

Interactive comment on “Wave–sea-ice interactions in a brittle rheological framework” by Guillaume Boutin et al.

Anonymous Referee #3

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In this work the authors coupled a wave model with a sea-ice model to investigate the impact of wave-induced sea-ice fragmentation on the sea-ice floe size distribution (FSD) and sea-ice dynamics. The focus is on the Barents Sea in October 2015. To study the FSD, five simulations are run: coupled and uncoupled runs with sea-ice thickness equal to 15 cm and 30 cm, and a coupled run with smaller floe size bins (more floe size categories). To study sea-ice dynamics, three simulations are run: one with a stand-alone sea-ice model (REF), one with wave radiative stress (CPL_WRS), and one with "damage" (CPL_DMG). The result is that waves modify sea-ice dynamics in the marginal ice zone (MIZ) by lowering the resistance of ice to deformation. The authors recommend that waves be included in sea-ice models to improve their forecasts.

I have not looked at the other reviews of this paper. This is an independent review.

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Main Comments

My main concern is with the FSD analysis. See page 14, lines 20-21, in reference to Figure 3: "we can distinguish two regimes separated by a cut-off floe size..." Look at Figure 3(a). I do not see two regimes separated by a cut-off floe size, and I don't believe that any statistical test would support such a conclusion. Look at the green curve for latitude 74.2 degrees north. It appears that a "line" has been fit using exactly 2 data points (see the green dashed line). By this method of analysis, one could distinguish a new "regime" for every pair of points. The purple and red dashed lines appear to be based on 3 data points. To my eye, all three curves appear to gradually steepen as the floe size increases. I don't see a cut-off or a regime shift.

The authors cite Toyota et al (2011) numerous times in the context of concave-down cumulative distribution functions (CDFs) with two regimes. A counterpoint may be found in this paper:

Stern, H.L., A.J. Schweiger, J. Zhang, and M. Steele, 2018. On Reconciling Disparate Studies of the Sea-Ice Floe Size Distribution, *Elem Sci Anth*, 6: 49. DOI: <https://doi.org/10.1525/elementa.304>

In particular, see their Figure 3 and the section called "Break-point analysis".

Page 23, Appendix B. "The shape of the CDFs shown in Figures 3 and 5 strongly depend on the parameterization detailed in section 2.2.2. The value of the cut-off floe size at which the transition between the small and large floes regime happens..." It seems highly undesirable that the shapes of the CDFs depend strongly on the parameterization. This would seem to inject a high degree of uncertainty into the whole simulation. And again, I question that a well-defined cut-off exists between small and large floes.

Minor Comments

Page 1, line 25. It looks like Lemieux et al (2016) is about landfast ice, not the sea-ice edge.

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Page 6, line 21. "floes in the largest floe category are not affected by lateral melt." I don't see how equation (4) reflects this statement.

Page 7, lines 2-3. "a uniform FSD made of the smallest floes ... evolves into a uniform FSD made of the biggest possible floes." This does not make sense. A uniform FSD contains floes of all sizes, in equal proportions. The authors probably mean a delta-function FSD, in which all floes are of the smallest size, evolves into a delta-function FSD, in which all floes are of the largest size.

Page 7, line 4. Check whether "uniform FSD" is appropriate here – see previous comment.

Page 7, line 6. "setting $\kappa = 5 \times 10^{-8}$ " κ is a rate (see line 1 of page 7). Please give the units.

Page 8, equation (8) and following. You need to say that Y is Young's modulus, ν is Poisson's ratio, and h is ice thickness. Please give values of DFS for $h = 15$ cm and $h = 30$ cm.

Page 10, equation (12). This equation is not correct – it is missing a factor of D inside the integral. If $g(D)$ is a probability density function then the mean value of D is the integral of $D \cdot g(D) dD$.

Page 10, lines 21-24. D_{\max} is supposed to be one order of magnitude larger than the longest wavelength, but lines 23-24 imply that D_{\max} does not become larger than 1000m. Shouldn't D_{\max} be 10 times larger than 1000m?

Page 11, end of Section 2. There are a LOT of parameters and empirical functions in this work. It might help to collect them in a table. My list includes these parameters: G_r , c_{new} , and β_{weld} from equation (4); κ from page 7; τ_{heal} from equation (5); τ_{WF} from equation (7); λ_{break} , $c_{1\text{FS}}$, $c_{2\text{FS}}$, $c_{1\text{Lambda}}$, $c_{2\text{Lambda}}$, d_w , Δt , D_{\max} . And these empirical functions: q (equation 11c), p_{FS} (equation 9a), p_{Lambda} (equation 9b), β (equation 10), Q (equation 7), and

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c_{broken} (top of page 11).

Page 15, line 5, and throughout the paper. Dates are given in the form day/month/year, as in 01/10/2015 for 1 October 2015. Perhaps this is standard notation for The Cryosphere. Just be aware that it will confuse readers from the U.S., who will interpret "01/10/2015" as January 10, 2015. If you switch to the format "1 October 2015" it should be clear to everyone. Just a suggestion.

Page 17, lines 24-25. I can't see the convergence north of Svalbard nor the divergence at the center of the domain in Figure 11d.

