Analyses of trends, sub-seasonal to interannual variability and extreme events in the Arctic Ocean from a physics-ice-biogeochemistry model

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I. Motivation

- Arctic under massive pressure and rapid change: air temperatures warm at twice the rate relative to the rest of the globe (Osborne et al. 2018).
- Sea ice decline and thinning (cf. Figure 1) has numerous implications for hydrology, ecosystems, carbon chemistry, climate, but also communities, economies and politics.
- Need of better understanding of processes, as well as past and current conditions to forecast climate change impacts on the Arctic Ocean.
- The harsh weather and distance from large population centres make in-situ observations scarce; sea-ice coverage and seasonal darkness prevent satellite remote sensing. Therefore, numerical models are of special interest to better understand the Arctic Ocean and its interactions with Pacific and Atlantic Oceans.

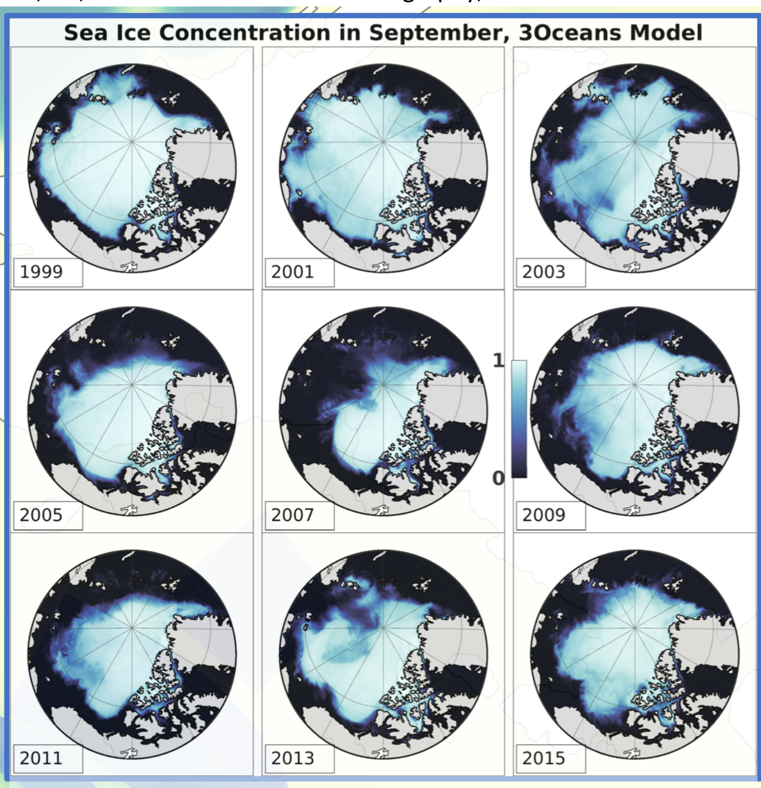


Figure 1: Sea Ice concentration averaged over September, as simulated by the 3Oceans model.

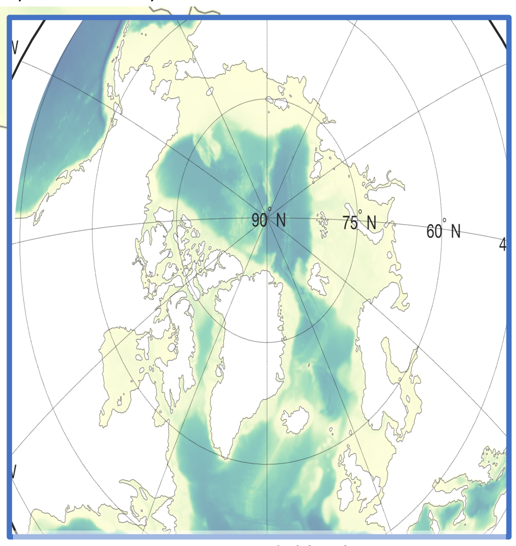


Figure 2: 3Oceans model bathymetric data and grid coverage.

