The Cryosphere Discuss.,
https://doi.org/10.5194/tc-2020-19-RC2, 2020

The Cryosphere Discussions

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

Anonymous Referee #2

Received and published: 1 March 2020

This paper follows a series of recent works by the authors and others in coupling ocean waves and sea ice in large scale models. Here, the Wavewatch III and neXtSIM models are coupled, and simulations with different levels of coupling are compared, with a focus on fragmentation of the ice cover and resulting changes in ice dynamics.

The main contribution of the paper is the inclusion of FSD memory, by using two FSD functions where one FSD (the "dynamic" FSD) evolves more slowly than the other one (the "thermodynamic" FSD). This is an interesting new avenue in sea ice modelling, and I'm surprised it hasn't been highlighted in the title of the paper. The authors motivate the memory by saying "there are reports of waves breaking ice at weak points such as refrozen leads and pressure ridges (e.g. Kohout et al 2016)" (p4, l3–4), but only ever refer to the one paper (Kohout et al, 2016). Are there any more reports of this kind?

If so, give them. If not, weaken the motivating statement. In either case, it would be useful to give brief descriptions of the events reported. I found the names of the FSDs difficult, as both depend on dynamic and thermodynamic source terms. Calling them, e.g., slow and fast would be easier (and probably more accurate).

Another motivation given for the study is that "neXtSIM is now including a Maxwell Elastomer-Brittle rheology" (p3, l31). But there is no explanation of why the MEB rheology is an improvement over the EB rheology for modelling marginal ice zone dynamics, or rheologies used in other models. Even if the authors don't intend this as a main motivation, they should discuss the relevance of the MEB rheology for the MIZ.

Wave attenuation, ice fragmentation and wave radiation stress models are very important for this study. The developments of these models, key assumptions, etc should be discussed, as all the models contain large uncertainties. Notably, only one sentence is given to wave attenuation models in the introduction (p2, l24; not including the short sentence referencing review papers), despite uncertainties in attenuation being identified as important later (bottom of p20). The scattering reference (Montiel & Squire, 2017) is actually a fragmentation (or ice breakup) study (see its title) and should be used elsewhere. The scattering model used for that study is the 3D model by Montiel et al (2016), but I'm not aware of 3D scattering models being available in Wavewatch III. The review of fragmentation models focusses on the FSD shape, and overlooks the models used to predict if waves are capable of breaking the ice cover. The lab model by Herman et al (2018) is relevant here (noting that it is for regular, low steepness waves only), as is the lab model by Dolatshah et al (2018). Similarly, the WRS model needs to be discussed; based on Williams et al (2017), it seems to contain large uncertainties and arbitrary assumptions.

Other comments, suggestions and questions:

The statement "There are two main processes through which waves can affect sea ice dynamics" (p2, l3) is far too strong. What about, e.g., collisions? Just say "we

investigate two processes..." or similar. The subsequent discussion on the role of WRS needs to be more balanced, e.g. Williams et al (2017) found that "wind stress dominates the WRS", and Alberello et al found negligible WRS in a pancake ice MIZ, even during large wave events.

On p2 l15, replace "fragmentation" by "floe size", as neither Shen et al (1986) nor Feltham (2005) included fragmentation in their models.

Saying "their FSD depends only on the wave field" (p3, l8) is not true, as D_max depends on the ice properties, as does the breaking criterion.

The work by Rynders (2018) is conspicuously missing from the introduction.

The line at the top of p6 is awkward and should be reworded. Regarding the reference to Roach et al two lines below, please clarify if you are considering an FSD or an ITFSD?

Does "lateral melt will not be discussed here" mean that it won't be included in the model for the study?

The opening paragraph of 2.2.2 is very long-winded for describing a simple method. Please give a reference to back the statement "sea ice fragmentation is a violent phenomenon ... impact the floe size". This doesn't seem to allow for fatigue.

Do the lines at the top of p8 mean D_N=1000m? On l10, "freedom" doesn't seem to be the correct word.

Say a bit more about tau_WF below Eq 7. Is it a numerical parameter of does it have physical meaning?

On p8 l11, please check the interval bounds, and on l13 reword "over within which".

At the bottom of p9, what exactly is being conserved?

Please clarify the two sentences starting p10 l19. Also, is this the ice-coupled or open-

water wavelength?

Should it be "fragmentation and/or refreezing" on p11 l6?

Has the sensitivity of the the coupling time step between the wave and ice models been tested (section 3.1)? Also, why is tau_heal set to 25 days?

You say "the other main novelties..." (p14 l11), but this is the first mention of novelty.

The CPL simulations first appear in 4.1.2, but in section 3.3 it says they will be used in section 4.2.

Explain the statement "this quick re-generation ... making welding very efficient" (p15, l8).

What "impact of waves on sea ice dynamics" is being referred to in section 5? Also, does "large fragmentation events" mean fragmentation over a large area or something else?

The sentence at the end of the first paragraph of p21 is incorrect. Bennetts et al (2017) use a parameterization based on in-situ measurements by Meylan et al (2014). More generally, starting with Bennetts & Squire and Williams et al (2013a,b), it is usual to model attenuation using a viscous dissipation term for low-frequency waves and a scattering term for mid-frequency waves (see also Squire & Montiel, 2016).

Check the inequalities on l4 and l9 of p23.

What are the vectors in Fig 2b?

There are quite a few typos to correct.

References

Alberello et al, Drift of pancake ice floes in the Antarctic marginal ice zone during polar cyclones, arXiv.1906.10839

Bennetts & Squire, 2012, On the calculation of an attenuation coefficient for transects

of ice covered ocean, Proceedings of the Royal Society of London A, 468

Dolatshah et al, 2018, Hydroelastic interactions between water waves and floating freshwater ice, Physics of Fluids, 30

Meylan et al, 2014, In-situ measurements and analysis of ocean waves in the Antarctic marginal ice zone, Geophysical Research Letters, 41

Montiel et al, 2016, Attenuation and directional spreading of ocean wave spectra in the marginal ice zone, Journal of Fluid Mechanics, 790, 492-522

Rynders, 2018, Impact of surface waves on sea ice and ocean in the polar regions, University of Southampton

Squire & Montiel, 2016, Evolution of directional spectra in the marginal ice zone, Journal of Physical Oceanography, 46

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