Comments to reviewers (Anonymous) – The Cryosphere

Thanks for a constructive and helpful review.

Specific comments: "Arctic" from title has been removed.

It strikes me that there was so much snow on both the thick and thin ice. Please discuss what the freeboard of the ice was and if there wasn't any flooding? How would the occurrence of flooding modify your conclusions?

Although there was a lot of snow on the thick fast ice in the fjord there was not natural flooding of the surface occurring at the time of our measurements (the ice cover was impermeable). When we installed ocean instruments (drilling through the ice) we created some artificial flooding. A widely distributed snow thickness surface however showed that flooding was limited to only the area immediately surrounding the installed instruments. Texture analysis of ice cores from ICEI also indicates that there had been flooding and snow ice formation at some point prior to our field campaign (see Fig.3a and page 5045 line 25 onwards). In the Polynya site the snow was much thinner and there was a positive freeboard (1cm) and no flooding. More snow will affect the freeboard and could cause flooding. However, the largest effect of snow on ikaite production will be through its effect on increasing temperatures within sea ice. Higher temperatures in sea ice will lower brine concentrations of calcium and bicarbonate and thus ikaite production. We have added a little more on this our revision.

P. 5042, l. 9-10: Why did you not calculate brine salinity directly from brine/ice temperature? This is the most common approach and is not affected by errors, which could be introduced into the brine volume calculations.

Brine salinity has been calculated directly (Unesco 1978) in the revised manuscript independent of brine volume.

L 13: how does the warming of the glass plates affect the crystals?

Ice texture analysis using the standard technique that we used requires a slight melting of the ice so that it can refreeze onto the glass plate. This is done by warming the glass plate to about room temperature and then pressing an even ice surface against it in the cold room. The slight melting and refreezing of the ice does not appear to affect the ice crystal structure (and no other study has found this either). The method does not warm the ice significantly to affect the ikaite crystals. Furthermore, we only used images from the outer part of the sections not affected by warming.

P. 5043 top and fig 6: The concentrations look great, but are derived by significant extrapolation to sample reference volumes. How many crystals (N) were really sampled/counted during the initial, original analysis?

On average 27 ikaite crystals were counted for each subsample - range 3 to 144.

The totality of all results was obtained from a larger number of cores at the two sites. How would small-scale, lateral variability affect your results?

We believe that the small-scale variability is already covered by our ikaite extraction procedure where subsamples (2-90 mg) of ice were cut of 3 random places within the 5-10 cm vertical sections in three parallel cores. The horizontal ikaite crystal variability will be the focus of another publication covering crystals in frost flowers, brine skim and surface ice layers.

P. 5045, l 25: are you sure this was polygonal granular ice?

This is determined visually from ice texture. Figure 3a clearly shows polygonal shapes of the sea ice crystals. These crystals may appear small compared to polygonal granular crystals observed in superimposed ice in e.g. Antarctica (Kawamura et al. 2004) but appear more similar to what has been seen in snow-ice in the Baltic Sea (Granskog et al. 2006). We believe this ice was snow-ice, i.e., formed through consolidation of snow and percolated seawater (as described).

P 5046, l. 8-9: Here and elsewhere, what do you really mean? Individual ice crystals consist of ice platelets/lamellae with brine layers in-between. If the crystals are in these interstices (brine layers), they would still be in contact with the brine. In addition, in young sea ice, the brine layers are well connected to the larger drainage network including brine pockets and channels, and thus are not separated from the brine as stated. Please describe more carefully the situation you think you observe.

Ikaite crystals were observed between the ice platelets/lamellae. We have tried to explain this more clearly in the revision.

Also, it is not clear why you point out this fact repeatedly. Do you expect that Ikaite crystals forming in larger brine channels would be flushed out together with the brine, and that therefore their location within the much smaller interstitial pore space is require to retain them and protect from flushing? Please clarify.

We expect the ikaite to be formed in the brine system. As they are particles they get trapped between the small interstitial pore spaces and therefore retained in the ice. In contrast the CO2 liberated (Eq. 1 in manuscript) from the production of CaCO3 can escape to the water column due to brine drainage. This will increase alkalinity in sea ice. We have made this appear clearer in the revision.

In any case, don't you think that Ikaite crystals would form anywhere in the brine space and that therefore the actual initial concentration would even be higher than you have observed?

Ikaite will form where the concentrations of Ca2+ and HCO3- is sufficiently high. It may even form and dissolve several times. At present we do not have sufficient data to evaluate this. However, concentrations of ikaite cannot obtain higher values than TA concentrations.

P 5048: Please better introduce and describe the FREZCHEM model.

A new sub-section has been added in the Methods section introducing the FREZCHEM modeling approach.

P 5049, l. 3-13: Related to my comments above, please be more clear about what the difference is between the "brine system" and interstitial space, and why this is important.

It is a key point as to exactly where the crystals are located. If they are in the brine channels then they can potentially move with the circulation of brine as the temperatures change internally in the ice. If they are isolated from larger brine networks and rather are at the interstices then they may remain trapped in the ice as convection occurs. This will make a big difference on the exchange through winter and well into spring. We end this paragraph in the revision with: As a result, TA increases relative to TCO_2 in sea ice in spring and summer. When ikaite crystals dissolve during sea ice melt, surface water salinity and pCO_2 will decrease. This is important as low pCO_2 values in surface waters will lead to a large CO_2 flux from the atmosphere into the ocean.

P 5051, l. 20-22: In which season? Or is this number an annual average?

During spring melt. This has been added.

P 5052: This discussion is confusing in places. Be more careful about describing the effects of ice formation, advection, and melt, and distinguishing between processes within the polynya in winter, the polynya region in summer, and the region away from the polynya

We have made this appear clearer.

P. 5053: The discussion of the effect of water masses from Fram Strait is interesting. However, how long would it take for that water to equilibrate with atmospheric pCO2, and thus not to be depleted any more when it reaches the study region?

That is a good question that is difficult to answer. The calculation is difficult to make as we do not know the air-sea transfer coefficient in such ice covered waters. Another recent study from the Beaufort Sea, however, shows that it can takes months to equilibrate with the atmosphere following ice-free conditions (Brent et al. JGR - in press). However, our area contains drifting sea ice year round. We expect the CO2 uptake to continue beyond our study area. Lots of sea ice is transported in the East Greenland Current and melts just outside our study area.

(Else BGT, Galley RJ, Lansard B, Mucci A, Papakyriakou TN, Brown K, Tremblay J-É, Babb D, Barber D, Miller LA, Rysgaard S (*in press*) Sea ice loss and the changing atmospheric CO_2 uptake capacity of the Arctic Ocean: Insights from the southeastern Canada Basin. Journal of Geophysical Research)

P5054, l. 3-6: Can you be more carefully differentiate between the polynya region and regions downstream where the ice melts?

We have provided more details on this in the revision.