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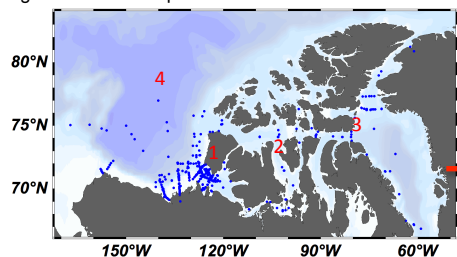
Introduction

Ocean acidification is a consequence of the anthropogenically-driven rise in atmospheric CO₂ levels. Roughly half of the CO₂ released to the atmosphere since the industrial revolution has been absorbed by the world's oceans¹, resulting in an increase in dissolved inorganic carbon (DIC) concentration and a decrease in seawater pH and saturation state of seawater with respect to the calcium carbonate minerals aragonite and calcite (Ω_A , Ω_C). These changes in seawater chemistry constitute a possible threat to the health of marine ecosystems, particularly to calcifying organisms whose ability to secrete calcium carbonate (CaCO₃) skeletons and tests might be hindered by a decrease in pH and Ω .

We present time series of carbonate parameters spanning 2003-2016 to assess their evolution and highlight their temporal and spatial variability in the Canadian Arctic Ocean. Concomitant with increasing atmospheric pCO₂, we expect a progressive enrichment of surface waters in DIC relative to total alkalinity.

Study Area

The Canadian Arctic Ocean is particularly vulnerable to acidification due to the weak buffer capacity of its cold waters and the steadily decreasing sea-ice cover, exposing a gradually larger area of surface waters to direct gas exchange with the atmosphere².

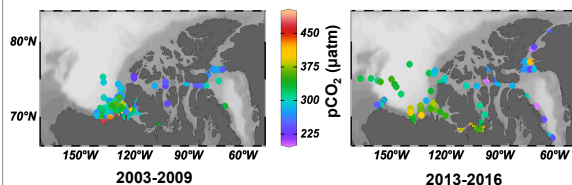


Methods

Basic hydrographic properties (salinity, temperature) and parameters relevant to acidification (total alkalinity, DIC, pH) were measured between 2003 and 2016 aboard the CCGS Amundsen icebreaker. Additional carbonate system parameters (in-situ pH, pCO₂, Ω_A , Ω_C) were calculated from total alkalinity (TA) and DIC using the CO2Sys algorithm³.

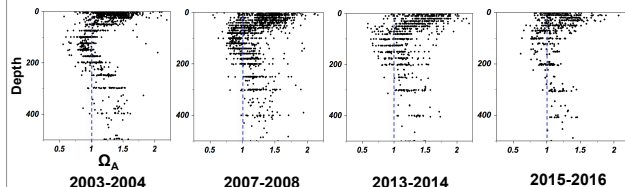
Results

Surface-water pCO₂



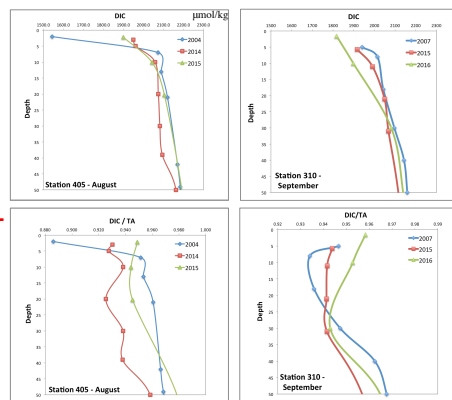
- Most surface samples were undersaturated in CO₂ relative to the atmosphere, indicating that the region remained a sink of atmospheric CO₂ throughout the study period.
- The small number of pCO₂ values higher than atmospheric levels coincide spatially with areas of upwelling and/or freshwater river discharge from rivers, along the North American coast.

Aragonite Saturation

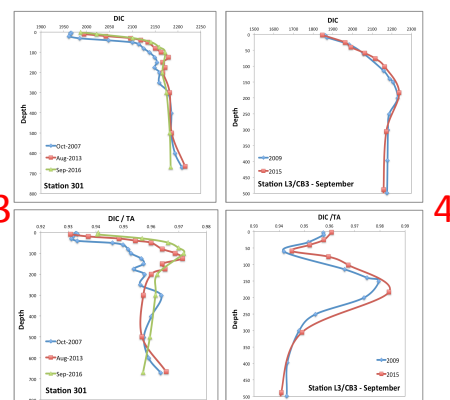


- Ω_A profiles reveal that a substantial fraction of surface waters are undersaturated with respect to the mineral; they vary similarly from ~0.6 to ~2 in all years.
- The Ω_A saturation minimum found at ~100 m depth is coincident with the location of metabolic CO₂-rich Pacific waters and its value increases progressively from west to east through mixing with other water masses.

Surface DIC profiles

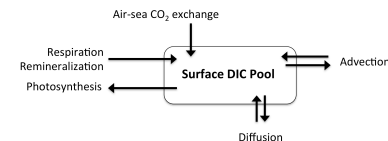


Full DIC profiles

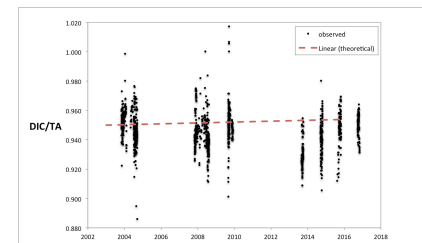


- Surface DIC and DIC/TA profiles show a large variability and do not consistently display expected acidification trends.
- Below the surface layer, the inter-annual variation of DIC and DIC:TA ratios is noticeably smaller.
- Temporal increases in surface-water DIC (top) can often be explained by increasing salinity rather than acidification, as illustrated by salinity-independent DIC:TA ratios (bottom).
- Time-progressive, continuous positive offsets of DIC/TA curves at some stations suggest that acidification extends from the surface to the upper halocline(3) or lower halocline(4).

Mechanisms and Theoretical Constraints



Biological processes (photosynthesis, respiration) and dilution of seawater by freshwater inputs (meteoric, water sea-ice melt) account for most of the variation in surface DIC concentrations. Only the latter affects TA significantly.



The above figure shows the expected increase in surface-water DIC/TA (<25 m) assuming instantaneous equilibration of surface pCO₂ with the atmosphere at a constant TA, compared to the much larger spread in observations.

Conclusions

- Surface and upper halocline waters show significant undersaturation with respect to aragonite throughout the study area, particularly in the Canada Basin.
- Over a ~15 year period, changes in carbonate system parameters due to acidification of surface waters are masked by a large seasonal and spatial variability, due in large part to biological processes.
- Complex interactions between sea-ice, biology and mixing of various water masses have to be taken into account in order to isolate the magnitude of acidification in Arctic waters.

References

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3. Lewis, E., Wallace, D.W.R., 1998. Program developed for CO₂ system calculations. ORNL/CDIAC-105, Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, US Department of Energy, Oak Ridge, TN.
4. Zeebe, R.E. and Wolf-Gladrow, D.A., 2001. CO₂ in Seawater: Equilibrium, Kinetics, Isotopes. Gulf Professional Publishing.