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The Cryosphere Discussions

Interactive comment on "Manufactured analytical solutions for isothermal full-Stokes ice sheet models" *by* A. Sargent and J. L. Fastook

A. Sargent and J. L. Fastook

asarge21@maine.edu

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We thank both referees for their constructive comments and corrections. The modifications suggested by the referees have been taken into account in the new proposed version of our paper. Bellow, we answer each point that was raised and indicate corrections made in the new version of the manuscript.

Referee O. Sergienko

Detailed comments

We agree with the comment that the choice of pressure in the form of Eqns (53) and (83) implies that exact solutions of the Stokes equations are such that horizontal divergence of the vertical shear stress components is zero. It is an interesting idea to use

this constraint to find the form of the specific solutions of the original Stokes equations. We were not able to do it.

Regarding the question whether the constructed solutions can be used to test the prognostic equation, the answer is following.

2-D manufactured solutions (48)-(49) satisfy the prognostic equation obtained by integrating the mass conservation equation along the vertical dimension: $\frac{\partial h}{\partial t} = \dot{a} - \frac{\partial}{\partial x}\left[\int_b^s u dz\right]$.

3-D manufactured solutions (80)-(82) do not satisfy the prognostic equation, they satisfy equation $\frac{\partial h}{\partial t} = \dot{a} - \frac{\partial}{\partial x}\left[\int_b^s u dz\right] - \frac{\partial}{\partial y}\left[\int_b^s v dz\right] + \Sigma_{prog}$, where $\Sigma_{prog} = -\frac{h'_y}{h^2}\int\left\{c_x\lambda_1\frac{\gamma_1+1}{\lambda_1+1}h'_x h^{\gamma_1+1} + \left(\frac{\partial s}{\partial t} - \dot{a}\right)h\right\}dy = -\frac{h'_y}{h^2}\int\left\{h\left[\frac{\partial h}{\partial t} - \dot{a} + \frac{\partial}{\partial x}\left(\int_b^s udz\right)\right]\right\}dy$. Although $\Sigma_{prog} \neq 0$, $\lim_{t\to\infty}\Sigma_{prog} = 0$. Thus, we agree that for 3-D problems, the solutions are limited to testing the codes solving the velocity equations only (unless a compensatory term Σ_{prog} is added to the prognostic equation) while 2-D solutions can be used to test the numerical codes with the prognostic equation included.

Technical comments

A statement about anti-correlation of the horizontal ice velocity and ice thickness for a 2-D steady-state solution has been added because the ISMIP-HOM experiments demonstrated that such behavior was predicted only by full-Stokes models and only for the smallest length scale $L = 5\,km$. "All the other approximations (LMLa, LTSML, L1L2 and L1L1) predict that ice velocity and thickness are positively correlated for all length scales" (pattyn, 2008, p. 102).

Text font size in all figures has been increased, vertical and horizontal dimensions and units have been added to all color-map figures, and number of labels on color bars has been reduced and their size has been increased.

All figures show dimensional parameters.

The Fortran script has been removed from the manuscript and added as a supplemental file.

Anonymous Referee $\#$ 1

Detailed comments

Size of all figure-annotations has been increased. We have also included units ([-] if non-dimensional).

Other issues:

All sliding conditions were renamed from a Newmann condition to a Robin condition.

We agree with the referee that for the Dirichlet condition problem the pressure $\tilde{p}$ cannot be set along a whole lateral boundary. This has been changed - the pressure boundary conditions can be set on only one side of $x-$ and one side of $y-$ lateral boundaries.

We agree with the referee that the limit $s \rightarrow b$ may cause an issue and should be taken into account in generating a particular solution. To avoid this issue all specific solutions in this work, which are defined by setting ice bed and surface evolution functions b and s, has been chosen such a way that the difference $s - b \geq 500\,m$ everywhere in the domain.

The implication of an explicit dependency of accumulation/ablation rate on the vertical coordinate, which would introduce an additional contribution $-\frac{\partial \dot{a}}{\partial z} \frac{z-b}{s-b}$ in equation (31), would be an additional contribution $+\frac{1}{s-b} \int \frac{\partial \dot{a}}{\partial z}(z-b)dx$ to the solution $u(x,z,t)$ in (48).

F77-code has been put into supplement.

The paper by O. Gagliardini and T. Zwinger has been referenced.

Interactive comment on The Cryosphere Discuss., 4, 495, 2010.