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Drivers, Dynamics, and Impacts of Changing Arctic Carbon Cycle: Challenges and Opportunities

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Abstract:
The Arctic region is one of the most sensitive regions on Earth to climate change with its warming rate being 2-4 times greater than the global average over the past century. Rapid climate warming and sea ice loss have profoundly changed the carbon cycle in the Arctic Ocean, with implications for the transport of CO_2 between the atmosphere and ocean and the internal cycling of carbon between shelves and deep basins.

Our recent studies demonstrated that while the western Arctic Ocean basins are not a large CO_2 sink due to strong stratification and shallow surface mixed layer during the summertime, the surface water CO_2 partial pressure (pCO_2) has increased at a rate twice that of the atmospheric CO_2 increase (Ouyang et al., 2020) and pH has decreased 3-4 times faster than the rate predicted from acidification due solely to atmospheric CO_2 increase (Qi et al., 2022). This is a combined effect of a decreased ocean CO_2 buffer capacity and an enlarged CO_2 and pH seasonality. In stark contrast, while the Chukchi Sea is a strong and increasing CO_2 sink, its surface water pCO_2 has not increased, and pH has not decreased due to a high and increasing biological removal of CO_2 there. Our studies also showed that in the basin subsurface, pH decrease and expansion of acidified water volume are primarily a result of the expansion of the Pacific Winter Water (PWW) (Qi et al., 2017).

Our up-to-date data compilation (1994-2019) showed that sea surface pCO_2 increase and pH decrease correlate most strongly with sea-ice loss from 1994 to 2012. Both the rates of pCO_2 increase and pH & carbonate saturation (Ωar) decreases have slowed down since 2012 as the overall sea-ice loss has oscillated in the past decade (Ouyang et al., 2020; Qi et al., 2022). Thus, it will be highly valuable to continue to observe and document whether the link between surface pCO_2 and pH changes and sea-ice loss has continued after 2012 and how such links may differ on the shelves and in different basin subregions.

Although our previous study based on the observations from 1994 to 2010 quantified the PWW expansion in the upper 250 m (Qi et al., 2017), we have not yet quantitively examined the change rates of DIC, pH, and Ωar due to the limitation of observation. Thus, *it is important to continuously document carbonate chemistry changes in the water column and quantify the rate of subsurface ocean acidification.* With a new carbonate parameters synthesis up to 2023, we will add another 13 years to the record and expand the timespan from 1994-2010 to 1994-2023, which will enable us to have a more comprehensive assessment of change rates and provide us with a deep insight into how PWW intrusion and its modification affect subsurface acidification. In addition, a highly relevant and important research question to ask is whether the DIC added to the PWW comes from the Chukchi shelf via organic matter remineralization within the bottom water, or from local respiration of the sinking organic matter from the surface in the Canada Basin or elsewhere. To address this question, we took the great cruise opportunity of the Mirai 2023 Arctic expedition to collect $\delta^{13}C$-DIC data. $\delta^{13}C$-DIC as a tracer, combined with other biogeochemical parameters, can be used to elucidate the carbon export pathways and partition of potential carbon sources. We anticipate the new observations of $\delta^{13}C$-DIC will

provide critical new information for deepening our understanding of the processes controlling the carbon cycle.

As a chemical oceanographer with a research focus on the Arctic Ocean, I have a deep appreciation for the crucial role of international collaboration within the Arctic research community. Without international collaboration, many of our research goals cannot be accomplished effectively because observational data in the Arctic Ocean is particularly sparse and limited. Therefore, it is eager to have more participators and new techniques for observational data acquisition because "observations which are not made today are lost forever (Wunsch et al., 2013)." I anticipate the launch of the new Japanese icebreaker and envision it as a pivotal contributor to Arctic research, not only equipped with state-of-the-art scientific instruments for collecting first-hand observational data but also serving as an incubator for innovation and an open platform supporting broad collaborations.

References

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