# REVIEW OF 'A PROGNOSTIC MODEL OF THE SEA ICE FLOE SIZE AND THICKNESS DISTRIBUTION'

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## 1. General comments

This is a nice paper, which I enjoyed reading very much. I recommend it for publication if my criticisms below can be addressed (may need "Major revisions").

## 2. Specific comments

### 2.1. Major comments.

- p2959, L22: [5] discusses a stochastic (GLV: Generalised Lotka-Volterra) mechanism for generating a Pareto distribution — did the authors look into this at all?
- p2970–2972: A limitation of this approach is that it only involves binary collisions. Direct numerical solutions (eg [4, 8]) have shown clear grouping and [4] showed the group size had a power-law distribution. This could be an interesting way to look at this, especially in combination with the thermodynamics part (letting the groups freeze together if it's cold enough).
- p2972 L17: "This choice eliminates the need for keeping track of sea ice morphology". If the model can produce a good estimate of ridging history (even just a ridging density), both [2] and [6] observed that floe break-up mostly happened at pre-existing weaknesses (cracks and ridges), so there could be some way of connecting floe size distribution with ridge density in the case of wave break-up.
- p2974 L15: It is worth discussing/mentioning [7] here.
- p2975 L10: here the amplitude depends on $\mathrm{d}\lambda$ — is this not a problem?
- p2975 L19 The authors are correct that wave heights are roughly Rayleigh distributed (assuming a Gaussian distribution of wave elevations [1] — ie this doesn't apply to mono-chromatic waves (swell waves)). However, I am not sure that it is correct to apply it to individual wave frequencies or frequency bands. [9] used a Rayleigh distribution for the strain spectrum, so the breaking probability considering the full spectrum was proposed to be:

$$P_{\text{breaking}} = \mathbb{P}(|\varepsilon| > \varepsilon_{\text{breaking}}) = (2/\overline{\varepsilon^2})\mathrm{e}^{-\varepsilon^2_{\text{breaking}}/(2\overline{\varepsilon^2})}$$

  This could be used as the total breaking probability but it doesn't give any idea about the floe sizes produced by the breaking. The authors are suggesting using the wave spectrum to get the floe sizes, which is not a bad idea. It could be used in conjunction with the above perhaps, eg.

$$P_f(\boldsymbol{r},\lambda) = P_{\text{breaking}}\theta(r-\lambda/2)\frac{\int_\lambda^{\lambda+\Delta\lambda} S(\lambda')\mathrm{d}\lambda'}{\int_0^{2r} S(\lambda')\mathrm{d}\lambda'},$$

$$P_{\text{breaking}} = \int_0^\infty P_f(\boldsymbol{r},\lambda)\mathrm{d}\lambda = \int_0^{2r} P_f(\boldsymbol{r},\lambda)\mathrm{d}\lambda$$

- Related to the above point: I think the Rayleigh distribution should be

$$P_{wa} = (2/\overline{a^2})\mathrm{e}^{-a^2/(2\overline{a^2})}$$

so

$$\overline{a^2} = \int_0^\infty S(\lambda)\mathrm{d}\lambda = H_s^2/16 = \int_0^\infty a^2 P_{wa}\mathrm{d}a.$$

Also, in (20), why truncate at $\lambda < r$ instead of $(\lambda/2) < r$ since a wavelength of $\lambda$ has maximum strain at both peaks and troughs (as the authors point out themselves)?

- p2975 L1: Breaking time-scale: the authors determine it from the grid size and the wave speed. I think this is similar to using the model time step such as done by [3] or [9]. Both are somewhat artificial. [2] noticed the breaking front travelled at $0.25c_g$ — perhaps this implies the time-scale should be $\approx 0.25$ times the wave period?

2.2. **Minor comments.**

- Is equation (4) correct? When I tried to derive it from (3) I got:

$$\begin{aligned}\partial_t\partial_r\partial_h C(\boldsymbol{r},t) &= \partial_t\left(\frac{f}{\pi r^2}\right)\\ &= \frac{1}{\pi r^2}\partial_t f - \frac{2f}{\pi r^3}\partial_t r\\ \partial_t f &= \frac{2f}{r}\partial_t r - \pi r^2\partial_r\left(\frac{f}{\pi r^2}\partial_t r\right) - \pi r^2\partial_h(f\partial_t h)\\ &= \frac{4f}{r}\partial_t r - \nabla_{\boldsymbol{r}}\cdot(f\mathbf{G})\end{aligned}$$

- Eqn (5): $\delta$ is used many times in many contexts in this paper. Perhaps reserve it for the delta function, and possibly also for the 1d function e.g. $\delta(r_p,h_p) \to \delta(r-r_p)\delta(h-h_p)$ (TC being a geophysical journal). Also perhaps define $\dot{A}_p$ nearer to (5) (there is a delay of 1 page before it's defined).
- What are the limits of the integral in (15)? Is it $\int_{\boldsymbol{r}_1}^\infty\int_{\boldsymbol{r}_2}^\infty$ (if so it is bad notation as $\boldsymbol{r}_1$ and $\boldsymbol{r}_2$ are also the integrated variables)
- Should the left hand side of (16) be $\partial_t f$?
- p2964: $\overline{h/r} \to \overline{rh}$? (More natural to define the average using $N$ as the weighting?)
- p2975 L19: I think the Rayleigh distribution should be

$$P_{wa} = (2/\overline{a^2})\mathrm{e}^{-a^2/(2\overline{a^2})}$$

so

$$\overline{a^2} = \int_0^\infty S(\lambda)\mathrm{d}\lambda = H_s^2/16 = \int_0^\infty a^2 P_{wa}\mathrm{d}a.$$

- p2975 L11: I couldn't see the "normalised energy spectrum" the authors were referring to on p11 of the WMO guide.

## 3. Typos

- p2959, L22: have same → have the same
- p2972, L19: the we → that we

## References


[1] D. E. Cartwright and M. S. Longuet-Higgins. The statistical distribution of the maxima of a random function. *Proc. R. Soc. Lond. A*, 237(1209):212–232, 1956.

[2] C. O. Collins, III, W. E. Rogers, A. V. Marchenko, and A. V. Babanin. In Situ Measurements of an energetic wave event in the Arctic marginal ice zone. *Geophys. Res. Let.*, 2015.

[3] D. Dumont, A. L. Kohout, and L. Bertino. A wave-based model for the marginal ice zone including a floe breaking parameterization. *J. Geophys. Res.*, 116(C4):1–12, 2011.

[4] A. Herman. Numerical modeling of force and contact networks in fragmented sea ice. *Ann. Glaciol.*, 54(62):114–120, 2013.

[5] Agnieszka Herman. Sea-ice floe-size distribution in the context of spontaneous scaling emergence in stochastic systems. *Phys. Rev. E*, 81:066123, 2010.

[6] A. L. Kohout, M. J. M. Williams, Takenobu Toyota, J. Lieser, and J. K. Hutchings. In situ observations of wave-induced ice floe breakup. *Deep-Sea Res. II*, in press.

[7] M. H. Meylan, L. G. Bennetts, and A. L. Kohout. In-situ measurements and analysis of ocean waves in the Antarctic marginal ice zone. *Geophys. Res. Lett.*, 2014.

[8] H. H. Shen and B. Sankaran. Internal length and time scales in a simple shear granular flow. *Phys. Rev. E*, 70(051308), 2004.

[9] T. D. Williams, L. G. Bennetts, V. A. Squire, D. Dumont, and L. Bertino. Wave-ice interactions in the marginal ice zone. Part 1: Theoretical foundations. *Ocean Modelling*, 71:81–91, 2013.