Geoscientific Model Development Discussions

Geosci. Model Dev. Discuss., referee comment RC1
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Comment on gmd-2021-126

Wouter van der Wal (Referee)

Referee comment on "Capturing the interactions between ice sheets, sea level and the solid Earth on a range of timescales: a new “time window” algorithm" by Holly Kyeore Han et al., Geosci. Model Dev. Discuss., https://doi.org/10.5194/gmd-2021-126-RC1, 2021

The paper adresses the problem of long computation times for simulation of sea level changes due to ice melt for (i) long periods or (ii) when high temporal resolution is required. This problem especially occurs when ice dynamic models and solid Earth models are coupled and the complete ice history should be considered at each time step. Large computation time currently limits the application of such simulations. The paper presents a solution which reduces the computation time significantly by using variable time steps with smaller time steps closer to the present (or the epoch of interest). The method can be implemented in different methods for calculating the sea level response. Explanations in the text are clear, figures are well designed and helpful. The method is shown to work in schematic tests and interesting results are obtained for two case studies, for a long time history simulation for the Northern hemisphere ice sheets, and for fast future ice melt in Antarctica.

All in all this is a very nice and complete paper which will benefit sea level modelers and people interested in the application of such models. I have a few general comments below and several specific comments mainly asking for additional clarification in the annoted pdf. Together these constitute a minor revision which can be dealt with by changes to the text. The pdf also contains typos and suggestions for rewording, which the authors can consider and which do not have to be addressed in a rebuttal as far as I’m concerned.

Wouter van der Wal

General issues

Some conclusions depend on particular choices made in the paper, which should be made clearer. For example, the increment in the ice history thickness is assumed to take place

at the end of the time step (as opposed to at the beginning of the time step) and from that follows several conclusions (for example 'missing viscous signals', line 565). See also the discussion on the choice of time steps in: Barletta, V. R., & Bordoni, A. (2013). Effect of different implementations of the same ice history in GIA modeling. *Journal of Geodynamics*, *71*, 65-73. Also the results hold for a spatial resolution selected (spherical harmonic degree 524)

Whether an error is acceptable depends on the application. The parameter used in the paper for precision is the ice volume and the bedrock topography, but I could imagine for some applications an error in ice volume at 70ky before present is less of a problem than the same magnitude error at 11 ky. If a larger uncertainty is acceptable larger time steps are acceptable, so the suggested time steps in the conclusion are not as general they are presented. Also the word "optimal" implies some optimization which is not exactly what is done, so there could be similar but larger time steps which give similar precision but smaller computation time.

The paper focuses on the sensitivity to the time between loading and present, and briefly mentions the effect of viscosity on this sensitivity. However, the role of viscosity can be large. I would guess that if viscosity is very high, sensitivity to temporal resolution in recent ice thickness changes is low. This should be discussed at least in the conclusions (see also comments in the pdf). It is probably useful to introduce the relation between mantle viscosity and relaxation time.

Please also note the supplement to this comment:
https://gmd.copernicus.org/preprints/gmd-2021-126/gmd-2021-126-RC1-supplement.pdf