The Cryosphere Discuss., 7, C2661–C2665, 2013
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The Cryosphere Discussions
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Interactive comment on "Morphology and distribution of liquid inclusions in young sea ice as imaged by magnetic resonance" *by* R. J. Galley et al.

Anonymous Referee #2

Received and published: 6 December 2013

In this contribution, the authors present MRI measurements of sea-ice microstructure and compare the inferred liquid fractions to those traditionally derived from ice-core studies.

I find that this paper requires a major revision before it might become suitable for publication, in particular since there is too little reference to existing similar work. This makes it difficult to assess the scientific progress presented here.

In particular, a discussion of the progress relative to the following, as of yet uncited work (and often references therein) would be necessary. Much of what is stated as "new" for the recent study has already been done before:

Hunter, M.W., Dykstra, R., Lim, M.H., Haskell, T.G., Callaghan, P.T.: Using Earth's field NMR to study brine content in antarctic sea ice: Comparison with salinity and temperature estimates, Applied Magnetic Resonance, 36 (1), pp. 1-8, 2009.

Aussillous, P., A.J. Sederman, L.F. Gladden, H.E. Huppert, M.G. Worste, "Magnetic Resonance Imaging of structure and convection in solidifying mushy layers", Journal of Fluid Mechanics, 552, 99-125, 2006.

Bock, C. and H. Eicken, A magnetic resonance study of temperature-dependent microstructural evolution and self-diffusion of water in Arctic first-year sea ice, Anal. Glac., 40(1), 179-184, 2005.

Callaghan, P. T., Dykstra, R., Eccles, C. D., Haskell, T. G. & Seymour, J. D.: A nuclear magnetic resonance study of Antarctic sea ice brine diffusivity. Cold Regions Sci. Tech. 29, 153–171, 1999.

Menzel, M. I., Han, S. I., Stapf, S. & Blumich, B., NMR characterization of the pore structure and anisotropic self-diffusion in salt water ice. J. Magn. Reson. 143(2), 376–381, 2000

From a more theoretical point of view, the structure of brine channels was discussed by: Wells, A. J., J. S. Wettlaufer, and S. A. Orszag, Brine fluxes from growing sea ice, Geophys. Res. Lett., 38, L04501, doi:10.1029/2010GL046288, 2011.

Also the following references are of interest for this study, though they are obviously somewhat harder to find:

Maus S, Huthwelker T, Enzmann F, Miedaner MM, Stampanoni M, Marone F, Hutterli MA, Ammann M, Hintermuller C, Kersten M. Synchrotron-based X-ray micro-tomography: Insights into sea ice microstructure. Proceedings of The Sixth Workshop on Baltic Sea Ice Climate, Vol. 61. Report Series in Geophysics. Helsinki: University of Helsinki; 2010, 28–45. Available at https://helda.helsinki.fi/bitstream/handle/10138/39291/Report_series_in_geophysics_61.pdf?sequence=1

Buettner, J., Permeability of young sea ice from microtomographic images, Master Thesis, University of Bergen, 2011, available at https://bora.uib.no/handle/1956/5633

Should the authors find that despite this long (and probably not exhaustive) list of existing previous work on this topic their study still provides sufficient scientific progress to warrant a revised version, the following additional points should also be addressed:

Abstract:

This will likely have to be substantially rewritten in the context of existing work.

Introduction:

The introduction is sometimes hard to read since its structure is not always clear. It seems, in particular on p 4979 and 4980, currently a little bit too much like a listing of previous work rather than a concise summary of our current knowledge. In particular, given the scope of this paper, it seems better to focus on our recent understanding and to not spend too much time on outdated insights. This holds in particular for p. 4980 l. 19 - p. 4981 l.13 (compare Notz and Worster, 2009).

p.4979, l.19: Add solid salts to this list

p.4980, l.6ff: Brine channels are sites of downward movement of salt, the upward movement occurs through the bulk of the sea ice between the channels.

p.4980, l.14ff: The suggestion that sea ice might become impermeable at a fluid volume fraction of 5 % was first made by Weeks and Ackley (1986) based on data by Untersteiner (1968).

p.4981, l.14: In the discussion of the horizontal movement within the ice, some of the theoretical insights gained in recent years should be discussed, see for examle the paper by Wells et al. mentioned above, and references therein.

p.4983, l.12: Reference to the "law of the fives" is unclear in the context of this study.

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Methods:

Either here, or in the results section, more discussion of sampling biases were needed:

- How much salt is likely lost during the sampling of the relatively warm, thin ice? (compare, for example, Fig. 9 of Notz et al., J. Glac., 51(172), 159-166, 2005, which shows in-situ measurements of salinity in a core of roughly the same length and temperature as considered here against data from traditional ice cores.

- Which impact does the storing of your ice core at -20 °C has on its microstructure and salinity? Compare Cox and Weeks, J. Glac., 32(112), 371-375, 1986.

- What's the impact of horizontal inhomogeneity? Compare Gough, A.J., Mahoney, A.R., Langhorne, P.J., Williams, M.J.M, & Haskell, T.G. (2012). Sea ice salinity and structure: A winter time series of salinity and its distribution. Journal of Geophysical Research–Oceans, 117, C03008. doi:10.1029/2011JC007527

Results:

This is possibly the most critical section for a possibly revised version of this manuscript. It is currently unclear what one really is to take away from this section and the given details on the experimental protocol and environmental conditions. In particular, there is no discussion as to which of these results are generally valid and which are probably only valid because the ice was grown under these particular, somewhat synthetic conditions in a tank without much turbulence. For the results that fall into the latter category, the authors should critically assess how much the scientific community will profit from their presentation. If more fundamental insights based on our modern understanding of the evolution of sea-ice microstructure were possible, this should more clearly be elaborated.

Discussion: p.4991, l.19ff: This sentence is unclear to me.

p.4992, l.13: The convectional patterns of gravity drainage imply that indeed all of the sea ice in which brine moves has some horizontal and some vertical movement of the

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brine, simply to close the path of upward and downward movement. See the paper by Wells et al. referenced above. The fact that brine also flows horizontally into sack holes has long been known, which is why for quantitative studies the walls of these sackholes should be covered (e.g., Freitag J., and H. Eicken (2003) Melt water circulation and permeability of Arctic summer sea ice derived from hydrological field experiments. J. Glaciol., 49(166), 349-358)

p.4992, l.21ff: This sentence is unclear (or simply inconsistent with our modern understanding as to how brine inclusions in sea ice form)

p.4992, l.26-p.4993, l.19: This discussion is very speculative and only relevant to this particular core. Which general insights can we gain from it?

p.4993, l.20ff: I do not see how the current work contributes to this entire discussion beyond the previously known functioning of brine dynamics.

Conclusions: p. 4995, l.4ff: This discussion can be made much more directly from the ice-core data, which also allow for an estimte of porosity. The relevance of the MR images for this discussion is not brought out clearly enough.

Interactive comment on The Cryosphere Discuss., 7, 4977, 2013.