Review RC2 (Eric Mortenson)

General comments
The study presents a comparison of the ice carbonate system throughout the ice column between two sites exhibiting different biological (ice algal) and physical (currents, snow cover) conditions. One of the main results is emphasis on the importance of brine drainage over secondary processes like primary productivity and ikaite precipitation in characterizing the ice-carbonate system. They acknowledge that air-sea exchange and ikaite precipitation may be important near the surface, and that primary productivity be important near the bottom, but the much thicker middle of the ice column has a stronger influence when averaging over the entire ice column.

RC2.01 The challenge to the main result above is the TIC and TA deficits in the surface ice, as shown in the S:TIC and S:TA plots (fig 7). Although this layer is small relative to the entire ice column (therefore making the deficits not as important when considering the entire ice column), why are the nDIC:nTA slopes (fig 8) so close to the ikaite precipitation slope?

I think the answer is that the different horizons are improperly weighted in fig 8. I.e., with the exception of the "high-resolution" core, there are an equal number of measurements for the relatively thin surface and bottom layers as there are for the thicker middle layer. I suggest making separate regression lines for each layer for the 2 cores, and stating that the thicker middle layer dominates the bulk characteristics (per unit area).

This is a very good point, and one we hadn't considered when constructing and interpreting Fig. 8. In response to your comment we attempted to draw regression lines on Fig. 8 for each of the horizons, but it became cluttered. Instead, we created a new table (Table 4) which reports the slopes for each horizon for each of the sites, along with some diagnostic statistics:

Table 4: Slope values of nTA/nTIC (see Figure 8) for each of the horizons at each site, and for all samples at each site. Also reported is the r^2 value for each regression, as well as a p-value testing the significance of each slope (against the null hypothesis that slope = 0).

		Thick FYI (TFYI)			Polynya (POLY)		
		Slope	r^2	p value	Slope	r^2	p value
HORIZON	Top	0.96	0.79	<0.01	1.03	0.91	<0.01
	Middle	0.37	0.39	0.01	0.87	0.86	<0.01
	Bottom	0.67	0.46	<0.01	0.50	0.48	<0.01
	All	0.65	0.88	<0.01	0.81	0.95	<0.01

To discuss this new table, and to address the point about the middle layer dominating the bulk characteristics, the discussion in section 4.4 has been revised to read:

"If primary production were significantly affecting any of the ice horizons, we would expect points on a graph of nTA vs. nTIC (Fig. 8) to fall along the photosynthesis/respiration line. Although statistically significant linear trends ($p < 0.01$) are apparent at both sites, and in all horizons, they do not follow the

photosynthesis line, even in the bottom ice horizon (Table 4). The slopes that we observed of nTA vs. nTIC all fell within the range of 0.50 – 1.03, with an overall slope of 0.65 at TFYI and 0.81 at POLY (Fig. 8). In their study of landfast sea ice in the Canadian Arctic Archipelago (Franklin Bay), Miller et al. (2011a) did see a few samples from May that fell along a photosynthesis line, but most followed a very similar slope to those presented in Fig. 8 and Table 4.

It may however be more instructive to consider the slope of the bottom horizon alone (Table 4), as the overall slopes are biased by the high number of samples collected at the surface and bottom, despite representing only a small portion of the overall ice volume. In the bottom horizon, we do see lower slope values (0.67 at TFYI, 0.50 at POLY), suggesting a shift towards the net respiration line, consistent with past studies that have found net heterotrophy in ice algae communities during the bloom (Campbell et al., 2017,2022; Rysgaard and Glud, 2004, Rysgaard et al. 2008). In the 2014 spring, Campbell et al. (2017) observed net heterotrophic conditions in the bottom ice of Dease Strait during a period of carbon accumulation, before switching to autotrophic conditions around 8-May. In a study near Resolute Bay, Brown et al. (2015) found substantial TIC drawdown near the beginning of an ice algae bloom, but that region experiences bottom ice Chl a value about 10 times higher than either of our sites (Leu et al., 2015). It is possible that the rate of ice algal production in Dease Strait is simply too low to have a noticeable impact on carbonate chemistry, or that primary production at our site was balanced or exceeded by respiration, highlighting that sea ice algae communities may have a complex role in carbon cycling in sea ice."

