The Cryosphere Discuss.,
doi:10.5194/tc-2016-270-SC1, 2017

The Cryosphere
Discussions
Open Access

Interactive comment on "Brief communication: Impacts of ocean-wave-induced breakup of Antarctic sea ice via thermodynamics in a standalone version of the CICE sea-ice model" *by* Luke G. Bennetts et al.

C. Horvat

horvat@fas.harvard.edu

Received and published: 31 January 2017

Dear authors,

The work shown here is extremely exciting. The inclusion of wave-breaking and a true floe thermodynamics into CICE is an important step towards improving sea ice models, and I look forward to future work implementing this model. I generally find the communication to be useful, but I wanted to bring up an important, and subtle, issue that I feel should be addressed in this communication and going forward. On pg. 4 line 5,

> "The floe-diameter parameter is a tracer field in CICE, and is transported within each ice category to give the total floe-size distribution at the end of a time step"

The mean floe diameter, however, does not advect as a tracer. In the parameterization of lateral melting based on *Steele* (1992), as well as the framework presented here, the mean floe diameter is computed as the average floe diameter across all of the floes within a grid cell, i.e.

$$\overline{D} = \frac{1}{N}\sum_{1}^{N} d_i = \int_{D_{min}}^{\infty} p(D)DdD, \tag{1}$$

where $\{d\}_i$ is the collection of N floe diameters, and I use the probability density function notation from this manuscript, where $\int p(D)dD = 1$. In general, the quantity $p(D)dD$ must be equal to the number of floes per unit area with diameter between D and $D + dD$, which I call $N(D)dD$, divided by the number of floes per unit area, $\mathcal{N}$, i.e.

$$p(D) = \frac{N(D)}{\mathcal{N}}. \tag{2}$$

By definition, $\mathcal{N} = \int N(D)dD$ and so p is properly normalized. Both $N(D)$ and $\mathcal{N}$ advect as tracers with the two-dimensional ice-velocity field. The probability density function, however, as the ratio of these two terms, will not. For this reason, the mean floe diameter also does not advect as a tracer. This can lead to pathologies in sea ice evolution (*Horvat and Tziperman*, 2017). The attached figure shows the evolution of normalized four state variables which are advected from an adjacent grid cell into and through a single grid cell. The two adjacent cells have different floe number, concentration, and mean thickness at t=0. In this case the full FSTD (floe size and thickness distribution) is computed and solved for at each model timestep. In the plot, 0 corresponds to the initial value, and 1 corresponds to the value from the adjacent grid cell.

Mean floe size has (and incidentally, mean ice thickness) has a different evolution than does concentration and volume, which have an exponential approach.

The simple explanation for this is that p has a normalization by a time-varying quantity (the total floe number). To properly include mean floe size within CICE, one has to account for the evolution of $\mathcal{N}$ in addition to p. This can be done by observing,

$$c = \mathcal{N} \int_{D_{min}}^{\infty} \frac{\pi}{4} D^2 p(D) dD, \tag{3}$$

where c is the ice concentration. Both p and c are available from the model, so $N(D)$ and $\mathcal{N}$ can be computed, and hopefully no major modifications to the model code are necessary. Quite possibly the proper mean floe size advection scheme is unimportant, but as you are the first to introduce this type of model, it is unclear, and is exciting to find out. If future models include a fully-evolving FSD, this fix will no longer be necessary.

I can provide more information, or a more mathematical derivation of the aforementioned pathologies if this point is not well-made here!

References

Horvat, C., and E. Tziperman (2017), The evolution and emergence of scaling laws in the sea ice floe size distribution, *J Geophys Res*, *In Review*.

Steele, M. (1992), Sea ice melting and floe geometry in a simple ice-ocean model, *J. Geophys. Res. Oceans*, *97*(C), 17,729, doi:10.1029/92JC01755.

Interactive comment on The Cryosphere Discuss., doi:10.5194/tc-2016-270, 2016.

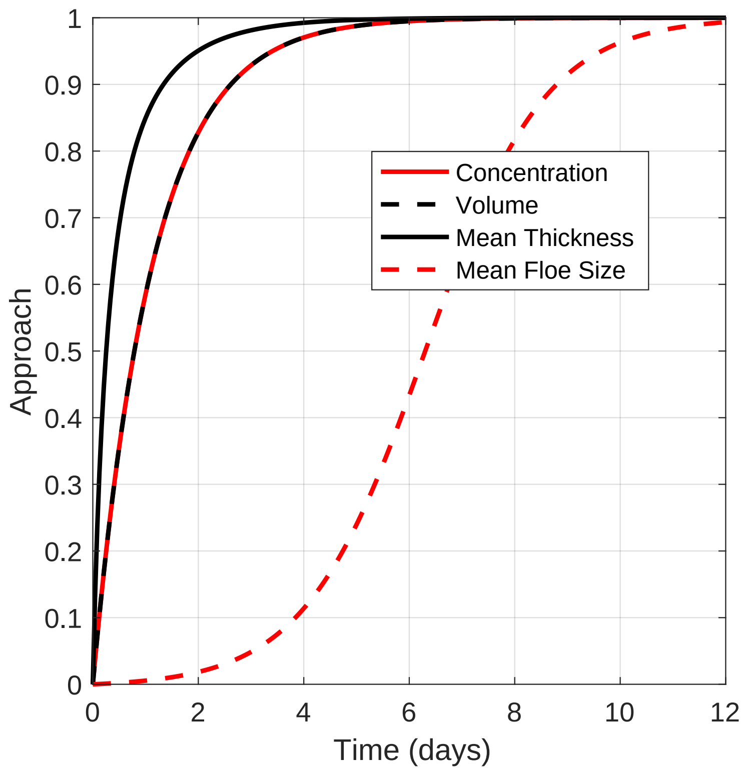

Fig. 1. Approach of several advected model variables