Estimating the Sea Ice Floe Size Distribution Using Satellite Altimetry: Theory, Climatology, and Model Comparison

The Cryosphere Discussions / August 11, 2019

Hi Chris,

Good idea to use satellite altimeter data to look at sea-ice floe chord lengths, which are related to floe sizes. This allows an Arctic-wide analysis over several years, which has not been done. Here are my (unsolicited) comments, in the nick of time (discussion closes tomorrow)!

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<u>Main Comments</u>

1. You reference Rothrock and Thorndike (1984) (R&T hereafter) in several places, which is very appropriate, since that is the fundamental paper on "measuring the sea ice floe size distribution". However, you did not give credit to R&T for the concept of the chord length distribution and its close relationship to the floe size distribution (FSD). This is from the Abstract of R&T:
"Another sampling strategy is to measure the lengths of line segments on floes. The distribution of these chord lengths is equivalent to the distribution of floe diameters."

Furthermore, there is an entire section in R&T called "Chord Length Distribution" in which its relationship to the FSD is derived. Look at R&T equation (4):

$$N(\rho) = \frac{2}{\pi} \int_{c=\rho}^{\infty} (c^2 - \rho^2)^{-1/2} \, dM(c)$$

Now look at your equation (9). The similarity in form, together with the meaning of the variables, must be more than chance. Surely R&T were onto something very similar to what you did. Not to take away from your theoretical development, which possibly goes beyond R&T, but please give proper credit to the originators and developers of the connection between chord length and FSD.

2. In the Abstract, you state: "we produce the first climatology and seasonal cycle of sea ice floe size statistics". However, two previous works also produced a seasonal cycle of floe size statistics, namely Perovich and Jones (2014), which you cite in a different context, and
        Stern, HL, Schweiger, AJ, Stark, M, Zhang, J, Steele, M and Hwang, B. 2018. Seasonal evolution of the sea-ice floe size distribution in the Beaufort and Chukchi seas.
Elem Sci Anth, 6: 48. DOI: https://doi.org/10.1525/elementa.305
        See Figure 8 in Stern et al.

3. First paragraph of Section 3 (top of page 8): CryoSat-2 radar echo returns have approximately a constant along-track spacing of 300 meters; floe chords are defined as a continuous sequence of two or more floe echoes; and single isolated floe returns are eliminated. Therefore it seems to

me that the shortest chords must be 600 meters long. Yet the paper states in multiple places that the analysis applies down to 300 meters. How is that possible?

4. As you state on page 5 (lines 18-19), the representative radius can represent only those floes whose size is larger than r_{min}, the smallest possible floe size sampled. Agreed. Furthermore, it seems to me that the representative radius is actually proportional to r_{min}. If r_{min} is halved, the representative radius is halved. So I don't really understand the use of a representative radius, e.g. as depicted in Figure 3, unless it's to look for changes over time. The absolute value of the representative radius is simply a reflection of the resolution of CryoSat-2; it doesn't seem to have an intrinsic meaning. The vast majority of floes in the Arctic are smaller than r_{min}.

Minor Comments

Page 5, equation (3).
The inequality $r < D/2$ is backwards. It should be $r > D/2$.

Page 5, line 10. For the beta function, use the letter B instead of the Greek β, and state that B is the beta function, because this is the first place where it appears in the paper.

Page 6, line 10. I don't understand what is meant by "where we leverage that because it is a probability distribution..." What is being leveraged?

Page 6, equation (13). Rn is not defined. Is it the same thing as Rn,ε of equation (12)?

Page 7, Figure 2.
(i) In panel (d), the label on the x-axis says "Spacing (m)" but it should be kilometers (km).
(ii) In panel (d), it's impossible to tell which tick mark corresponds to "1 km". Please use short tick marks for unlabeled values and long tick marks for labeled values.
(iii) The caption says that the satellite track is from January 21, 2014, but the text (page 8, line 17) says January 14, 2018.

Page 8, line 17. Check date, compare to Fig 2 caption.

Page 8, line 19. Should "red circle" be "blue circle"?

Page 10, Figure 4.
(i) I don't understand "p" in this figure. Panel (a) has three curves, two of which have p=0. Panel (b) has three curves, one with p=0 and one with p=5. The caption refers to $p < 0.1$ and $p > 0.1$. What is p?
(ii) The x-axes of panels (a) and (b) are labeled "m" (meters?) but should probably be "km".
(iii) The caption (line 3) refers to equation 11 but should probably be equation 13 or 14.
(iv) I don't understand the shading in panels (a) and (b). The caption says that the gray (or blue) shading is the difference between the blue and black curves. But where the blue and black curves cross, the difference should be zero, but the shading doesn't reflect that.

Page 11, the "MLE method", and Appendix C. You might mention that the "MLE method" was also recommended and applied by Stern et al. (2018) (On reconciling disparate studies...): see their Section 5.1 for a summary. Your Appendix C through equation C5 is essentially the same as Stern et al. Appendix A.

Page 11, line 16. The range from 300 m to 100 km is not 3 orders of magnitude, it's 2.5. Also, if the smallest chords are in fact 600 m long (see Main Comment #3) then the range would be 2.2 orders of magnitude.

Page 13, lines 18-21. "There is a seasonal cycle in the steepness of the distributional tail: shallowest in early winter and steeper in late winter... the changes across the winter months may be due to a reduction of the largest floes..."
These observations are similar to the ones made by Stern et al. (2018) (Seasonal evolution of...), e.g. in the Abstract: "The mean power-law exponent goes through a seasonal cycle... consistent with the processes of floe break-up in spring followed by preferential melting of smaller floes in summer and the return of larger floes after fall freeze-up." You might add a sentence comparing your results to those of Stern et al.

Page 13, line 30. Change "resolve" to "resolved"

Page 15, line 8. Change "Straits" to "straits" (lower case)

Page 16, line 3. I'd suggest changing "global" to "Arctic-wide" or "pan-Arctic". Also, the use of the phrase "high-resolution" here is highly questionable. Stern et al. (2018) catalogued 18 studies of the FSD. Fifteen of them used higher-resolution data than this study.

Page 16, line 6. Again, I don't think 3 orders of magnitude is accurate.

Page 20, line 4. This sentence doesn't make sense. It should say something like: Take the derivative of L with respect to α and set the result equal to zero to arrive at (equation C4).

Page 20, line 15. There is no $C\alpha$ in Appendix A. Perhaps it should say Equation 10.

Page 20, equation C9. The final summation is missing the natural logarithm function, i.e. it should be the sum over $\ln(D_i/D^*)$.

Page 20, line 22. "...that lie below D^*." – should this be "above" D^*?

Page 21, line 4. Change "least" to "at least"

Page 21, line 10. Either change "radii" to "radius" or delete the word "a" before "representative".

Page 24, Rothrock and Thorndike (1984) is listed twice.