

## ***Interactive comment on “CO<sub>2</sub> and CH<sub>4</sub> in sea ice from a subarctic fjord” by O. Crabeck et al.***

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Received and published: 9 September 2014

Dear Editor

Below are our comments and responses to the questions and suggestions by the reviewers. In addition, we have attached a revised version of our manuscript. As you will see we have addressed all reviewer's comments and followed most of their suggestions and revised accordingly. We have provided our answers below in blue text. We would like to thank you for constructive comments and suggestions that improved our manuscript.

On behalf of all authors Odile Crabeck

Anonymous Referee #1 Received and published: 17 June 2014 1. The paper presents a suite of new and interesting data, however the aim or goals of the paper have not

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become apparent to me. Individual sections contain relevant discussions, however whether and how those relate to each other has not been made very clear in my view. In my view the paper would strongly benefit, if the authors identify the main points, or the main red line, and then design the paper accordingly. I am confident that this can be achieved.

We agree, in order to clarify the main points of paper we modified the title to: 'CO<sub>2</sub> and CH<sub>4</sub> in sea ice from a subarctic fjord under influence of riverine input.' We added a clear description of three main points of the paper at the end of the introduction Line 72-78: In this study we had three main objectives: (1) To document and discuss the interaction between landfast sea ice, riverine input and gas dynamics. (2) To quantify CH<sub>4</sub> concentrations in bulk sea ice and to gain key information on the effect of sea ice cover on methane emissions in ice-covered seas. (3) To increase our understanding of the pCO<sub>2</sub> dynamics in sea ice we made measurements of the spatial and temporal distributions of pCO<sub>2</sub> in the surface ice. Combined these are all highly pertinent for evaluating the role of coastal Arctic sea ice in the carbon cycle (Parmentier et al., 2013).

And finally, we modified the structure and the title of the discussion The first part of the discussion 5.1 and sub-titles are in relation with the first objective of the paper: “document the interaction between the landfast sea ice, the riverine input and gas dynamics within sea ice cover”. The second part of the discussion is in relation with the two last objectives: “include measurements of CH<sub>4</sub> concentrations in bulk sea ice and add further to the understanding of pCO<sub>2</sub> dynamics in sea ice. “ 5. Discussion 5.1 Riverine input and sea ice fjord system 5.1.1 Fresh water input at the ice-water interface 5.1.2 Fresh water for earlier ice growth 5.1.3 Gas content and fresh water input 5.2 Greenhouse gases in sea ice 5.2.1 Methane 5.2.2 pCO<sub>2</sub>

2. A reoccurring pattern, which makes it difficult to read the paper, are long and detailed discussions, of what is not the case. While, I do see the need and the purpose of such sections, eventually the reader spends quite some time and thinking to learn what is

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NOT the case. Examples: the last section of the abstract is unrelated to the paper, or the long discussions about the sources of CH<sub>4</sub>, which ends with the statement: unfortunately, our data set does not provide any proof....Again, I think these discussions are thoughtful, and possibly required, it is however unclear, which purpose they serve.

We agree, the last section of the abstract has been removed & also we have extensively modified the rest of the text to address this issue raised by the referee.

In the discussion about the CH<sub>4</sub> sources, we clarify the sources and pinpoint the river has major input of methane: Line 430-431 : Like CH<sub>4</sub> maxima in the overlying sea-ice also coincide with salinity minima, the Kapisillit river is most likely the major sources of CH<sub>4</sub> into the fjord system

About the bubbles sources, according to your comment and the second reviewer comments we decide to delete the point (3) concerning the presence of ebullition process from sea floor.

Minor points: Rewrite abstract to summarize the paper, not the key topics in this field of research. We have revised our abstract as suggested. Revised Abstract We present the CH<sub>4</sub> concentration [CH<sub>4</sub>], the partial pressure of CO<sub>2</sub> (pCO<sub>2</sub>) and total gas content in bulk sea ice from subarctic, land-fast sea ice in the Kapisillit fjord, Greenland. Fjord systems are characterized by freshwater runoff and riverine input and based on  $\delta^{18}\text{O}$  data, we show that >30 % of the surface water originated from periodic river input during ice growth. This resulted in fresher sea ice layers with higher gas content than is typical from marine sea ice. The bulk ice [CH<sub>4</sub>] ranged from 1.8 to 12.1 nmol L<sup>-1</sup>, which corresponds to a partial pressure ranging from 3 to 28 ppmv. This is markedly higher than the average atmospheric methane content of 1.9 ppmv. Evidently most of the trapped methane within the ice was contained inside bubbles, and only a minor portion was dissolved in the brines. The bulk ice pCO<sub>2</sub> ranged from 60 to 330 ppmv indicating that sea ice at temperatures above -4°C is under-saturated compared to the atmosphere (390 ppmv). This study adds to the few existing studies of CH<sub>4</sub> and CO<sub>2</sub>

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in sea ice, and we conclude that subarctic sea can be a sink for atmospheric CO<sub>2</sub>, while being a net source of CH<sub>4</sub>.

Page 4049, line7: CH<sub>4</sub> is given in mg L<sup>-1</sup>, the rest of the paper is nmol L<sup>-1</sup>. Please use nmol L<sup>-1</sup> consistently. Agreed, line 44: CH<sub>4</sub> is given in mg m<sup>-2</sup> d<sup>-1</sup> because is a flux that is 125  $\mu\text{mol m}^{-2} \text{d}^{-1}$ . The rest of the paper concerns concentration in nmol L<sup>-1</sup>.

Page 4051, line2: saturated mercury chloride SOLUTION. Please also add volume of spike. Revised, line 114-115: Samples for dissolved methane were stored in 60 mL vials poisoned with 60  $\mu\text{M}$  of saturated mercury chloride (HgCl<sub>2</sub>).

Page 4054, line17. In my print it reads "atm", not "mikro atm"? Revised

Page 4054, Line23: evacuated instead of vacuumed Revised

Page 4061, section 5.3: please spell out STP and IFSW once. Revised, STP is spelled out in the section 3.4 total gas content Line 154-155: The total volume of gas within sea ice (content in mL STP (standard temperature and pressure) of gas per kg of ice) was measured using the wet extraction method (Raynaud et al., 1988) IFSW is defined earlier in the section results 4.3.1 Line 247-248: All values are below the expected content of Instant Freezing Sea Water (IFSW) (Cox and Weeks, 1983) and ranged between 4 and 21 mL STP kg<sup>-1</sup> ice (Fig. 2f.).

Page 4065, line 4: denitrification yields more energy per organic carbon unit than methanogenesis. These processes deliver energy, they do not require energy. Agreed, in our revised manuscript we change the line 454-456: Secondly, denitrification, which is an anaerobic process producing more energy per organic carbon unit than methanogenesis was not active within the sea ice due to presence of oxygen.

Figs. 2 and 4 are FAR too small. Revised

Fig. 6: please correct y-axis label. It says Si (silicate), not S(ice). Thanks, however Si is the international abbreviation for silicate, in the field of sea ice research Si is the accepted abbreviation for bulk ice salinity. In our revised manuscript, Si is spelled

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out line106-107: Bulk ice salinity (Si) was measured with a conductivity meter (Orion Star Series Meter WP-84TP, Beverly, USA ) which had a precision of  $\pm 0.1$  for deduced salinity. To stay in line with the literature, we choose to use Si everywhere in our revised manuscript.

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Interactive comment on Biogeosciences Discuss., 11, 4047, 2014.

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