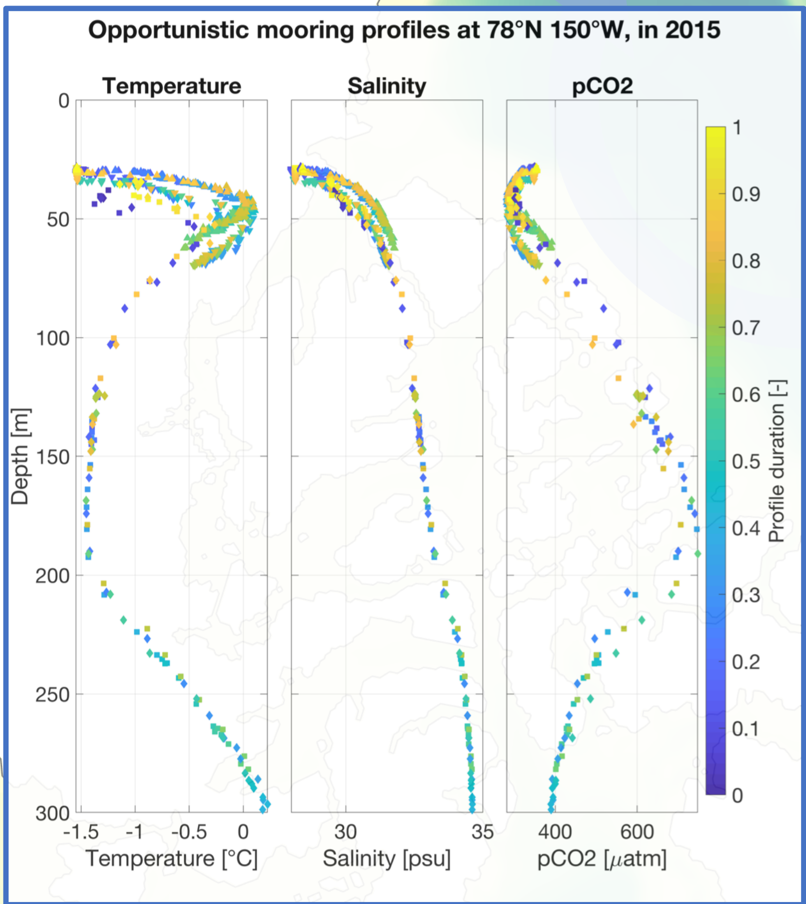


Figure 3: Opportunistic profiles in the Beaufort Gyre for Temperature (left), Salinity (center) and pCO_2 (right). Different symbols account for different dive events, while color accounts for normalized dive duration; a dive typically lasts 5 days.
Data provided by Mike DeGrandpré (University of Montana).

II. Steps

- We will use unique in-situ mooring and ice-tethered profiler data, and 1D models to parametrize processes such as the sea-ice carbon pump, then expand those parametrizations to a 3D model.
- The 1D biogeochemical model will be PISCES, plugged into the 1D hydrodynamical model GOTM through the FABM framework.
- The observations, provided by Mike DeGrandpré (University of Montana), have been collected at the heart of the Beaufort Gyre over several years, with a bihourly temporal resolution (cf. Figure 3).
- The 3D physics-ice-biogeochemical model is the 3Oceans model (NEMO-LIM-PISCES), covering the North Pacific and Atlantic, and the whole Arctic at a 1/4° resolution, such as displayed in Figure 2.

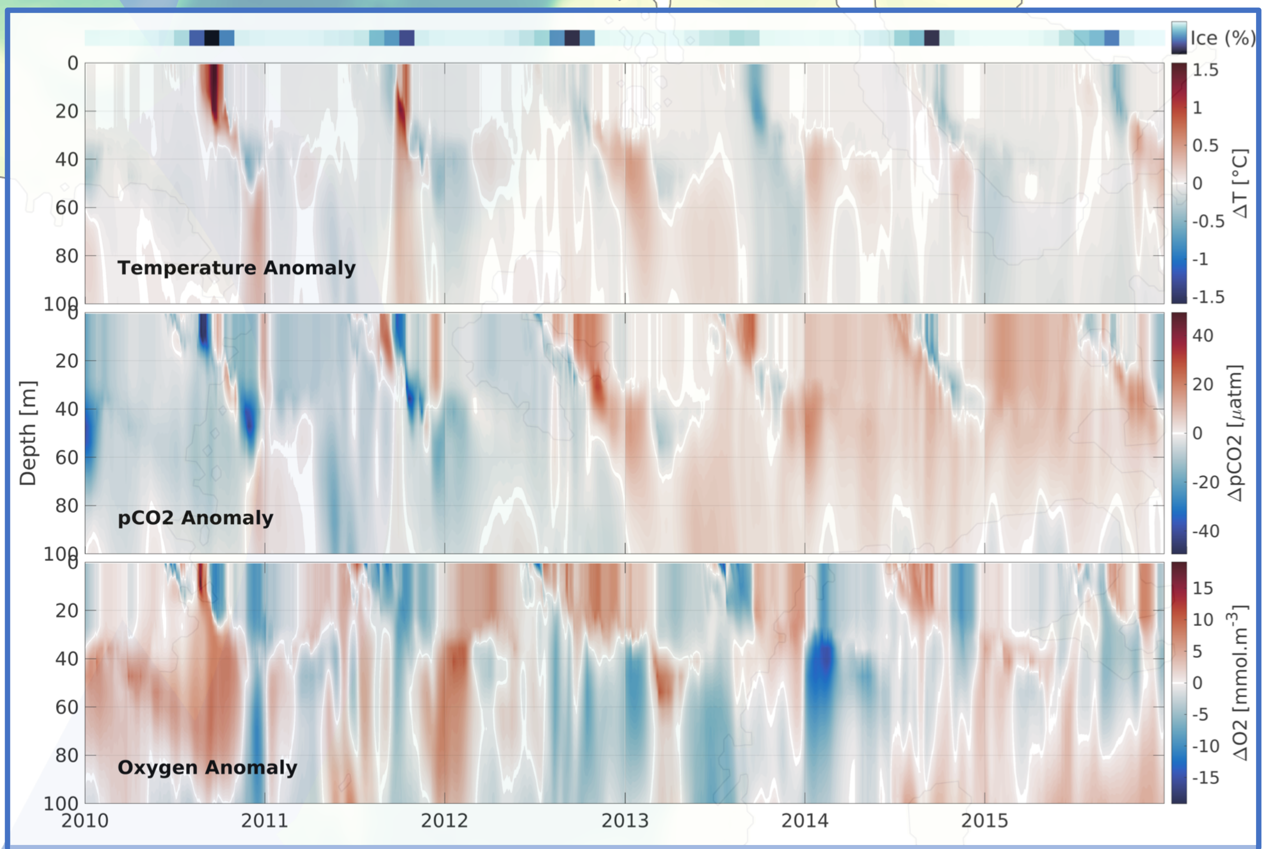
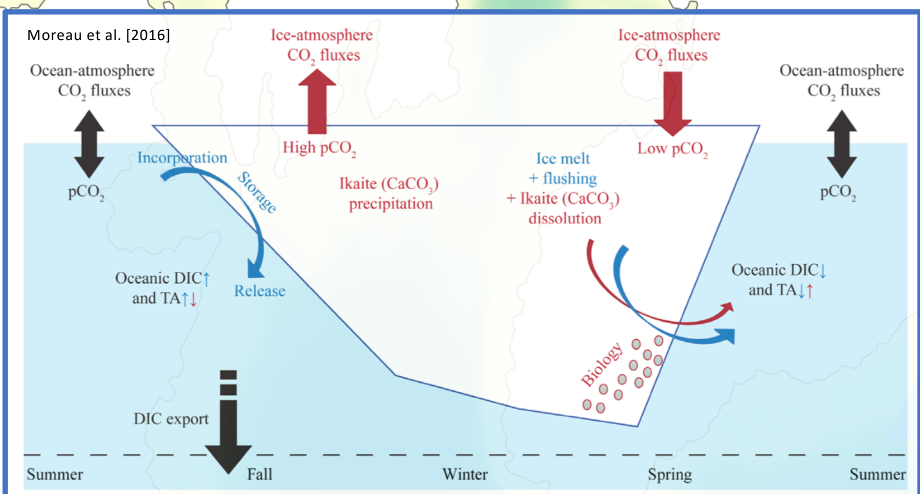


