Interactive comment on **"Ikaite crystals in melting sea ice – implications for** pCO2 **and pH levels in Arctic surface waters"** ***by*** **S. Rysgaard et al.**

Anonymous Referee #1

Received and published: 10 April 2012

This manuscript presents new data of ikaite in sea ice from a decaying floe in the Fram Strait and its potential impact on the CO2 cycle. It is well written and the message is clear. I think it should be published in The Cryosphere. However, there are some points that should be cleared first. An interactive comment (full review) of this manuscript by S. Papadimitriou was published on 28 March 2012 on The Cryosphere website, in which many of the points I would like to raise were addressed. It is not useful to repeat this in the same or slightly other words. Therefore, I would like to refer to those comments.

At the end of the discussion, the authors touch upon the role of melting sea ice and conclude that it may have a significant effect. This is an interesting result which is certainly worthwhile being brought here. However, what I would also like to read here is the role of ikaite on an annual scale, i.e., combined for sea-ice formation in autumn and melting in spring. This would give the reader some idea about the net effect of the ikaite cycle. Possibly, the authors cannot give definite answers to this question, but some speculation will also do (when marked as such). At least, they should mention the whole ikiate cycle and its consequences here.

We acknowledge the positive and constructive comments by this reviewer and will answer in detail below. In addition, we have elaborated a little more on the annual ikaite cycle and its consequences.

Below, I have listed some additional minor comments.Minor comments P1016,L4 . . . (a polymorph of CaCO3.6 H2O) . . .

Suggestion followed.

P1016,L23-26 Please explain how CO2 can be more efficiently rejected than alkalinity, as this is not self-evident.

Crystallization of $CaCO_3$ [$Ca^{2+} + 2HCO_3^- \rightarrow CaCO_3(s) + H_2O + CO_2$] increases the concentration of CO_2 in the brine during growing sea ice conditions. $CaCO_3$ crystals trapped within the ice crystals will cause a more efficiently rejection of CO_2 than total alkalinity (TA) during ice formation (Rysgaard et al., 2007) and this will, over

the winter, lead to enriched TA conditions relative to total dissolved inorganic carbon (TCO_2) conditions in sea ice as compared with the ratio in seawater.

A detailed explanation is provided in the revision.

P1017,L25 On 22 June, . . .

Linguistic correction made according to suggestion.

P1018,L3-4 Please add the country how this is usually done. I guess this is not Lebanon.

USA has been added.

P1018,L5-7 It is fine that the authors realize that brine is lost during handling. However, I do not understand ("Thus, ...") how they can be so certain that this is about 10%. Please explain.

Brine loss during handling is well known but the point of approximately 10% loss (plus or minus 5%) is based on unpublished data collected during the IPY-CFL project in 2008. The measurements were done by replicate samplings (core extraction) from a small area of uniform first-year sea ice (area of about 10 m^2). Salinity was measured from these cores and the variability in the measurements is used to estimate what the potential loss of the brine would be. Thus the expectation is that the brine volumes would be approximately equal over this small area and most of the variability would be due to variable brine drainage. These data are unpublished thus we leave the terminology that we 'speculate' that this rate is 'approximately' what we expect.

P1018,L11 Lenzkirch (typo) P1018,L23 Konduktometer (typo)

Typo corrected.

P1019,L17 To avoid confusion with reading, add gaseous to CO2, i.e., . . . and gaseous CO2 by gas chromatography . . .

Suggestion followed.

P1022,L18 delete first comma

Yes.

P1023,L2 . . . is in line with the existence of . . . ("strongly suggests" suggests that you need evidence, but you have observed the crystals indeed)

Suggestion followed.

P1023,L3 were, instead of was

Changed according to suggestion.

P1023,L5-6 I do not see an obvious reason for this contention. Please explain better.

We have rephrased this sentence.

P1023,L19-20 I would suggest something like: Our ikaite data originate from the off-shore Fram Strait . . .

Suggestion followed.

P1023,L21 delete: may

May – deleted.

P1023,L23 delete: Normally

Normally – deleted.

P1024,L22 add: "into the water" at end of sentence

Added as suggested.

P1025,L1 It is not clear how these figures were obtained. For example, for obtaining air-sea CO2 fluxes you need wind velocity. Please present a detailed description of the calculation.

We have included more on this calculation as requested:

Assuming that all ikaite crystals dissolve in the sea ice or in the mixed layer, melting of 0.2 m sea ice with an average temperature (-1.1°C), salinity (3.9), TA (420 μmol kg^{-1}) and TCO_2 (221 μmol kg^{-1}) from Table 2, into a 20 m thick mixed layer with average water column characteristics of temperature (-0.2°C), salinity (32.6), TA (2203 μmol kg^{-1}) and TCO_2 (1987 μmol kg^{-1}) from Table 1, will result in a 3.8 ppm decrease in $p\mathrm{CO}_2$ per week. This decrease is calculated from the resultant conditions in a 20 m mixed layer of temperature (-0.2°C), salinity (32.2), TA (2186 μmol kg^{-1}) and TCC2 (1970 μmol kg^{-1}) using the CO2SYS program – see materials and methods. Assuming no $CaCO_3$ crystals e.g. TA and TCO_2 concentrations are both 221 μmol kg^{-1}, the resultant $p\mathrm{CO}_2$ decrease will be 2.2 ppm per week. Based on average conditions during the field campaign (Table 1 & Table 2), this corresponds to an air-sea CO_2 uptake of 10.6 mmol m^{-2} sea ice d^{-1} or to 3.3 ton CO_2 km^{-2} ice floe week^{-1} (with $CaCO_3$) and 4.9 mmol m^{-2} sea ice d^{-1} or 1.5 ton CO_2 km^{-2} ice floe week^{-1} (without $CaCO_3$). It should be noted that we do not take wind mixing into account, but just consider the resultant CO_2 uptake of melting 0.2 m sea ice into a 20 m mixed layer after a return to initial $p\mathrm{CO}_2$ conditions. An important finding here is that the presence of $CaCO_3$ in sea ice will double the air-sea flux as compared with melting of pure sea ice.

P1025,L4 . . . using 14C. (everyone understands 14C)

Suggestion followed.

P1025,L5 "may potentially" This is rather vague.

Ok – we make it appear stronger.

P1027,L12 Year appears to be wrong.

Correction made.

P1027,L23 Mehrbach

Typo corrected.

Figure 1 Please include latitude and longitude

Included in revision

Caption Figure 1: . . . on 30 June 2010.

Linguistic correction followed.