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The Cryosphere Discussions

Interactive comment on "Tidal bending of ice shelves as a mechanism for large-scale temporal variations in ice flow" *by* Sebastian H. R. Rosier and G. Hilmar Gudmundsson

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We thank Martin Lüthi for his helpful comments, our responses to each of the main points (in bold) are included below (in italics). All of the minor comments will be addressed in a revised version of the manuscript.

One point that needs attention is the intermingling of viscous and elastic stresses in the theoretical investigation (section 3). Elastic bending stresses are taken from beam theory, and then suddenly interpreted as viscous stresses. From the discussion it is not clear whether this is done because of the assumption of a Maxwell body, but then one would have to argue why elastic displace-

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Discussion paper

ments are ignored.

In section 3 we take bending stresses from elastic beam theory and use them in a Maxwell rheological model. With a Maxwell rheology, the stresses in the elastic and viscous components are equal and so this is a reasonable approach. Next, we throw away the elastic deformational component and we justify this for two reasons. Firstly, as we show in appendix A, the time derivative of the across flow shear stress is negligible, and so this elastic term will become very small. Secondly, we are primarily interested in how an ice shelf can generate a nonlinear Msf response to a tidal forcing and this elastic term will only directly yield a linear response. These points are made in the text but could be clearer and so we will emphasise them in the revised manuscript.

It would be helpful to extend several figures, especially Figure 5 (adding τE) and Figure 6 (adding τE, extending it to all three experiments). Additionally, a figure showing time series of forcing, horizontal displacement, velocity, τE and strain heating in the shear zone would be most helpful.

We will explore ways to include adding the effective stress into the figures without adding too much clutter, we agree that this would be helpful for the reader. However figure 6 is a periodogram and it is unclear how this could be incorporated. A figure showing the time series of forcing etc. will also be added.

One of the strong points of the paper is that no state change in the ice is required to produce the period doubling. However, there are three obvious mechanisms which should be discussed: grain size, fractural weakening and strain heating. All of these effects have been invoked to explain ice stream shear margins, so there is ample pertinent literature. It seems very likely that these processes are also active in a shelf shear margin, which is very similar to a fatigue experiment in material science. Certainly grain size will adapt to the continuous forcing, the material might su er damaging, and strain heating (which is a model output) will warm and therefor soften the ice.

We agree that a discussion on these other shear margin processes will greatly add to our paper and will add one to the revised manuscript.

As a side-note, the authors seem to adopt (as in the recent glaciological literature) the term "full-Stokes" to mean Finite Element model, even if they don't solve the Stokes equation, but a visco-elastic extension thereof. There is no such thing as a "full-Stokes" equation, but "reduced-Stokes" solvers which ignore some terms of the Stokes equation. This is mentioned in many comments below, but should be consistently purged.

In our numerical treatment we include all terms of the momentum equations, apart from the acceleration terms. In the glaciological literature the resulting form of the momentum equations is commonly referred to as the 'full Stokes' equations, and to remain consistent with previous work we use this terminology (it is certainly not intended as a substitute for Finite Element model). It is important that a reader understands that our model includes all the equilibrium stress balance terms, as against other commonly used approximations in glaciology such as the SSA/SIA. The term 'reduced-Stokes' is likely to cause confusion in this regard, but we are happy to go with the editor's recommendation.

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