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Interactive comment on "Brief communication: Pancake ice floe size distribution during the winter expansion of the Antarctic marginal ice zone" *by* Alberto Alberello et al.

Anonymous Referee #2

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The authors acquired images of pancake ice floes from a ship-based camera on July 4, 2017, in the Antarctic marginal ice zone at about 30E, 62S. An automatic algorithm identified pancake ice floes in the images, whose size distribution was then plotted. They found three size regimes: diameters 0.25 to 2.3 meters, 2.3 to 4 meters, and 4 to 10 meters (see Figures 3b and 3d). They conjecture that the small regime is driven by the growth of pancakes from frazil ice, and the large regime is driven by the welding together of pancakes.

This paper is basically a report of data analysis. The conjectures regarding the small and large floe regimes are just that – conjectures – without supporting evidence. I

have questions about the analysis, detailed below, as well as other comments. In my opinion, this paper needs major revisions.

I would like to note that I have not read any of the comments posted on the discussion page that accompanies this paper, so this is a completely independent review.

Comments in page order

Page 1, lines 9-10. The floe size distribution (FSD) was first integrated into a sea-ice model by Zhang et al in 2015 and 2016:

Zhang, J, Schweiger, A, Steele, M and Stern, H. 2015. Sea ice floe size distribution in the marginal ice zone: Theory and numerical experiments. J Geophys Res 120. DOI: https://doi.org/10.1002/2015JC010770

Zhang, J, Stern, H, Hwang, B, Schweiger, A, Steele, M, Stark, M and Graber, H. 2016. Modeling the seasonal evolution of the Arctic sea ice floe size distribution. Elem Sci Anth 4. DOI: https://doi.org/10.12952/journal.elementa.000126

Page 1, lines 12-15. The authors imply that there is not much "field data" available on floe sizes. I assume this refers to in-situ data such as that acquired from a ship in the ice. But there is plenty of remote sensing data, and it's not clear to me that field data is any better than remote sensing data, so the lack of field data does not seem like a shortcoming. The only advantage I can see to field data is the higher spatial resolution – in this case, the ability to identify floes as small as 0.25 m in diameter. But this advantage is not mentioned by the authors. Perhaps one of the values of this study is that it identifies floes that are smaller than in any other study. The fact that it consists of data collected in the field is not in itself a selling point, in my opinion.

Page 2, lines 2-4. This is really an oversimplification. It is certainly true that observations do not support a unique scaling exponent of the FSD – that was the subject of an entire paper (Stern et al 2018) which is cited by the authors later but not here. Only some of the 18 studies examined in that paper report "two distinct scaling exponents".

The authors imply that those exponents are given by Toyota et al 2011, but other studies have found different exponents over different ranges, and some have reported that a single exponent characterizes the FSD.

Page 2, lines 5-6. "The validity of power law scaling has not been demonstrated yet and its adoption is mostly justified by the wide range of floes diameters". Actually the validity of power-law scaling has been demonstrated in some cases, and I have never seen a paper that claims that power-law scaling is justified by the wide range of floe diameters. The papers cited by the authors don't make that claim.

Page 2, lines 6-7. "Scaling parameters are typically estimated on the log-log plane with a least square fit" – it would be good to note that such a procedure leads to a biased estimate of the scaling parameter.

Page 2, line 12. "Existing observations do not provide quantitative descriptions of the floe size distribution for pancake ice floes", but line 19 says "Shen and Ackley (1991) reported pancake floe sizes..." so doesn't that contradict line 12?

Page 2, line 26. "To our knowledge, the pancake floe size distribution has yet to be characterized." Take a look at: Parmiggiani, Moctezuma-Flores, and Guerrieri, Identifying pancake ice and computing pancake size distribution in aerial photographs, Proc. SPIE 10422, Remote Sensing of the Ocean, Sea Ice, Coastal Waters, and Large Water Regions 2017, 104220K (13 October 2017); doi: 10.1117/12.2277537 http://spie.org/Publications/Proceedings/Paper/10.1117/12.2277537

Section 2, Sea ice image acquisition. All good, nice work. I do have one comment: page 3 line 14 says that morphological image processing was used "to improve the shape of the pancake floes." I don't think "improve" is the right word! How about "to smooth"?

Page 4, lines 15-17. There is more than one way to define the floe diameter D. The first study of the FSD, Rothrock and Thorndike 1984, used the mean caliper diameter.

Page 5, line 5. "a power law N(D) proportional to Dˆ-alpha as a benchmark and using the maximum likelihood method". Here, N(D) is the cumulative distribution function (CDF), but the maximum likelihood method yields the best-fitting exponent of the probability density function (PDF), not the CDF. If the authors used the maximum likelihood method to obtain the best-fitting exponent of the PDF (call it -beta), then they would have had to convert it to the exponent of the CDF (via -alpha = -beta + 1). Did they do this?

Page 5, lines 6-8. The authors note that the range of floe sizes for the large regime (4 to 10 meters) spans less than a factor of 10, and therefore "the estimation of the scaling exponent for D > 4 m is rigorously not applicable". Well, the same is true for the small floe regime (0.25 to 2.3 meters) – it spans less than a factor of 10, so apparently the estimation of the scaling exponent for D < 2.3 m is rigorously not applicable either. Doesn't that destroy the basis of the floe size analysis here?