Figure 4: Time series of anomalies of Temperature (top), pCO_2 (middle) and Dissolved Oxygen (bottom) as simulated by the 3Oceans in the Beaufort Gyre (75.5°N, -162°W). Climatology calculated using low pass filter over daily time series covering 2010-2015.



Did you know… the Sea Ice Carbon pump?

1) When ice forms, salty and DIC-enriched brine is rejected below:
   - DIC-enriched surface waters outgas CO_2 to the overlying air.
   - The brine might sink and sequester DIC at depth.
2) Inside the ice:
   - Ikaite ($CaCO_3$) crystals precipitate, with TA/DIC ratio of 2/1.
   - Biological processes can consume CO_2.
3) When ice melts:
   - Ikaite crystals dissolve and increase the surface TA/DIC ratio.
   - Meltwater dilutes surface water, so TA and DIC decrease.
   - Both processes will potentially decrease pCO2, leading to a net CO_2 uptake.

For more details, cf. Rysgaard et al. [2011], Moreau et al. [2016].

III. Objectives

- We aim to better assess variability and extremes in biogeochemical properties such as Dissolved Inorganic Carbon (DIC), as well as their physical drivers (cf. Figure 4).
- How to best parametrize the Sea Ice Carbon Pump (SICP) in numerical models?
- What is the impact of the SICP at the Arctic Ocean scale? How will the decline in sea-ice extent affect carbon uptake and sequestration? How will increasing seasonal ice impact it?
- How are biogeochemical extreme events correlated to physical properties? E.g. how will the rise of ocean temperature affect ocean acidity and therefore ecosystem composition?
- What is the role of anthropogenic climate change in variability, trends and extreme events of biogeochemical and physical properties of the ocean?

References

- Moreau, S., Vancoppenolle, M., Bopp, L., Aumont, O., Madec, G., Delille, B., Tison, J.-L., Barriat, P.-Y., Goosse, H., 2016. Assessment of the sea-ice carbon pump: Insights from a three-dimensional ocean-sea-ice biogeochemical model (NEMO-LIM-PISCES). Elementa: Science of the Anthropocene 4, 000122. https://doi.org/10.12952/journal.elementa.000122
- Osborne, E., Richter-Menge, J., Jeffries, M., Eds., 2018. Arctic report Card 2018.
- Rysgaard, S., Bendtsen, J., Delille, B., Dieckmann, G.S., Glud, R.N., Kennedy, H., Mortensen, J., Papadimitriou, S., Thomas, D.N., Tison, J.-L., 2011. Sea ice contribution to the air–sea CO_2 exchange in the Arctic and Southern Oceans. Tellus B: Chemical and Physical Meteorology 63, 823–830. https://doi.org/10.1111/j.1600-0889.2011.00571.x