Review of Glacier damage evolution over ice flow timescales

General Comments

This paper looks at how damage can be incorporated into ice sheet models. It seeks to quantify the importance of damage and its effect on mass loss from ice sheets. The damage is described by a scalar variable and incorporated into the ice sheet model in a continuum fashion, where the damage causes the ice viscosity to decrease. The authors suggest a simplified model for damage evolution, based on the assumption that the damage production timescale is much less than the timescale for advection. Hence, the ice can be assumed to be instantaneously damaged when the stress exceeds a certain threshold. This has the appealing advantage of removing many free parameters which occur in continuum damage evolution models, with little effect on the results as the mechanisms for damage production need not be modelled or parameterised. The results of this simplified model are first compared to the transient damage model to test this assumption. The model is then applied to the MISMIP+ benchmark to assess the impact of damage on grounding line retreat.

Generally, I think the paper is of very good quality and can be published subject to minor corrections.

Originality: The diagnostic model proposed is novel, and the new model is also applied to estimate the effect of damage on grounding line position and on ice mass loss over the next century.

Scientific Quality: The science is of good quality. The simplifying assumption is well tested with the non-dimensional analysis, though I would like to see more detail in the possible values of δ (see specific comment). Furthermore, the extension of the model to the MISMIP+ case serves as a good test, and they also link the impact of damage to final changes in mass loss. The discussion is well thought out and the conclusions are backed up by the main text.

Significance: The paper is significant for two reasons: firstly, proposing a novel diagnostic model for damage which should be easier to include in ice sheet models. Secondly, they also highlight the importance of damage on grounding line position and mass loss

Presentation quality: The paper is well written and concise. The figures are clearly explained in the text.

Specific Comments

As the other reviewer mentions, I think the authors should be clear on the uncertainties within their estimates of the advection and production timescales, and how does this propogate through to δ. What is the maximum and minimum value that δ can take given these uncertainties on the stress threshold, glacier length etc.? Where might this assumption not be valid?

The supplement is significant, and I think it would be helpful to move some of it into the main text. In particular, I think Fig S2 and the accompanying text would be helpful to further show that this diagnostic model is still valid in less idealised configurations.

Line 324: Am I correct in thinking that limiting the value of Dmax effectively limits the maximum softening caused by damage? Such that Dmax = 0.5 gives a max softening of 8 etc.? If so this may be helpful to explain in the text.

Technical Comments

Fig 5: The label for (b) (i) “Damage field after 100 years” is directly over a subplot for t=0 years: this label should be changed for part (b) of the figure.

Supplement Line 119: WhenIf