This is a second review of Boutin et al (2020) - who look at the interaction of wave fracture and improved rheological modeling in the neXtSIM model. The paper was substantially revised between the first and second revisions, largely following comments made by the set of reviewers. The literature review has been improved and in general I am happy with the way comments were received. With the central premise of the model developments aside (the dual FSD), the remainder of the paper seems appropriately constructed and discussed.

Now that the explanation has been improved, the challenges with the second FSD are clearer to me. The authors need to be wary of including this "intuitive" parameterization without presenting it rigorously. This can lead to confusion for users and readers, and make extending this work a challenge in the future. Or, it can lead to counterintuitive results, one of which I highlight here:

Evolution of the dual-FSD model under thermodynamic-only forcing The actual evolution of the second FSD can be determined within some limits. I tried to do this using the available text, and found some typos. For example in Eq. (5), those Ds should not have subscripts, I think - as $\Phi_{th,slow}$ should be $\Phi_{th,slow}(D)$. Anyways, in a limiting case we can take u=0, Φ_m=0, and observe:

$$\frac{\partial}{\partial t}\left(g_{fast} - g_{slow}\right) = -\frac{g_{fast} - g_{slow}}{\tau} + \Phi_{th,fast}. \tag{1}$$

Generally speaking, the implementation of lateral melt in CICE/LIM/neXtSIM follows,

$$\int_{\mathbf{r}^+} \Phi_{th,fast} \propto \alpha Q, \tag{2}$$

where Q is the heat available to the sea ice, and α is the proportion of that heat flux that goes to lateral processes. Then integrating over all $r > 0$, and noting as in your eq. (1)-(2) that the integral of g over all positive r is the sea ice concentration,

$$\frac{\partial}{\partial t}\left(c_{fast} - c_{slow}\right) = -\frac{c_{fast} - c_{slow}}{\tau} + \alpha Q^*. \tag{3}$$

where we use $c_{fast/slow}$ to denote the integral of $g_{fast/slow}$ over positive r, and Q^* has suitable units. Unless the RHS of that equation is zero always, which can only happen if τ and α are variables instead of parameters, there are clearly two concentrations that evolve independently - not just two FSDs! This will be a particular problem when you have a wave event, which essentially resets g_{fast} to g_{slow} over a model timestep - since they have a different concentration, you will add or lose sea ice concentration instantly because of a mechanical process that should preserve concentration.

This type of restoring equation (in that case, advection from a stationary distribution) was examined in detail in *Horvat and Tziperman* (2017), Sec. 3.1, and the consequences are significant: all moments of these two FSDs, not just the concentration, will have different evolutions over time even if they are apparently identical!

While it might be true that the two observational definitions of the FSD might also have different concentrations, I believe this would only be that the "slow" sea ice concentration is less than the "fast" sea ice concentration, as it might not count the frazil between floes as sea ice. But here the slow concentration *lags* the time evolution of the fast concentration. When melting, the slow ice will have a higher sea ice concentration than the ”fast” ice.

Here are my main suggestions:

1. Add a figure clearly explaining the difference between these two FSDs. In the text you comment that SAR imagery offers motivation, but without a demonstration of this point. Please do so, so that the reader can understand the choice.

2. Proofread the math in Section 2.2., adding a section explaining the influence of this second FSD on quantities that arise from the FSD - I would do this in the context of conserved quantities so you know nothing crazy is going to happen - and consider adding terms to your Eq.s (3)-(5) that account for this lack of conservation.

3. Evaluate the lack of conservation in your two FSDs and put that in the text. If you integrate them, do both yield the area/volume? If they are normalized to one in your code, are the equations you are using to evolve them suitably normalized as well? This is a trickier problem than it might appear.

I look forward to discussing further, and encourage the authors to contact me with any questions. I again find this an interesting approach - it makes plenty of sense! But the actual equations being solved need to be analyzed with a bit more rigor because the consequences might be more significant than they appear at first glance and should be constrained some.

Chris Horvat

References

Horvat, C., and E. Tziperman (2017), The evolution of scaling laws in the sea ice floe size distribution, *Journal of Geophysical Research: Oceans*, *122*(9), 7630–7650, doi: 10.1002/2016JC012573.