Reviewer Comment

Interaction between ice sheet dynamics and subglacial lake circulation: a coupled modeling approach

By Thoma, M., Grosfeld, K., Mayer, C. and Pattyn, F.

This work is concerned with the coupling of an ice dynamics model with a lake dynamics model, that was adapted from an ocean model. The basic idea is to improve the estimation of the heat transport from the lake into the ice and thus obtain a basal melt rate at the lake/ice interface. This is a very valuable goal. However, the work is in not mature to be published in this form. It is not explained which equations are additionally solved in the ice model, or which boundary condition was chosen. The entire study misses a validation and some results are questionable. At some occasions, it remains unclear if the assumptions are in fact fulfilled (the lake volume is supposed to be constant, while the area might vary, whereas the vertical extent does not change). The discussion of the results of the coupling does fill only one page, which symbolizes quite well that the entire study is in a very early stage and needs some extension, even if it is only applied to a simplified geometry. The only 'physical experiment' is the influence of the coupling after 100.000 years – a question worth to ask, but the estimated effect of melting is dubious. The figures of this manuscript are impertinent and definitely need to be improved.

Concluding this seems to be a documentation of the derivation of the process of improving and coupling two models (which is a great amount of work that every modeller acknowledges), but it is not a study of the 'Interaction between ice sheet dynamics and subglacial lake circulation' as yet only compares 'uncoupled' versus 'coupled' modeling.

Specific comments:

Page 807:

Line 15: Schiermeier, 2008 is not a scientific publication and it is questionable if news are supposed to be cited this work.

Entire page: This study is partly concerned with the ice dynamics and how the ice flow velocity changed while the ice is flowing over the lake. There are studies which estimated the flow velocities over some subglacial lakes. The authors shall cite this work and use the data later on to compare their estimated velocity changes with the measured ones.

Page 808:

Line 9: Frank Pattyn still needs to be in capitals, and it is probably not based on the person Frank Pattyn, but on his ice model.

Line 11: full-Stokes (check everywhere)

Line 12: Is beta really vanishing entirely? Or is it some kind of epsilon-style value, which stabilizes the numeric's?

Line 11-13: These lines contradict Fig1 and page 810, line 4-23.

Line 20-24: It remains unclear which value you chose and if Pattyn (2008) does not count as a traditional ice model. Reword this into something like: There is a general agreement to use n=3, while some models (e.g. Pattyn, 2008) use n=1 in order to ….

Page 809:

Line 2: 168100km^2 LARGE domain.

Line 11: Figure 3 does not show the lake geometry in a way that one can see where the lake thickness is zero. Chose a color scale that shows a clear difference between vanishing lake thickness and a non-zero lake depth.

Line 12: If this simulations wants to assemble lake Vostok, -50°C is an odd choice.

Line 15: The motivation of the choice of the geothermal heat flux is quite strange. The choice of the value should be motivated by datasets, however sparse they might be. Fox & Maule 2005, Shapiro&Ritzwoller, 2004, are two sources.

Line 20: are ignored

Entire section 2.2: It remains unclear if the coupling between ocean and ice model uses the heat conduction and convection equation or solves the energy balance at the ice/lake interface. It is mandatory to show this or these equation(s) and discuss the magnitude of the terms.

It also remains unclear what the boundary condition is across the lake: for ice and ocean models usually assumes the temperature at the ice/water interface to be the freezing point of (sea) water. The choice of this boundary condition is critical and you should definitely discuss this more in detail.

Page 810:

I suggest to shift this section one level up and first explain the new model and its substantial changes to Frank Pattyn's original model (You claim a new name, thus a kind of new product, so it's presumably a rather large addition? Is the implementation of a Gaussian filter & a smoothing coefficient an addition that justifies that?) and then discuss the model setup. This also solves my question about n=?.

Line 9: If the numerical runs are not stable without this stabilization, is Fig. 2a meaningfull?

Line 12: time increases without

Line 21: Do you really mean that your result that your remedies lead to stability is only a preliminary result? If your study is a preliminary study, you should consider to re-submit at some point in future, when the results are not preliminary any more.

Line 23: Please tell the reader your convergence criterion.

Line 26: If quasi-steady state is reached after 300 000 years, why do you show in Sect 4.2 the results after 100 000 years?

Page 811:

Line 5: I see it in Fig. 3b, but not in Fig. 3c.

Line 10: 0.7 to 1.2m/a equals 71%.

Line 13: This is a cross-section through the temperature field. Please note: the most interesting quantity is the vertical gradient of the temperature. I recommend to include a panel showing the temperature gradient between all vertical layers for all nodes in that cross-section.

Line 17-24: You conclude that the model resolution does highly influence the ice flow velocities. If so, you need to PROOF that 1km, 500m ... resolution will not again have a significant impact!

