Temporal and Spatial variations of air-sea CO_2 fluxes in the Canadian Arctic Archipelago

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Background and Motivation

- The Arctic Ocean is currently at the forefront of climate change driven by both natural and anthropogenic factors as a result of sea ice loss, sea surface warming, physical and biological changes.
- The Arctic Ocean absorbs CO_2 on the order of -66 to -199 Tg C year^{-1} (Tg C= 10^{12} g C) contributing 5-14% to the global balance of CO_2 sinks and sources[1]. However, the spatiotemporal variability of CO_2 uptake and fluxes are not consistent across all Arctic shelves, and accurately estimating CO_2 uptake can be difficult due to a lack of field observations.
- Although the Canadian Arctic Archipelago (CAA) represents about 20% of the total Arctic continental shelf area[2], the CAA role in the biogeochemical and biological production in the Arctic is still poorly understood and there is a knowledge gap in regards of air-sea CO_2 fluxes.
- The aim of this study is to identify the key biogeochemical factors controlling the dissolved CO_2 in seawater and develop a model to calculate the spatiotemporal variations of air-sea CO_2 fluxes over the CAA.

Study Area

- The CAA is characterized by large (~1.5 x 10^6 km^2 marine surface area) and complex Arctic Ocean shelf (vast portions of this region remain oceanographically not surveyed) with narrow channels and interconnected basins formed by glacial action, and separated by sills[3].
- The CAA is an outflow shelf that is located in east of Beaufort Sea and is recognized as a corridor of oceanic water from the pacific and Arctic Oceans into the North Atlantic Ocean via Baffin Bay and the Labrador Sea.
- The CAA partitioned into four regions (Parry Channel, Victoria Strait, Coronation Gulf and the Amundsen Gulf) in this study for easier interpretation.

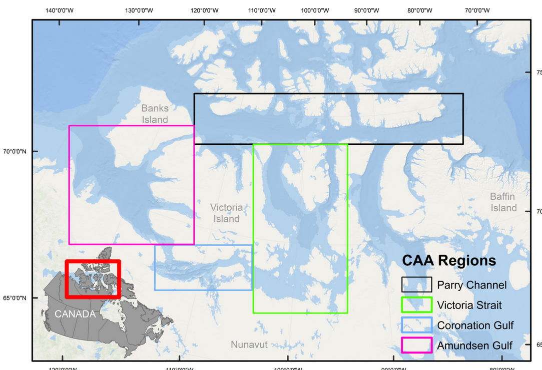


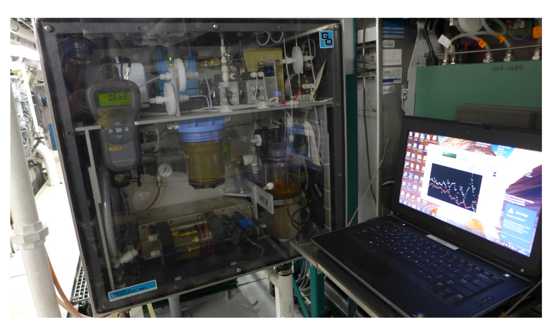
Figure 1: Geographic location of the Canadian Arctic Archipelago (CAA).

One of the most exciting moments of my fieldwork in the CAA in 2016 when I saw the first polar bear in my life!

Methods

- Field datasets of sea surface salinity (SSS), sea surface temperature (SST), oxygen saturation, and dissolved CO_2 in seawater (pCO_{2sw}) were collected across the CAA aboard the CCGS Amundsen for seven year (2009, 2010, 2011, 2013, 2014, 2015, and 2016).
- The ship observations were conducted throughout the cruise using an underway pCO_{2sw} system (General Oceanic's model 8050[4]), that samples water from a high-volume inlet located near the bow of the ship at a nominal depth of 7m. The system calibration was monitored with twice-daily checks against three certified gas standards. In addition, the ship stopped at several locations along the route to conduct sampling using a conductivity-temperature-depth (CTD)/rosette system.
- Ice coverage (in tenths) was obtained from weekly ice charts prepared by the Canadian Ice Services at each point along the ship track across the CAA.

CCGS Amundsen Icebreaker



Underway pCO_{2sw} system

CTD/ Rosette System

Results

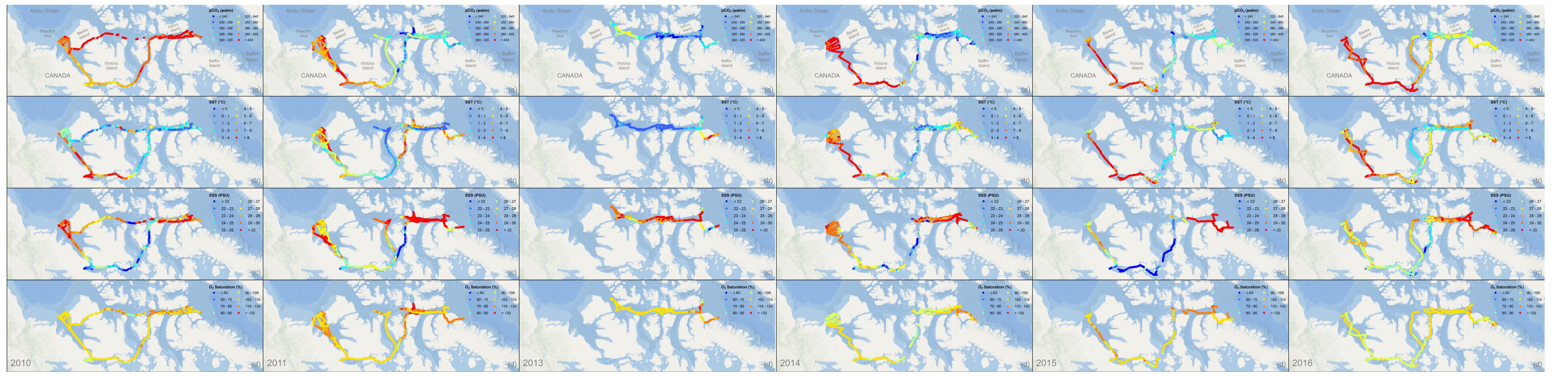


Figure 2 : Spatial underway surface water measurements: (a) observed pCO_2 in µatm, (b) sea surface salinity (SSS) in ‰, (c) sea surface temperature (SST) in ºC, and (d) Oxygen saturation (%) for the study area during 2010, 2011, 2013, 2014, 2015, and 2016.

