**The Cryosphere
Discussions**

# *Interactive comment on* "Analytical analysis of small-amplitude perturbations in the shallow ice stream approximation" *by* G. H. Gudmundsson

G. H. Gudmundsson

Received and published: 7 May 2008

I found both of the reviews to be very helpful and I like to thank the reviewers for their work and the editor for his work in obtaining the reviews.

## Answers to issues raised by C. Raymond

C. Raymond addresses the very interesting question of the relative importance of form drag versus skin drag as a function of wavelength. In the theoretical treatment that I use skin drag is ignored. C. Schoof looked into this issue JG 48(162) 2002. I also investigated the effects of skin drag numerically together with my coo-author M. Raymond (JGR, 101, 2005, doi 10.1029/2005JB00368). C. Schoof concludes that form drag is not significant on ice streams and M. Raymond and I found skin drag not to significantly affect the bed-to-surface transfer characteristics. However I do feel that C.

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Raymond raises a very important issue that needs to be addressed in more detail in the future. I say this because C. Schoof's treatment does not take into account the form drag of long wavelengths, and in my own numerical treatment of this problem form drag was not explicitly calculated. Again, in this work there is no possibility of assessing the importance of form drag because the perturbations do not affect the datum flow. I've added a short discussion of C. Schoof paper on form drag.

C. Raymond suggested a number of improvements to the text and I've done almost all of the changes as suggested.

- time history and the reasons for selecting it explained in more detail

- references to FS solutions added.

- values of exponents n and m are now given in all captions

- discussion about low dependency of Tsb on m improved.

- Expression for Tuc for transverse perturbations listed and compared to similar expressions in Raymond, JG 42(140) 1996

- wording in figure caption 10 improved as suggested.

**Answers to issues raised by C. Schoof**

The slip ratio is of course $O(\delta^{-2})$. This is explained in the appendix. There was one typo in the paper were it was stated incorrectly that it was $O(\delta^{-1})$ and I am thankful for C. Schoof to spot this.

I like the suggestion of C. Schoof of plotting the transfer functions as functions of C for a fixed wavelength. I think in combination with numerical studies such a plot would indeed be very useful.

I do not understand C. Schoof comment that the domain of the shallow stream problem does not need to be transformed. This must be done for the boundary conditions to be applied at the actual deformed upper surface.

The use of the Laplace transform is as far as I can see not 'superfluous'. The Laplace transform is used to solve the transient problem and the contour integration gives the time-dependent solution. The Fourier transform is only done with respect to the $x$ and $y$ spatial variables.

C. Schoof feels that the paper is too complicated to those not familiar with the use of perturbations methods, and not detailed enough for those who are. I disagree with him on this point. I've had considerable response to the paper already and a few modellers who usually do not bother reading papers with equations are now busy using the theory to test their models. I've also used an earlier manuscript of the paper while teaching a course on glacier mechanics to graduate students at the univ. of Utrecht. The students found the paper very straightforward to understand and the level of mathematical detail give sufficient to follow all the steps in the derivations of the transfer functions.

- p. 38, l. 10: I clarified for what value of slip ratio the statement refers to.

- p. 40, l. 19: Changed wording as suggested.

Greetings

G. Hilmar Gudmundsson

Interactive comment on The Cryosphere Discuss., 2, 23, 2008.