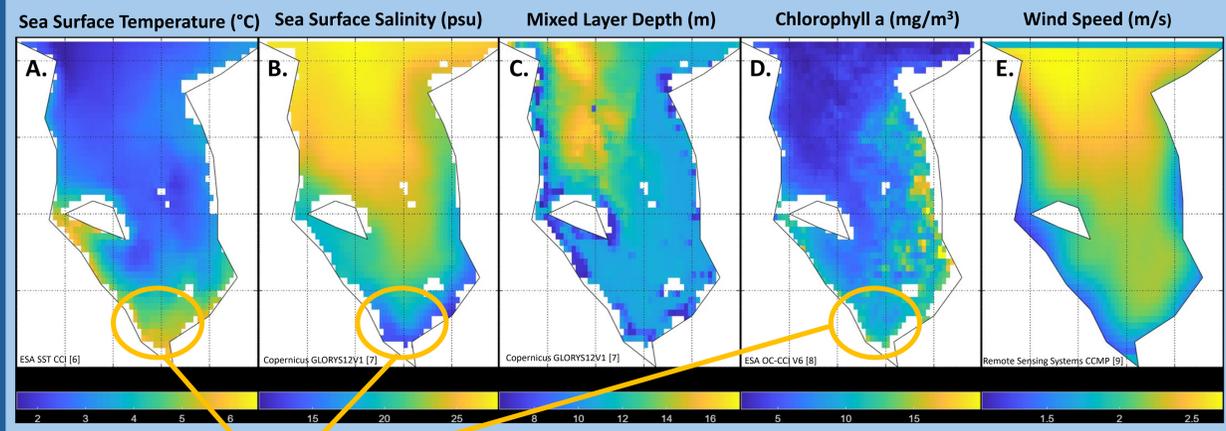
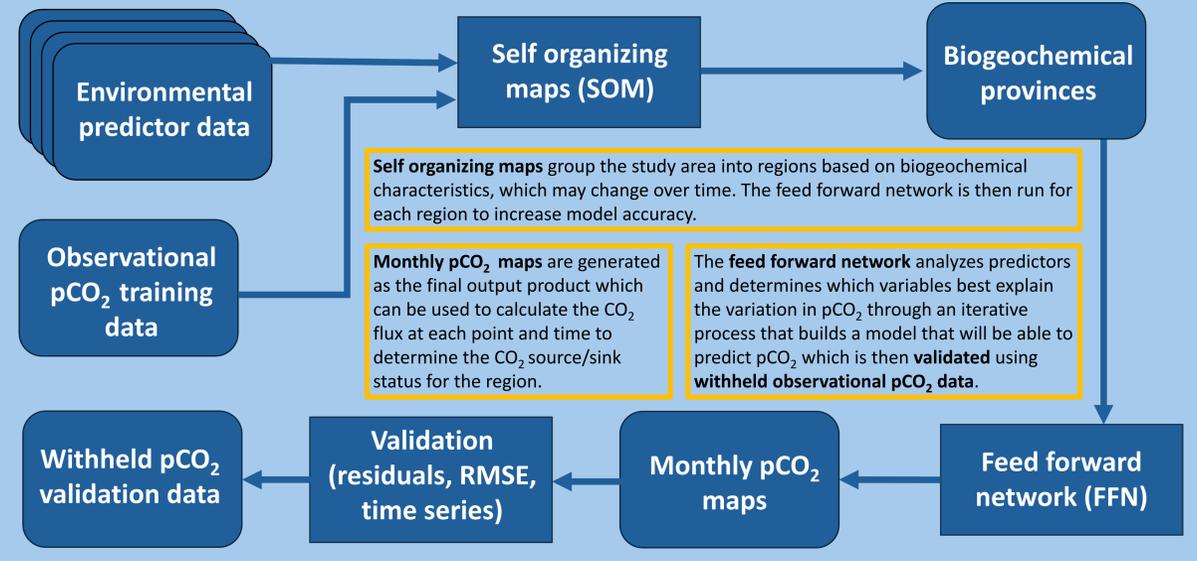


Fig. 3: Average values for the five predictor variables in use, obtained from remote sensing and atmospheric reanalysis data.

The southern tip of James Bay shows some of the highest pCO₂ (Fig. 2) but also has very high temperatures (Fig. 3A), very low salinities (Fig. 3B) and elevated chlorophyll a (Fig. 3D). Visually, we can see that these variables are likely driving high pCO₂ in this area...but why?

Machine Learning Workflow: Self Organizing Map Feed-Forward Network [10][11]



4. Riverine Influence on pCO₂

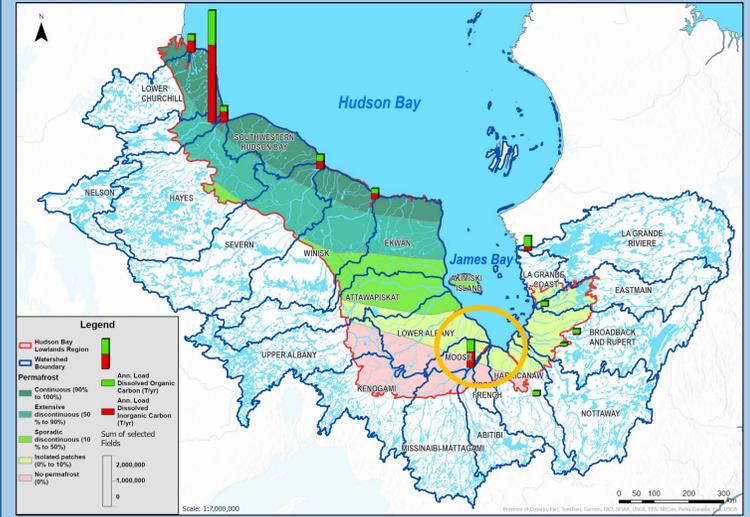


Fig. 4: The watersheds of the Hudson Bay Lowlands showing the permafrost gradient and the estimated annual dissolved organic and inorganic carbon load, based on summertime concentration measurements and average annual discharge. The Moose River outlet is highlighted in orange.

- Rivers are warm relative to the receiving seawater and transport organic and inorganic carbon from land to sea [12]. James Bay is fed by several large rivers that drain boreal Canada and the Hudson Bay Lowlands, which store vast quantities of carbon (Fig. 4) [13].
- Once in the ocean, both the warmer water and influx of carbon from degraded organic material contribute to increased pCO₂ [14], explaining why there is higher pCO₂ near the Moose River outlet.

5. Next Steps

- Complete a first pass run of the entire model (including SOM & FFN) → *Early-February*
- Validate and tweak model → *Mid-February*
- Extrapolate CO₂ fluxes over space and time to determine CO₂ source/sink status → *End of February*
- Use results to assess drivers of pCO₂ in James Bay and better anticipate future gas exchange rates → *March*

Key Takeaways

- Rivers play a large, but not completely understood role in the variation in pCO₂ and CO₂ fluxes in James Bay
- Modelled CO₂ fluxes in James Bay will help us understand the global ocean's role in mitigating continued climate change