Line 25: (HOM) is not required.

Line 27: You NEED to tell the reader, if the set-up of the higher order model is similar to this model and if there are differences in e.g. the definition of the rate factor and temperature boundary conditions … otherwise we can't estimate if the differences are representing 'stabilized' full-Stokes vs higher order model or different choices of model parameters and setups.

The entire section misses to discuss and compare measured flow speeds.

Page 813:

Line 4: Since you do not show any equations it's quite confusing what your Qice really is. I first thought it's the heat flux into the ice that is usually calculated by ocean models, but this quantity is most often called q_sea. Is Qice = \kappa (grad T * \vec{n}) = q_sea – rho_ice L a_b - (rho_sw – rho_ice) g h_b a_b ?

Line 9: Fig3c shows the temperature and not the temperature gradient. As one of achievements of this work is indeed the treatment of Qice, please give the reader the value for Qice at locations similar to those where you evaluate 24 & 27 mW/m^2.

Line 17&18: Could you please be so kind to tell us the magnitude (e.g. as number in brackets) of the mass transport for these two lakes, which would allow us to guess how close to the sophisticated lake Vostok the lake in this study is.

Line 20: 'results' – does this really result in a decrease of **, or is the slope a result of the melting/freezing or is this some kind of hen/egg problem?

Page 814:

Line 13: The use of the initial values might be justified here, as the flow speeds are small and you ignore snow accumulation anyway, however this is the wrong design for the coupler, as you may want to apply it to locations where all that is not longer valid.

Line 15: An additional process has to be considered or IS considered? Below you write that the volume of the lake is constant. To me this seems to be a major inconsistency.

Line 26: re-use

Page 815:

Line 9: Check the lake volume and convince the reader that you assure this definition.

Line 10-12: Your snow accumulation rate is still zero. Assuming steady state, the basal melt of about 12mm/a, would accumulate in 100 000 years to 1200 m (assuming that the flux terms are only small)?? How meaningful is the impact on the ice sheet volume anyway, as you neglect the snow accumulation?

Line 18, 22 & 26: I'm not entirely sure, but I think this should be Firstly, Secondly and Thirdly,...

Page 816:

Line 1: This reduced temperature (compared..) – this is not an anomaly.

Line 3: This is not an artificial cooling, this is 'the reality'.

Line 6: I doubt that OBSERVATIONS FROM SPACE show that subglacial lake have a significant impact of the dynamics of the Antarctic ice sheet. As far as I know remote sensing shows the presence, the location and the dynamics of the subglacial hydrology, while you need in situ measurements to show the effect of subglacial water on the dynamics of the Antarctic ice sheet (like the estimation of flow speeds before, during and after drainage of a lake). If you disagree, be more specific and give references.

Line 9: Give citations for the observed re-direction!

Line 15: No, the lake-exclusive studies are based on a model and not vice versa.

Line 16: ...while you didn't change the lake volume???

Page 817:

Line 1: The ice sheet bottom IS the bedrock-based ice. What exactly do you mean?

Line 6-8: Yes, obviously. Delete this sentence or write about plans etc..

Figures:

All figures : annotations are too small.

Figure 1: y-axis: beta^2*10^6.

Figure 2: The viscosity probably has a unit. The yellow of beta^2 seems not to appear in the color bar, otherwise it would be bright yellow and not pale yellow. Chose a color scale which clearly marks beta^2=0 and beta^2=10^6. The color bar of log(eta) is shifted to the left in my printout.

Figure 3: Adjust the color bar in a such that we see where the lake depth is zero. The magnitude 1.2m/a is reached nowhere. Chose a vector which eases the measuring of the length of the arrow

(which one can't anyway, so you might want to show the direction with arrows of similar length only?) b) Velocity in x-direction. Are these contour really need to be labeled? c) Add the temperature gradient from layer to layer or at least a plot like a showing the gradient at the bottom. It's a cross-section through the temperature field.

Figure 4: What's that line above the color bars?

Figure 5: We are all no graphic designers, but this figure matches only the lowest level of aesthetics. (a) Label it as Qice. I can't see a value that is larger than 30mQ/m^2 and you even write in the text 24-27mW/m^2. How about adjusting the range? (a-d) can you read the contour labels without zooming in the pdf file to 300%?

Figure 6: You ruin our eyes! Choose rectangular boxes instead of triangles and increase the font size!

Figure 7: The labeling of the contour lines makes it really difficult to see if panel d shows something at the margins of the lake! Qice instead of heat conduction.

Figure 8: I'm surprised that the temperature in the lowest part of the ice sheet across the lake has not changed!! I doubt that. Authors, please clarify!