And portions of the discussion in section 4.5 have been revised, now reading:

"Of course, the TA:TIC ratio is not the only available evidence of ikaite precipitation in sea ice. There is microscopic evidence (e.g., Rysgaard et al., 2013), and crystals extracted from sea ice have been positively identified by x-ray diffraction (Dieckmann, et al. 2008). We did not have access to such techniques, but Figure 8 provides evidence that ikaite precipitation did occur in our study. At both sites, linear relationships between nTIC and nTA with slopes between 0.5 and 1.0 (Table 4), were observed through all horizons. These slopes are similar to those observed by Miller et al. (2011a), who hypothesized that such a relationship is the result of combined ikaite precipitation and respiration in the ice. Similar slope values were observed by Geilfus et al. (2012) and Brown et al. (2015) in brine. The differences we observed in slopes between horizons are likely the result of specific processes occurring near the surface (i.e. outgassing, see section 4.2) and the bottom (net respiration, see section 4.4) but with a strong tendency towards the carbonate precipitation/dissolution line in all horizons. Therefore, ikaite precipitation certainly seems to be occurring in our study area; our contention is simply that at this location (and apparently at several others) the amount of ikaite precipitation is not enough to result in a large fractionation of TA and TIC within the sea ice."

In addition, please see our response to Reviewer 1's comment RC1.01, which describes a minor change to the abstract.

After addressing the above, as well as fixing the minor comments below, I would recommend this article for publication in The Cryosphere.
Cheers,
Eric Mortenson
Specific comments

RC2.02 -84: I suggest adding underlined: …and under-ice seawater temperature and currents…

Change made

RC2.03 -104: I suggest adding underlined: …a function of under-ice seawater nutrient concentration and turbulence, …

Change made

RC2.04 -259-260: Note that the respective magnitudes of tidal amplitudes and of tidally-induced currents are not necessarily related (e.g., currents can be quite strong at the mouth of an enclosed bay with a small opening, due to small amplitude changes in the enclosed bay)

Good point, we revised this statement to improve clarity:

The increase in currents at POLY were likely due to a spring tide, but this was difficult to confirm with the Cambridge Bay tidal stage predictions (Fig. S1) where amplitudes are low due to the wide geometry of the bay.

RC2.05 -323: As mentioned just above this line, snow cover has a strong effect on light penetration, it would be nice to see a number for (or quantitative comparison to) Dalman's snow cover measurement.

We have added:

"The distribution of ice algal biomass we observed was different from that reported in Dalman et al. (2019) who reported Chl a biomass averaging 9.3 mg m^{-2} at the polynya site and 1.4 mg m^{-2} at the thick ice site (c.f. Table 2) with an average snow thickness of 2.8 +/- 0.5 cm."

RC2.06 Table1/2: It would be nice to see these separated by date, in addition to the totals, at least for mean and standard deviation

We created this table. It is rather large, and does not contribute significantly to the interpretation of data, although it does help show that the ice chemistry was quite stable between sampling dates. We will place it in the supplemental information. Note also that we will make all data on an open access data server available as per The Cryosphere's data policy, and will include citations to the database records in the revised manuscript.

Technical corrections
RC2.07 -Please be consistent using either DIC or TIC, but not both.

Thank you, corrections have been made to TIC, except in a few instances in the introduction where DIC was the more appropriate term.

RC2.08 -Just a stylistic comment, why use "horizons", instead of strata or levels?

Good question, we went back and forth on this ourselves. Our hope is that horizon is a well-understood term from geology/geography (e.g. soil horizons, geological horizons) that can be well understood by our audience.

RC2.09 -102-103, twice there are "(" with no ending parentheses, replace with commas maybe

Thanks, we fixed this.

RC2.10 -Lines 119 and 125, Please spell Mortensen with "-son"

Correction made, and our apologies!

RC2.11 -To me, it seems a bit clearer if the paragraph on all cores collected (lines 187-196) came before the paragraph on individual core carbon sampling (lines 177-186)

We did find this section a little difficult to organize but prefer the current structure.

RC2.12 -Line 372: Nomura, Nomura should be Nomura, 2014

Correction made

RC2.13 -Line 433: remove "to" at end of line

Correction made

RC2.14 -Tables 1 and 2 appear to be identical, but with slightly different captions.

Yes, sorry about that… Very bad "typo". The revised manuscript has the correct table, and we have copied a version of this table in our response to Reviewer 1's comment RC1.08

RC2.15-Fig. 1: I recommend changing the font color for POLY to white to improve visibility

This change has been made, along with some other improvements for visibility. Please see our response to Reviewer 1's comment RC1.18.