Page 20 line 35 and page 21 line 1. "The sensitivity to τ_{heal} was investigated by re-running our experiments using this time $\tau_{\text{heal}} = 15$ days..." You might want to remind readers that the default value is 25 days, because they probably won't remember (from page 11, line 27).

Page 22, lines 1-2. "waves pose a hazard as they make sea ice thicker" – this must be during freezing conditions, not during melting conditions, right?

Page 22, equation A1. What is G ? What is " k " in the function $N(k)$? Is it supposed to be k_i ?

Page 22, line 24. Is $k_{i,\max}$ the same thing as the quantity inside the square root on the right-hand side of equation A1? If yes, then wouldn't it make sense to first define $k_{i,\max} = \max(\dots)$ (as in A1) and then $\lambda_{\text{break}} = 2\pi/k_{i,\max}$? And then go on to equations A2 and A3, if necessary?

Page 29, Figure 3. In panel a, the symbols are plotted at the mid-point of each bin. For example, the smallest bin represents floes of size 10-20 meters, and the symbol is plotted between 10 and 20 meters. But in panel b, the symbols are plotted at the left end of each bin. For example, the smallest bin represents floes of size 5-10 meters, and the symbol is plotted at 5 meters. So the data in panels a and b are not plotted consistently.

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Typographical Notes

Page 2, line 13. "to conclude on" should probably be "to arrive at"

Page 5, line 6. "recovered" should be "covered"

Page 5, line 21. "the caliper diameter" should probably be "the mean caliper diameter"

Page 5, line 28. Delete the word "respectively"

Page 6, line 9. "associated to this process" should be "associated with this process"

Page 9, line 8. "B" should be "Appendix B"

Page 10, line 7. "ran" should be "run"

Page 10, line 8. Capitalize "Appendix A"

Page 10, line 27. Capitalize "Introduction"

Page 11, line 3. "in general of at least" – delete "of"

Page 11, line 22. "Wave-current [not currents] interactions"

Page 11, line 31. "similarly" should be "similar"

Page 13, line 3. "ran" should be "run"

Page 14, line 5. "Similarly" should be "Similar"

Page 14, line 28. "presented on 3" should probably be "presented in Figure 3"

Page 15, line 8. "large lambda values" – is this lambda_break?

Page 15, line 14. "CDFs (b,c)" should be "CDFs (b,d)"

Page 15, line 14. "at the time of shown" – delete "of"

Page 15, lines 18-19. "flatten the slope of the large floes regime" should be "flattening of the slope of the large floe regime"

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Page 16, line 3. Delete "that"

Page 16, line 4. "16 and 60 meridians" should be "16E and 60E meridians"

Page 16, line 31. "sea ice produce" should be "sea ice produces"

Page 17, line 13. Delete "is responsible"

Page 17, line 16. "wave" should be "waves"

Page 18, line 28. "exceeds the one of the wind stress" should be "exceeds that of the wind stress"

Page 18, line 35. Something is missing after the word "REF"

Page 20, line 7. "opposes" should be "poses"

Page 20, line 27. Delete the word "a"

Page 23, lines 4 and 9. The parameter "c₁,FSD" should be "c₁,FS" (see page 9, equation 9a and following).

Page 23, line 4. "Basically, if $c_{1,\lambda} \lambda_{\text{break}} > c_{1,\text{FS}} D_{\text{FS}}$ " Page 23, line 9. "Oppositely, if $c_{1,\lambda} \lambda_{\text{break}} > c_{1,\text{FS}} D_{\text{FS}}$ " But the inequalities on lines 4 and 9 are the same, not opposite.

Page 24, line 10. "Tech. rep." is not enough information to locate this technical report.

Figures

Figure 2. (i) Consider labeling Point Barrow in the lower left corner of a, b, c. (ii) What are the solid and dashed curves in a, b, c? (iii) In panel b, it's almost impossible to see the green cross. (iv) In panel b, what are the black arrows? (v) In panel c, it's impossible to tell whether black represents +100 or -100. Both values are black on the color scale. (vi) In panel d or in the caption, say that the distance along the transect (km) is from north to south.

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Figure 3. "Cumulated" should be "Cumulative" in the axis labels and in the caption.

Figure 4. The last sentence of the caption refers to a cross. I don't see it.

Figure 5. (i) In the caption, "cumulated" should be "cumulative". (ii) The caption should probably say that the histogram bars at 200+ meters in panels a and c represent unbroken ice.

Figure 7. In the caption and the legend, "meridian component" should be "meridional component".

Figure 8. In panel d, it's hard to tell the green arrows from the blue arrows.

Figure 9. (i) In b and d, it's impossible to tell whether black represents +0.25 or -0.25. Both values are black on the color scale. (ii) The caption says that panels a and c are "damage" but the x-axis labels in those panels say "Sea ice thickness". (iii) The caption refers to green and blue arrows in panels b and d. I don't see them.

Figure 10. In panels a and b in the legend, "DMG/WRS" should probably be "CPL_DMG".

Figure 11 (b,d) and Figure 12 (all panels). Same comment about the color scale – both ends are black. How can we distinguish the highest values from the lowest values?

Figures 2, 4, 6, 8, 9, 11, 12. Why not make all the panels larger?

Interactive comment on The Cryosphere Discuss., <https://doi.org/10.5194/tc-2020-19>, 2020.