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The Cryosphere Discussions

Interactive comment on "A balanced water layer concept for subglacial hydrology in large scale ice sheet models" *by* S. Goeller et al.

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1 General comments

This paper present a new approach for the modeling of steady states water distribution at the base of ice sheet. This approach uses the Shreve approximation (Shreve, 1972) to compute the hydraulic potential which is used to compute the water fluxes. This new approach take advantage of the existing development of the balance flux concept which is based on the same working hypothesis. The improvement of this methods lie in the fact that it allows to compute the water fluxes and so the conservation of the mass of water. The major achievement of this approach is the ability to model subglacial lakes which are clearly identified underneath Antarctic ice sheet and have a non negligible impact on ice dynamics.

The hydrological model is coupled to the thermo-mechanical ice model RIMBAY which allow to compute the water inputs needed by the hydrological model and also gives the ice geometry which will allow the computation of the hydraulic potential. The retroaction between hydrological and ice sheet model is handled through the basal boundary condition. This retroaction on sliding is defined as a free slip condition above subglacial lakes and a Weertman type friction law which could be defined with a water flux dependent parameter.

As stated in the paper, the water layer concept allow the diagnostic modeling of subglacial lakes and then their effect on ice dynamics. This is a great improvement with respect to the preceding balance flux concept. I am more doubtful on the relevance of the relation between glacier sliding and water fluxes. With regard to the last development in subglacial hydrological modeling (Schoof, 2010; Hewitt et al., 2012) it seems that the convenient value to compute the retroaction between hydrology and sliding would be the effective pressure (*i.e.* ice overburden pressure minus water pressure) which is fixed to zero in this approach. Commenting on this point would be an interesting development to add to the paper.

The writing of the paper is clear but I will advise to shift part 2 and 3 to put the description of the hydrological model first. Moreover, current part 2 is treating more of the coupling of the hydrological model to the ice model and I would rename it to reflect that.

2 Specific comments

2.1 Abstract and introduction

Abstract and Introduction goes to the point of the study and are well referenced and clearly written. I have noted a few points that could be modified or improved :

- Regarding the hydraulic potential, there is a misunderstanding in the given definition. In it's original form, the hydraulic potential ϕ does not include any effect of the ice pressure, it writes :

$$\phi = \rho_w g z + P_w, \tag{1}$$

  with ρ_w the water density, g the acceleration of the gravity and P_w the water pressure at the considered point of elevation z. This expression can be simplified while stating that the effective pressure at the base of the glacier (ice overburden pressure minus water pressure at the bedrock) is null. Under this approximation the hydraulic potential could be written as :

$$\phi = \rho_w g z + P_i, \tag{2}$$

  with P_i the ice pressure.

- The reference to Lythe and Vaughan (2001) could be updated to Fretwell et al. (2012) for the second version of Bedmap.

2.2 Ice Model

Apart from the position and title change of this part I don't think it needs much modification. The possibility to fix β^2 to 0 in case of a lake should be introduced in the presentation of the sliding law (Equation 1) rather than in Section 4.2. I don't really see

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the point of neglecting the frictional basal heating term which is known to be dominating the water input at the base of ice sheets (Cuffey and Paterson, 2010). I think that this point needs more explanation or that this term should be included.

2.3 The balance water layer concept

The only improvement that I see in this section is the adjunction of a general figure of the model where the different altitudes of Equation 6 would be depicted.

2.4 Experiment and results

My appreciation is that some small change in the phrasing in this section could lead to a better clarity and understanding. I find that there were to much figures (volume and fluxes) that are not easily compared. In my opinion, these figures could be replaced to comparison with the quantities of the reference simulation and written in the form of percentage that will give a much clearer image of the different simulations. I would also drop the reference to the cardinal points which is not really relevant in the case of a synthetic geometry to replace it by the “geometric terms” (front, divide and sides). I am also quite not sure of the boundary condition that are used for the ice model from the given terms and don’t see at any point the boundary condition that are applied to the hydrological model.

2.5 Discussion and conclusion

In this section, the introduction of a number of comparisons between the experiments using percentage values make it much clearer than in the preceding one.

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3 Technical comments

- page 5227 line 4 : replace modeling by model
- page 5227 line 8 : replace into the base... by at the base...
- page 5228 line 1 : I don't get the meaning of "data basis" perhaps the correct term is "data base"
- page 5230 Equation 2 : Meaning of ρ_{ice} is not given in the text
- page 5234 : I find the first sentence hard to understand it could be rephrased as " ... the difference of the potential (Eq. 11). These transfered amount are bounded by the maximum available volume of water so that $\epsilon\Delta_x P_{i,j}$ or $\epsilon\Delta_y P_{i,j}$ will never exceeds $W_{i,j}$."
- page 5236 Equation 19 : Typo error in the equation
- page 5236 line 8 : I would replace model by grid
- Figure 7 : As a colorblind person I could not make anything out of this figure I would suggest to change the color scale.

References

Cuffey, K. and Paterson, W. S. B. (2010). *The Physics of glaciers*. 4th ed., Butterworth-Heinemann, Oxford.

Fretwell, P., Pritchard, H. D., Vaughan, D. G., Bamber, J. L., Barrand, N. E., Bell, R., Bianchi, C., Bingham, R. G., Blankenship, D. D., Casassa, G., Catania, G., Callens, D., Conway, H., Cook, A. J., Corr, H. F. J., Damaske, D., Damm, V., Ferraccioli, F., Forsberg, R., Fujita, S., Gogineni, P., Griggs, J. A., Hindmarsh, R. C. A., Holmlund, P., Holt, J. W., Jacobel, R. W.,

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Jenkins, A., Jokat, W., Jordan, T., King, E. C., Kohler, J., Krabill, W., Riger-Kusk, M., Langley, K. A., Leitchenkov, G., Leuschen, C., Luyendyk, B. P., Matsuoka, K., Nogi, Y., Nost, O. A., Popov, S. V., Rignot, E., Rippin, D. M., Riviera, A., Roberts, J., Ross, N., Siegert, M. J., Smith, A. M., Steinhage, D., Studinger, M., Sun, B., Tinto, B. K., Welch, B. C., Young, D. A., Xiangbin, C., and Zirizzotti, A. (2012). Bedmap2: improved ice bed, surface and thickness datasets for antarctica. *The Cryosphere Discuss.*, 6:4305–4361.

Hewitt, I. J., Schoof, C., and Werder, M. A. (2012). Flotation and free surface flow in a model for subglacial drainage. part 2. channel flow. *Journal of Fluid Mechanics*, 702:157–187.

Lythe, M. B. and Vaughan, D. G. (2001). Bedmap: A new ice thickness and subglacial topographic model of antarctica. *Journal of Geophysical Research: Solid Earth*, 106(B6):11335–11351.

Schoof, C. (2010). Ice-sheet acceleration driven by melt supply variability. *Nature*, 468:803–806.

Shreve, R. L. (1972). Movement of water in glaciers. *J. Glaciol.*, 11(62):205–214.