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The Cryosphere Discussions

Interactive comment on "Estimating basal properties of glaciers from surface measurements: a non-linear Bayesian inversion approach" *by* M. J. Raymond and G. H. Gudmundsson

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1 General Comments

The article "Estimating basal properties of glaciers from surface measurements: a non-linear Bayesian inversion approach" describes a new way of inferring basal properties from surface observations. The paper is well written. The method detailed in this article is completely different from the well-known "Control Methods" and seems to be a promising technique (even if further testing is necessary). The paper is easy to read even for people not very familiar with probability theory. The authors make it easy to follow the fundamental steps that lead to the inversion algorithm.

I highly recommend this paper for publication within TC after some minor revisions have been done. Olaf Eisen has already commented the article in detail, and I agree with him on most points but I also have some comments to add.

2 Specific Comments

2.1 Major issues

Even if, as I mentioned in the general comments, the non-linear Bayesian approach is a promising technique, the paper limits the experiments to simplistic cases. This is probably enough for an article but extending this method to real cases is more challenging. I would have liked to see at least one experiment applied on a realistic geometry, even using a flow-line model. A comparison with classical control methods would have been useful. Here are the reasons why applying such a technique on real ice sheet system would not be straightforward:

1. the forward model (184). Even if the model is based on a reduced set of Stokes equations, the assumption of plane strain (no lateral shear) is made. This assumption is valid for a flow line of an ice stream but is not true at all everywhere on a real ice sheet system.

2. the geometry (186). The glacier geometry is "a uniformly inclined plane slab of constant thickness on which perturbations in bed and surface topography are superimposed". This geometry is nice to test an inversion algorithm but is much too simplistic to be able to justify the conclusion that this method improves on other existing techniques. With a well-tuned control method and a good cost function,

control methods would solve the problem with the same amount of iterations as the Bayesian approach for such geometries.

3. the Fourier space (191). This paragraph explains how to use the Fourier Space. If a flow line with periodic boundary conditions is considered, such an hypothesis may apply, but for a non-regular closed 3d geometry, this assumption breaks down.

2.2 Minor Issue

187 About the implementation of the drag in the finite element model, the authors explain that they add "a uniform thin layer of different viscosity to the base of the glacier such that [the basal friction equation] is fulfilled", which probably requires a mesh refinement at the base. I am somewhat puzzled by this approach as the basal friction equation can be rewritten as

$$\tau_b = c(x)^{-1/m} u_b^{1/m} \tag{1}$$

and this equation can be directly introduced into the finite element stiffness matrix as a stress boundary condition (Neumann).

183.23: constructing data sets WHERE, to a ...

187 I also wonder why there is no single point constraint in the model. How do you get rid of the translation modes? (it introduces a zero eigenvalue in the stiffness matrix which makes it singular).

189.5 the system state DOES not affect...

190.22 About the Newton method, O. Eisen mentioned (S84) that he wondered why the Hessian of the cost function was used. I think the authors were right in identifying

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Interactive Comment

this method as such because by trying to minimize the cost function, you are seeking the zero of its gradient. The Newton method is not applied on the cost function but on its derivative. The first derivative of this function is therefore required and it is the Hessian of the cost function. So I think you are right when you use the term "Newton method".

Interactive comment on The Cryosphere Discuss., 3, 181, 2009.