The Cryosphere Discuss., 8, C2073–C2077, 2014
www.the-cryosphere-discuss.net/8/C2073/2014/

The Cryosphere Discussions
Open Access

Interactive comment on "Thermal structure and basal sliding parametrisation at Pine Island Glacier – a 3-D full-Stokes model study" *by* N. Wilkens et al.

S. L. Cornford (Referee)

s.l.cornford@bristol.ac.uk

Received and published: 14 October 2014

1 General comments

The paper investigates basal traction laws based on measured bed roughness for PIG, studying them using a rather sophisticated new Stokes model. A typical PIG flow experiment finds the basal traction $\vec{\tau_b}$ through an inverse problem and then assumes a physical law of the form $C\vec{\tau_b} = u^{m-1}\vec{u}$ for use in prognostic simulations, holding $C(x, y)$ constant in time. The authors compare this conventional kind of approach with two roughness based laws, with the roughness derived from measurements (measured along flight lines and extended to the whole region). The resulting C would still be constant in time (unless some roughness evolution model was added), but its time independence would have some more physical justification.

If the model had reproduced all the features of the flow using these measurements, this would support the conventional approach, but perhaps supplant it. However, the model does not reproduce the observations as well as it does with an inferred C (even when the inversion, as in this paper, is not as sophisticated as elsewhere) and so the authors find that C is not just a function of roughness but other fields that are not observed – which could include roughness at the scales below those measured, or other physics, including physics that could evolve on short – such as basal hydrology. Nonetheless, the paper shows that many of the flow features can be accounted for by measured roughness, so that the proposed laws could form part of more complex laws, and I suggest could be directly useful in, for example, paleo ice stream simulations where the ice has gone but bed roughness data might be available.

The friction laws themselves are presented are in the results section, but I think they are more important to this paper than the description of the Stokes model, so should be described earlier. I also think that the sections describing the laws need some revision, in particular the manuscript needs to summarize the way in which the one-parameter roughness was measured (inferred from airborne radar, in Rippin 2011, estimated to be sensitive to roughness wavelengths > 500 m), and explain the calculation of the two-parameter roughness in more detail.

At the same time, a temperature distribution is estimated. This is a useful result on its own.

TCD
8, C2073–C2077, 2014

Specific comments

L10: Some inverse problems seek effective viscosity (or some equivalent) as well as or instead of a basal friction coefficient in some inverse problems. Especially in the ice shelf, but to some extent in shear margins, effective viscosity determines the flow. This is mentioned in the discussion.

P4916 : 'Changes in basal conditions, by for example grounding line migration (Park et al., 2013), subglacial erosion (Smith et al., 2012; Rippin et al., 2014) or dynamic hydraulic systems, can not be considered with this approach. '

I agree that subglacial erosion or evolving hydrology defeat a inverted C that is constant in time, but I don't think that is true for grounding line retreat – the evolution of C (becoming zero in newly grounded regions) is straightforward in that case.

2.3.2.

Temperature transport includes strong advection, but you don't say whether this affects your numerical scheme (you just say that you use linear elements) Do you ensure the local Peclet number is always low by choosing a mesh, or add artificial diffusion, or use DG methods, or something else?

You say that all Dirichlet conditions are implemented as weak constraints. Does this mean you are adding a source term S to the equations on the basal face along the lines of $S = a(T_0 - T)$, so that as $a \to \infty$ the solution approaches $T_0 = T$. If so, you are actually implementing a Robin condition (which is fine).

Your heat flux condition looks like a softening of the step change around $T_{b,max}$, did you have problems with a sharp step?

TCD

8, C2073–C2077, 2014

Interactive Comment

2.3.3

I don't think that the aspect ratio requires an unstructured mesh (and indeed, several models use structured or block-structured meshes). Even the need for fine horizontal mesh resolution near the grounding line / shear margins is a little contentious, for example you might use high order elements instead. The figure looks as though you have extruded a 2D mesh of triangles vertically to get prisms with a vertical extent that varies only with thickness, (in which case you have structure in the vertical direction). That could be because we can't see into the mesh - maybe you have finer vertical resolution in the regions with finer horizontal resolution. If so, is it possible to make a cut into the mesh figure to show that?

2.3.4

Which direct linear solver: MUMPS? UMFPack ? A citation might be in order. I think this paragraph could do with some attention, although the meaning is clear to me, the grammar is a bit awkward. Especially, you say that you use a directed segregated solver which solves iteratively, which sounds self-refuting. I think that what you do is a kind of quasi-Newton iteration to solve a non-linear problem in u, p, T where you 1. Choose initial u^*, p^*, T^*, 2. Use u^*, p^*, T^* to define a linear system which is solved directly to get u, p 3. use u, p, T^* to define a linear system which is solved directly for T 4. Set $u^*, p^*, T^* \leftarrow u, p, T$ and repeat 2-3 until your error estimate is small.

3.3.2

Figure 5 could be replaced (or complemented) with a map of differences. With fig 5 as it is, you have to point out that the differences are exaggerated at low speeds and suppressed at high velocities, given the choice of log axes, which you need because so

TCD

8, C2073–C2077, 2014

Interactive Comment

much of the glacier is slow. At the same time, there are maps to compare your results with in e.g Morlighem 2010. The same goes for figures 8 and 11.

Technical corrections

L8: Dependend → Depending

2.2.2 Stokes → Stress, or velocity

p4923, L18 :The temperature is *solved for* with linear elements : → discretized

p4925, L9 : 'The basis data A. Le Brocq used are for the surface elevation from Bamber et al. (2009), which combines satellite radar and laser measurements. The ice thickness data is from Vaughan et al. (2006).' could be something like 'The Le Brocq data are based on the the surface elevation data of Bamber et al. (2009) and the ice thickness data of Vaughan et al. (2006)'.

Interactive comment on The Cryosphere Discuss., 8, 4913, 2014.