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Ocean Science Discussions

Interactive comment on "Measurements of bubble size spectra within leads in the Arctic summer pack ice" *by* S. J. Norris et al.

Anonymous Referee #2

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General comments

This paper presents the first measurements of the bubble size spectra within Arctic pack ice, and the data show consistently high numbers of bubbles in this environment. This is significant because wave-breaking is not a possible mechanism of production for these bubbles, and few other mechanisms have been proposed that can explain observed oceanic bubble populations. A link is made between bubble numbers and the heat flux from the ocean surface, which is consistent with a tentative hypothesis for bubble production that the authors propose. This hypothesis relates to the cooling and saturation of a thin surface water layer in low-turbulence conditions, leading to de-gassing and bubble nucleation when this cooler water sinks. This paper provides a welcome new data set for a previously unsampled environment, and points the way

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towards new studies of aerosol production in the Arctic ice and its importance for cloud formation in those regions.

Specific comments

There are many long unpunctuated sentences that are very hard to follow, and the majority of them are in the introduction. I suggest that the authors go through the whole text carefully, checking that each sentence is unambiguous and well-structured. For example, the sentence starting: “Measurements of CCN composition. . .” should be split into two separate sentences, and this is just one example of many.

Section 1, line 20: Perhaps “previously discussed non-wave related sources” (or something similar) might be a better start to this sentence. Later in the paper the authors describe a mechanism not mentioned here, so this is not a complete list.

Section 1, line 24: Are these gels the same as the transparent exopolymer particles (TEPs) discussed by Wurl & Holmes (2008) and references therein? [“The gelatinous nature of the sea-surface microlayer”, Marine Chemistry] If so, it might be useful to specify this more modern term as well and to include the more recent references.

Section 2, line 8: The comparison between acoustic and optical measurements shown in the Brooks et al. paper does not act as a calibration of optical against acoustical measurements. The optical and acoustical measurements were taken at different times and in different conditions, and both involve considerable temporal averaging. This comparison cannot be used to justify the phrase “close agreement”, although the laboratory results listed may. I suggest removing this reference.

Section 2 describes the distribution of individual measurements in time, and it seems that it should be possible to plot the change in bubble population on timescales shorter than a day. This omission leaves the reader curious about why no such data is mentioned. If it is a requirement for sampling purposes (i.e. the variation between individual samples is large), then that should be stated. It would be fascinating to see the scale

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of the variation on the timescale of a few hours. Are there large differences between successive samples? Is there a diurnal variation? This is important information in evaluating the suggested bubble generation mechanism. There should be a comment included about whether any systematic variation was seen, and if no statistical variation was observed then this should be quantified (i.e. all samples for the day were within 10% of the mean). However, it would be very useful to the reader if some data was shown for the shorter timescales.

Section 3, line 10 (and related to the point above). I would prefer use of the term "standard deviation", rather than "standard error". "Error" implies that there is a measurement uncertainty, which is not intended (I think). This table aims to show how much deviation there is from the daily mean over an entire day, and does not quantify measurement uncertainty. However, since there could be genuine variation in the bubble measurement data on short timescales, even the term "standard deviation" needs to be used with care.

Table 1: This way of presenting this data is hard to read and gives little insight unless the reader copies it out and makes plots themselves. Given the online nature of this paper, the size and complexity of the table might be acceptable here even though it would certainly be unacceptable for traditional paper publication. If the authors consider that this table is essential in its current form, I suggest that they make a data file available as supplementary information. At least this would prevent someone else needing to type out the data again for themselves.

Section 4, line 20: "... the largest only film droplets". It might be appropriate to reference Bird et al, (Nature 2010 "Daughter bubble cascades produced by folding of ruptured thin films") here, since is describes a mechanism generating jet-producing smaller bubbles as a large bubble burst at the surface. This is just a suggestion, but it demonstrates the complexity of setting size limits on the production of jet droplets and film droplets.

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Figure 1: It's hard to tell the red and pink lines apart. Please choose colours that are easier to distinguish. I think that the blue line refers to the ice edge, but this is not stated in the caption.

Figure 6: I think that this would be easier to read if the open ocean spectra were omitted. Presumably the point is to show the approximate variation in bubble spectra, but the grey lines make it hard to see the thinner coloured lines. If it's felt to be important to include some open ocean spectra, perhaps only the highest and lowest (circles and diamonds) could be included.

Technical corrections

Line 2: spelling: Arctic

Section 2 line 15 and others: It's conventional (and would be helpful in this case) to use the word for numbers less than eleven and the numerals for numbers greater than ten. The line "126 2-min. . ." is awkward and it would be easier to read if the word "two" was used.

Interactive comment on Ocean Sci. Discuss., 7, 1739, 2010.