Quantification of calcium carbonate (ikaite) in first– and multi–year sea ice

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Summary

Ikaite ($CaCO_3 \cdot 6H_2O$) is a metastable calcium carbon mineral that precipitates out of sea ice at ~–2.2ºC under standard seawater conditions (Assur, 1958). Ikaite may play a significant role in the sea ice carbon pump (Rysgaard et al., 2007), but its spatial and temporal dynamics are still poorly understood, due to the challenges in measuring its concentrations in sea ice. Here we report the development of a simple and reliable method for quantifying ikaite in sea ice based on the measurement of dissolved inorganic carbon (DIC) in filtered ice samples. This technique has the potential to rapidly expand the database of ikaite measurements in sea ice and improve our understanding of the regional and global importance of the sea ice carbon pump.

Methods

- Sea ice cores were collected from the Sea–ice Environmental Research Facility (SERF), Winnipeg in January 2013, Station Nord, Greenland in April 2015, and Cambridge Bay, Nunavut in May 2016.
- Ikaite concentrations were determined using image analysis (Fig. 1) and DIC analysis of filtered crystals (Fig. 2) and results were compared.
- Environmental parameters (air and sea ice temperature, bulk salinity, TA, DIC, snow depth, and ice thickness) were also measured at each sampling location.

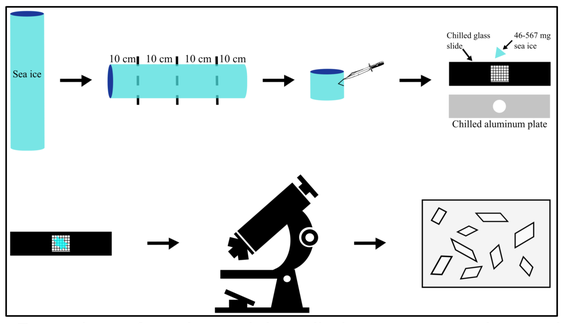

Figure 1: Procedure for determining ikaite concentration using image analysis. Details for this technique are outlined in Rysgaard et el. (2013).

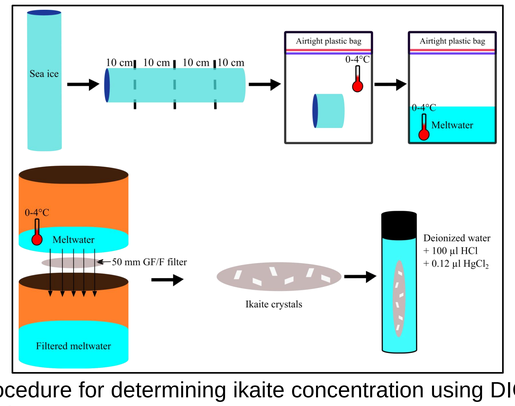

Figure 2: Procedure for determining ikaite concentration using DIC analysis of filtered crystals.

Results

- Ikaite crystals ranged from 5 to ~100 µm (Fig. 3). Ikaite concentrations at SERF were calculated using image analysis only (Fig. 4a) and using both image analysis and DIC analysis of filtered crystals at other sampling sites (Figs. 4b–4d).

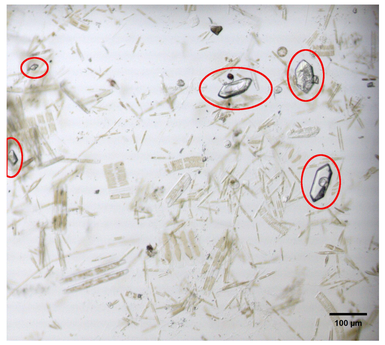

Figure 3: Ikaite crystals (circled in red) observed with sea ice algae, Cambridge Bay, Nunavut, May 2016. The presence of algae may increase the pH, creating conditions that favour ikaite precipitation.

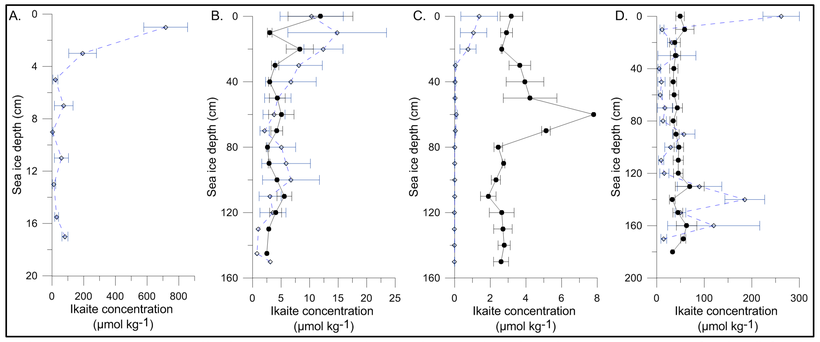

Figure 4: Average ikaite concentrations determined using image analysis (blue) and DIC analysis of filtered crystals (black) from (a) SERF, (b) first–year sea ice at Station Nord, Greenland, (c) multi–year sea ice at Station Nord, and (d) first–year sea ice at Cambridge Bay, Nunavut.

- The average values of each measured environmental parameter at each sampling site are shown in Table 1. In general, sea ice temperature increased with depth and bulk salinity and TA and DIC concentrations had C–shaped vertical profiles through the ice.

Table 1: Average values of each measured environmental parameter at each sampling site.

Sampling site	# of cores	Air temp. (ºC)	Snow depth (cm)	Ice thick. (cm)	Sea ice temp. (ºC)	Bulk salinity	TA (µmol kg^{-1})†	DIC (µmol kg^{-1})†
SERF	1	~–22	0	20.0	–7.5±1.1	9.6±2.3	605.4±126.8	453.2±63.8
Station Nord (FYI)	4	–16.1±2.9	107.0±7.0	122.0±9.9	–2.7±0.3	1.9±0.2	147.1±13.2	211.1±22.7
Station Nord (MYI)	2	–12.3±2.1	128.5±6.5	165.5±3.5*	–5.3±0.4	0.26±0.04	78.9±11.5	81.4±5.5
Cambridge Bay	7	–4.3±0.8	10.4±3.6	173.8±3.7	–4.2±0.3	5.3±0.2	407.1±12.1	356.1±9.9

Abbreviations: FYI = first–year sea ice; MYI = multi–year sea ice.
†Concentrations are given in µmol kg^{-1} melted sea ice.
*Due to the limitations of the coring equipment, it was not possible to collect full multi–year sea ice cores.

Figure 5: Sea ice core collection, Cambridge Bay, Nunavut, May 2016.

Discussion and conclusions

- DIC analysis of filtered crystals is an effective and efficient method of determining ikaite concentration in sea ice that agrees with existing techniques and we recommend it be used for ikaite quantification in future.
- Ikaite concentrations are highest in cold sea ice with high bulk salinity and TA and DIC concentrations.
- Ikaite precipitates more readily in first–year sea ice than in multi–year ice. Seasonal sea ice cover is becoming more common in the Arctic, so ikaite concentrations are expected to increase. More ikaite in sea ice will store more TA, enhancing the sea ice carbon pump and increasing the contribution of ice covered seas to global carbon fluxes.
- Using the new technique to quantify ikaite will lead to increased understanding of its spatial and temporal dynamics as well as its role in carbon fluxes in ice–covered seas.

References

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