Page 5, lines 12-13. "the steeper slope indicates that their size is governed by different underlying physical mechanisms." Or by the finite size effect, in which larger floes are under-observed because the finite size of the images makes it less likely to see larger floes in their entirety. This has been described in the literature. Can the finite size effect be ruled out here?

Page 5, Figure 3. It looks to me like Figure 3b (the area distribution, a(D)) is not compatible with Figure 3d (the PDF, n(D)). In 3b, the area distribution increases as D increases, from D=0.2 to D=3. In that range, alpha_S = 1.1 so alpha_S + 1 = 2.1 so the PDF n(D) scales like Dˆ-2.1. The area of a floe scales like Dˆ2. So the area distribution a(D) should scale like Dˆ(-2.1 + 2) = Dˆ-0.1. That means the area distribution should DECREASE as D increases from D=0.2 to D=3. But Figure 3b shows a(D) increasing as D increases over that range. Is there something wrong with the plots, or with my analysis?

Page 5, line 13. "the majority of the large floes are composed of two or more welded pancakes." Does this explain some of the scatter in Figure 3a, in which a welded pair of pancakes would have a large major axis (D1) compared to minor axis (D2)?

Page 6, lines 16-18. It's commendable that the authors applied a goodness-of-fit test, and that they admit that neither the small nor the large floe size regime follows a power-law distribution according to that test. This result is actually not too surprising, given the very small size ranges over which the power laws were fit.

Page 6, lines 19-20. "N(D) possesses a slightly concave-down curvature across all the diameter ranges (in a log-log plane)". This phenomenon has been noted, or can be seen, in many previous studies, such as Rothrock and Thorndike 1984, Toyota et al 2016, Wang et al 2016 (JGR), and Stern et al 2018, where it is discussed at length.

Page 6, lines 25-29. This is a good paragraph, with entirely appropriate conclusions. Please note that it applies only to the pancake floes analyzed here, and not to the FSD in general.

Page 6, Conclusions. This section simply re-hashes the division of the FSD into three regimes. It claims that the small and large floe size regimes are "qualitatively close to power law scalings", but that is a very dubious characterization, especially for the large floe regime, where the range of floe sizes spans less than half an order of magnitude: log(10.8/4) < 1/2.

The authors do not give a mechanism by which the FSD of the small floe regime comes to be qualitatively close to power-law scaling. They only state that the "pancakes are experiencing thermodynamic growth". How does that lead to power-law scaling?

For the large floe regime, they write that "floes are typically formed by welding". That's a mechanism that can be easily simulated in a numerical experiment, and the results compared to the actual (observed) distribution. I have taken the liberty of conducting such an experiment, which did not take very much time to code up – see the attached figure. I started with 20,000 floes whose sizes were distributed according to a power

law with exponent -2 and ranging from 0.25 to 3.0 meters in diameter. See the black curve in the attached figure. I then simulated a welding process in which two randomly chosen floes were welded together according to D_new = sqrt(D1ˆ2 + D2ˆ2) where D1 and D2 are the diameters of the floes to be welded, and D_new is the diameter of the welded floe. The floes with D1 and D2 are removed from the distribution, D_new is added to the distribution, and the process is repeated 5000 times, leaving 15,000 floes. The resulting distribution is shown by the red curve. The procedure is repeated again (5000 times), leaving 10,000 floes (green curve), and again (5000 times), leaving 5000 floes (blue curve). The blue curve has some qualitative similarities to Figure 3d. This is not a very sophisticated simulation, and I am not suggesting that the authors need to do something like this, but it does demonstrate the potential for mimicking certain processes. Of course a physical model would be better, but that is probably beyond the scope of the present study.

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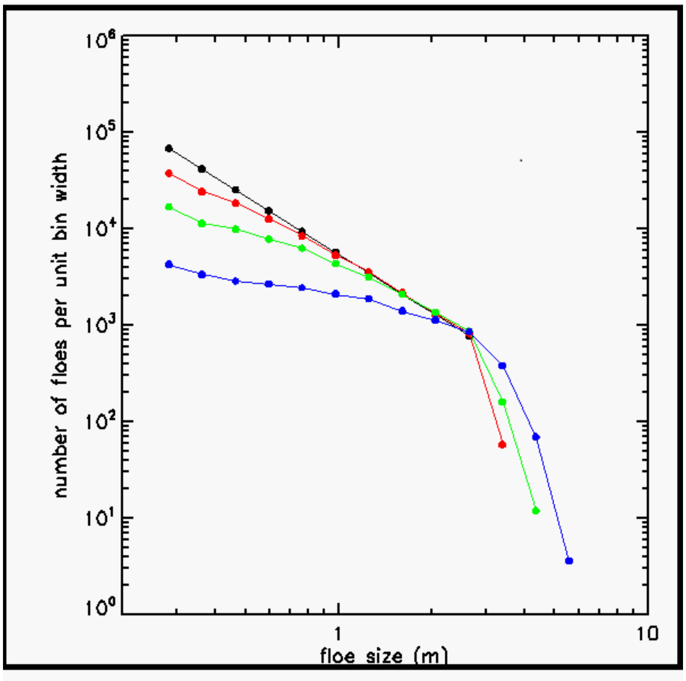
number of floes per unit bin width
floe size (m)
10^0
10^1
10^2
10^3
10^4
10^5
10^6
1
10

Fig. 1.