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The Cryosphere
Discussions

Interactive comment on "Possible groundwater dominance in the subglacial hydrology of ice sheet interiors: example at Dome C, East Antarctica" *by* Brad T. Gooch et al.

Anonymous Referee #1

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Comments on "Possible groundwater dominance…" by Gooch, B.T. et al. for The Cryosphere"

This paper presents results of numerical modelling of the subglacial hydrology below Dome C, East Antarctica that couples Darcian groundwater flow in the bed with a water sheet at the ice/bed interface and the subglacial lakes. Including these three elements typically modelled separately by other workers in a single model is the main strength of this study. The results demonstrate the importanceâĂŢif not necessityâĂŢof considering groundwater flow when investigating the formation of subglacial lakes and water sheets under glaciers resting on permeable beds. The model is applicable to the interiors of large, slowly moving ice sheets and thus may be relevant also to the

reconstructions of the Pleistocene continental ice sheets. The paper is well written, the mathematical model formulation is sound, the results seem well constrained by the actual field observations and the conclusions are, to a large extent, supported by the data presented. Given the recent research focus on the subglacial lakes in Antarctica but also the inferences regarding the past ice sheets the topic is timely and the results help to better understand why, where and when water would accumulate under the ice eventually leading to lake formation. It is good to see this new contribution of groundwater flow study in subglacial hydrology, the field that has been long neglected hanging between the chairs of classical glaciology and hydrogeology and then illuminated by the pioneering studies of G.S. Boulton (Boulton et al. 1993 and onwards). The article is well worth being published; I only have minor comments that do not question any issues of fundamental importance but may be considered in revision.

The model is a 2D simulation along a vertical transect. One should be very cautious with conclusions derived from such models that refer to spatial (3D) phenomena. In flow transects the groundwater flow lines are, naturally, artefacts forced onto a vertical projection plane neglecting flow components non-parallel to the direction of the transect. The true flow field (e.g. around obstacles) is not represented. Accordingly, this limitation is carried on to the calculations of fluxes and any conclusions related to it. The authors are aware of this issue and address it in passing in Discussion and Conclusions but it should be better emphasized since it influences the robustness of the result interpretation. Another issue is the representation of hydrogeological parameters in the model. The authors assume that the aquifer under the ice sheet is homogenous and isotropic (with a range of model runs involving/calculating different permeabilities). Since their equations refer to water flow through a porous medium (vs. karstic systems likely present in this area) the distribution of the permeability values is crucial. Given the complex geological history of this area, the modelled aquifer (c. 1200 m thick, c. 180 km long) certainly is heterogenous (across several orders of magnitude) and anisotropic (with horizontal conductivities much larger than the vertical ones). This too deserves a stronger emphasis. Also, I would welcome a comment on the fact that the simulation is for steady-state conditions. Given the fact that we deal with a low-dynamics ice sheet here, a steady-state simulation is justified but, again, it is a simplification of the natural system. Finally, I miss more information about (1) the constant head boundary on top of the model since the hydraulic head at the ice/bed interface may vary considerably, and (2) the justification of no-flow boundary on the right side of the model – strictly speaking this would only be correct at the ice divide only; is there no groundwater inflow from further up-ice?

In the Discussion the authors comment on the groundwater flow field and discuss it in the context of surface and bed slope. Again, if the more realistic distribution of K-values in the subglacial aquifer were taken into account, it would most probably turn out that these values have the dominant influence on the geometry of the flow field (see e.g. Piotrowski 1997 and Piotrowski et al. 2009 for examples including reversed flow directions). If so, it is tempting to speculate to what extent the location of fine-grained deposits in the bed triggers water accumulation at the ice/bed interface and eventually the formation of subglacial lakes. Worth mentioning is that in parts of the ancient Scandinavian Ice Sheet subglacial channels (tunnel valleys) occur preferentially in low-permeability areas of the bed (Sandersen & Jørgensen 2012).

The figures are well designed and informative. I suggest inserting some groundwater flow vectors in Fig. 6b to better visualize the flow directions.

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