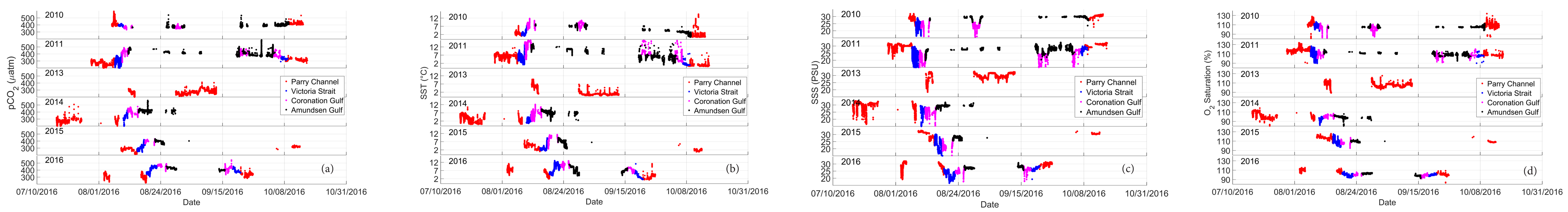


Figure 3: Temporal underway surface water measurements: (a) observed pCO_2 in µatm, (b) sea surface temperature (SST) in ºC, (c) sea surface salinity (SSS) in (‰) and (d) oxygen saturation (%) for the Parry Channel, Victoria Strait, Coronation Gulf, and Amundsen Gulf regions during 2010, 2011, 2013, 2014, 2015, and 2016.

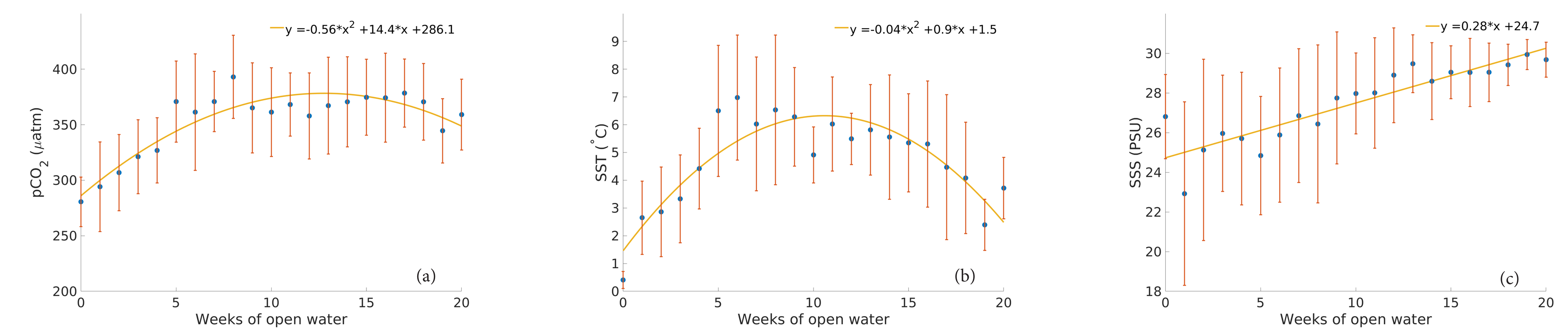


Figure 4: The variability of (a) pCO_2 in µatm , (b) sea surface temperature (SST) in ºC (c) sea surface salinity (SSS) in ‰ with the number of weeks of open water across the study area during 2009, 2010, 2011, 2013, 2014, 2015, and 2016.

The pCO_{2sw} is highly variable spatially and temporally within the CAA with undersaturated values occurs in early summer to supersaturated values in late summer to undersaturated values in autumn with the respect to the atmosphere. This large variability in pCO_{2sw} within the CAA are strongly controlled by changes in seawater surface temperature (SST) and sea surface salinity (SSS). The changes in SST and SSS corresponds to changes in sea ice melt and formation as shown in figure 4.

Conclusions and Future Work

- Early summer (July to mid-August), sea ice melt lowers sea surface temperature, reducing sea surface salinity and enhancing biological activity leading to overall undersaturation for pCO_{2sw} in the CAA.
- Late summer (mid-August to mid-September), the length of open water increases sea surface temperature and decreases biological activity, resulting in saturation or supersaturation in pCO_{2sw} in the CAA.
- In autumn (mid-September to the end of October), sea surface temperature decreases and sea ice starts to form, eventually resulting in pCO_{2sw} undersaturation in the CAA. However, there are regions where the pCO_{2sw} still saturated with pCO_{2sw} as a result of the uptake during the previous weeks and to mixing with deep CO_2 rich water.
- Sea ice conditions could be used as a predictor for the pCO_{2sw} variability as it is influencing the sea surface temperature, sea surface salinity, and the timing of the biological activity.
- In the next step, we will build a model based on the sea ice conditions to calculate the air-sea CO_2 flux in the CAA.

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References

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