The Cryosphere Discuss.,
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The Cryosphere Discussions

Interactive comment on "Methane cycling within sea ice; results from drifting ice during late spring, north of Svalbard" *by* Josefa Verdugo et al.

Anonymous Referee #1

Received and published: 10 November 2020

This manuscript presents a unique data set of observations of methane concentrations and isotopic composition in Arctic sea ice and ocean during late spring in the Eurasian Basin. Several types of sea ice were sampled allowing to explore the impact of sea ice structure and age on storage and release of methane in the environment. This is an area of active research with potential for strong implications for the climate system. The theory presented here is that in the observed conditions (late spring Eurasian Basin), the predominant methane pathway is from sea ice into the ocean as opposed to sea ice to the atmosphere. Also discussed is the impact of ocean dynamics such as current and stratification on the storage and further pathways of methane into the system.

The quality of the English is mostly ok but lacks fluency and needs some attention. The introduction covers well the topic. The Material and Methods section is excellent.

The Results section should be less repetitive and less descriptive. The Discussion is interesting even if it sometimes sounds speculative; this might be inherent to the topic of methane pathways in Arctic sea ice and ocean which is still in its infancy. The Summary section is good and the figures are overall quite clear.

Major comments:

- Results: Most of the results are direct descriptions of the figures without any further take or analysis. It is very repetitive and sometimes hard to link to the further steps you take in the Discussions. It might be useful to move some of the discussion results in the Result section.

- Discussion and conclusions: what are your main findings or take-home message? At the moment it is not obvious. For example, in the abstract the last sentence states 'We point to sea ice as a potential source of methane'. This sounds very speculative with 'we point' rather than 'we find'; and with 'a potential'. Either be more assertive about what you have found, or if you must stay speculative, then suggest more alternative theories that explain your observations. For example, you never mention the potential of the local sediments as sources of methane in the water column, for example nearby or on the Yermak Plateau? Why could this not be the case? Please try to better highlight your key findings throughout the manuscript (abstract, discussion and conclusions).

Minor comments:

- Some English grammatical and formulation issues, as well as missing words and typos. Please read and check carefully before resubmission.

This manuscript presents original and novel data, and the purpose of the work is

clearly articulated. The results section needs a re-write and the discussion needs to be strengthened to be less speculative and better highlight the key findings. I recommend the manuscript to be reconsidered after major revisions and look forward to seeing a revised version.

Individual comments

1.Introduction:

- L25-27: Add somewhere that you are talking about enhanced methane emissions from the ocean to the atmosphere.

- L27: 'Because the Arctic holds large natural sources of this highly potent. . .' again, do you mean the 'Arctic Ocean'?? or sea floor or sediments?

- L37: 'sea ice charged with methane' Consider using 'sea ice loaded with' or another term?

- L39: 'during the last years' please add if you can a time period here to better indicate what you mean by 'the last years'.

2. Material and methods:

- Section 2.2: excellent

- Section 2.3: excellent

- Section 2.4: excellent

3. Result:

- Table 1: For clarity, could you add '-' when you don't have values for the isotopic composition? I expect that for station C9, the 3 values of isotopic composition is 3 different estimates? Can you add that information in the Table caption?

- L122: 'has an age of 1 to 3 years, respectively' What do you mean by respectively there?

- Section 3.11 and 3.12: These 2 sections are rather tedious reading; they very carefully describe each panel of Fig2 one by one. There might be a way to pull the numbers together in a way that builds on from Fig2.

- Line 196: 'at 90-100 m depth (Fig. 6a and 7a).' You refer to Fig 6 and 7 after Fig 2, without having mentioned Fig 3-5. You will have to reorder the figures to match the order you refer to them.

- Figure 7: There are 6 subplots but you only label 5 of them (a-e). The odd one out is the 3rd from the top, which I think is the ice melt estimates? Please add a subplot letter and clarify the figure caption.

4. Discussion:

- Fig.3: Very nice figure. We can guess most of the media but they should still be annotated: Atmosphere, ocean, sea ice, snow? In (IIa), what's the white section with blue dots? Why the gradual change in color of the blue ocean? And do all the CH4 annotation in the ocean indicate concentrations? If so, make it more obvious. Also add a definition of the black arrows in the caption.

- L278-279: 'With changes in sea ice dynamics, more of this complex ice structures may be formed, which in turn may promote changes on the methane cycling within sea ice.': here you mean to discuss implications for the future Arctic but its not obvious. Please rephrase.

- L343-344: 'In summary, the excess of methane in the surface water clearly point to sea-ice-sourced and early melt events as most important factors for methane release.' . This seems like too strong a statement considering the evidence you have presented.

- Section 4.2.2: some attention needs to be given to the English in this section, with many language choices that are not English based. Eg: 'the more joint journey is

made. . .', 'According the drift direction, one would'

5. Outlook/conclusion

- L379: 'We suggest that sea ice methane-released into the ocean, and in this case into the PSW, is the favored pathway in early spring.' Do you mean anywhere? In the whole Arctic? In this region only? Please add details.'

- L385: 'The final fate of the methane (excess) thereafter depends on to which extent it is diluted by additional meltwater.' What about the dilution by ocean mixing, currents, tides etc..? You don't mention the role of stratification here.

- L390-393: You mention warmer waters and Atlantification, Atlantification also changes the vertical ocean stratification in the region. If stratification was to increase, then methane released in surface waters could be trapped close to the surface during summer, leading to potentially increased exchanges with the atmosphere (and transfers into the atmosphere). If stratification was to decrease, methane could spread deeper into the ocean.

- L394-398: The overall transfer of methane from sea ice to the ocean stays the same, whether the ice and ocean 'travel' together or not. But changes in how far from the source, the methane is released into the ocean and atmosphere. This you don't mention here. There is also the acceleration of sea ice drift in the Arctic which means that sea ice rich in methane that formed on the Siberian shelves, is now potentially drifting further out with the TPD towards Fram Strait before melting and changing and therefore before releasing its methane.

- L396-398: Process modelling studies are a great idea.

Figure 1: Make it clearer which part of the drift is in Region 1 and which part in Region 2.

Figure 9: Add 'Within ridges / rafted sea ice' for FYI and 'Under ridged / rafted sea ice' for PSW on the figure. The arrow for the atmospheric background signature is not

great. Could you not instead have a dot, or create another color rectangle to represent standard local atmospheric ranges?

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