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The Cryosphere
Discussions

Interactive comment on "Surface undulations of Antarctic ice streams tightly controlled by bedrock topography" *by* J. De Rydt et al.

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Re Specific Points:

1. The linear transfer theory neglects surface accumulation, as the referee correctly points out. A significant surface accumulation can invalidate the first order approximation of an undisturbed flow along an infinite plane slab geometry. However, we think this is not an issue here. In order to motivate our use of the linear theory, we included the radar profiles of the surface and bed geometry along all flightlines (see figure 1 here included), as well as the surface velocities (see figure 2 here included). In Figure 1 we depict the plane slab approximations used in this study by dashed blue lines. It can be seen that the mean state is a reasonable approximation for all profiles, with the mean amplitude of the deviations Δs smaller than $0.01H$ and the mean amplitude of Δb between $0.035H$ and $0.24H$. Locally Δb can be up to $0.6H$ for E10, and $0.7H$ for E11 and E12, but only for a small fraction of the profile length. In addition, it should be noted that in the case of a linear rheology, the transfer functions can be used reliably for undulations with amplitudes up to one half of the mean ice thickness, as pointed out by (Raymond and Gudmundsson, 2005).

   On the other hand, from Figure 2 it is clear that most profiles (C1-C5 and E2, E5 and E6 being exceptions) show a significant large-scale variability in surface speed, with speeds gradually increasing towards the grounding line. This can be explained by several a priori indistinguishable mechanisms, including surface accumulation as suggested by the referee. Other possible factors are large-scale changes in basal sliding and/or lateral confinement of the ice stream. As a result, the mean slip ratio varies significantly along most profiles, and the use of one mean value along the entire profile is indeed questionable. However, the main aim of our work is to show that for high enough values of the slip ratio (i.e., $C^{(0)} \gg 1$), the transfer function develops a local maximum, as predicted by theory. Despite the large variability of $C^{(0)}$ along individual radar profiles, its value is always significantly larger than unity along the entire length of the fast flowing Rutford and Evans ice streams, and hence a local maximum is expected. This is confirmed by the observations.

2. There are some clear differences in the flow behavior between an ice mass encountering a topographic feature at the bed, and ice encountering a change in basal slipperiness. The most important differences are summarized in Figures 1 and 2 of (Gudmundsson, 2003), where the flow over a Gaussian bedrock and slipperiness perturbation is simulated. Generally speaking, the response is much larger in the former case, intuitively because the ice has to physically flow over and around the obstacle. This results in a more localized response and hori-

zontal and vertical speeds that are generally an order of magnitude larger than for the basal slipperiness perturbation. In the latter case, the response tends to spread out more, changes in velocities are lower, and as a result, the surface response is much less pronounced. In terms of transfer functions from the bed to the surface, this translates into an amplitude which is much reduced for basal slipperiness perturbations as compared to bedrock perturbations, intuitively explaining the absence of a maximum in the former case.

3. This has been addressed in 1.

4. The suggested relationship in section 5.2 between a low power in the basal spectrum and suppression of the transfer function is a hypothesis which needs to be tested. We have presented a synthetic model similar in length and spatial resolution to the radar sections in this study, and synthetic results support the hypothesis of a reduced transfer for frequencies with a low basal spectral power. However, no significant evidence for this mechanism was found in our radar data, i.e., there is no significant correspondence between minima in the basal power spectrum and minima in the transfer function. Hence this explanation is unsatisfactory, as has been pointed out at the end of section 5.2, and the exact origin of the multiple maxima in the transfer function remains unexplained. In a new version of the manuscript we will add a few sentences to bring further attention this point.

5. In the theoretical treatment, no a priori spatial correlation between basal slipperiness and bedrock perturbations is assumed. Their distribution is therefore arbitrary, and a potential correlation would not alter the transfer amplitudes as a function of wavelength. The fact that a peak in the bed-to-surface transfer is observed for the profiles in this study, confirms that the basal topography has an important impact on the surface properties of these ice streams. It does not rule out the existence of local variations in basal slipperiness though, and a spatial cor-

relation with bed topography cannot be excluded. However, Bayesian estimates of basal properties of the Rutford Ice Stream (Raymond-Pralong and Gudmundsson, 2003) have shown that no substantial local variations in basal slipperiness are required to explain surface properties.

6. The value 0.25 as mentioned in the manuscript is erroneous, and will be replaced by its correct value, 0.3.

Re Technical Points:

1. *Pg. 4491, line 25.* An additional reference to (Gudmundsson, 2003) will be added to the figure caption.

2. *Pg. 4496, line 10-13.* All necessary information is contained in the references. However, a good introductory treatment to the subject of transfer functions can be found in many textbooks on data processing, see e.g. (William H. Press et al., Numerical Recipes: The Art of Scientific Computing. Cambridge University Press, 3rd edition, 2007) for a methodological approach.

3. *Pg. 4497, line 13.* An few additional words about 3D effects will be included in the next version of the manuscript.

4. *Pg. 4502, lines 1-2.* This is a fair remark, although the synthetic results are based on the flow across a Gaussian bedrock perturbation, which could underpredict the estimated transfer as compared to a more realistic bedrock profile. This experiment shows that the presence of transverse wavelengths in the basal spectrum leads to a suppression of the surface response, but is not intended to quantify this effect.

5. *Pg. 4505, lines 12-13.* Point taken.

6. *Pg. 4505, line 24.* The optimal least-square fit value of 70% will be used.

7. *Fig.4 caption.* The average surface inclination for the mean states in this study is 0.004 rad. The chosen value $\alpha = 0.003$ rad has no specific meaning other than it is representative for the ice streams in this study.

Interactive comment on The Cryosphere Discuss., 6, 4485, 2012.

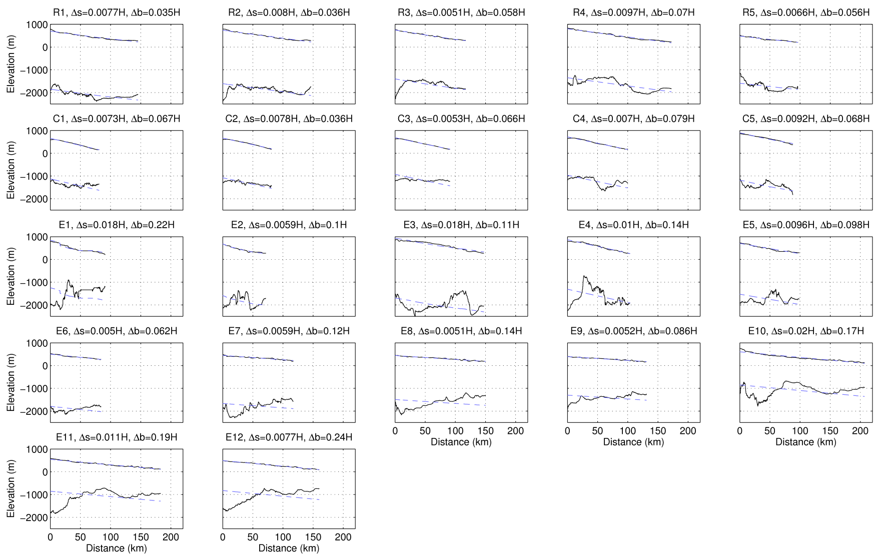

Fig. 1. Measured bed and surface radar profiles for all section in this study. The dashed blue lines determine the plane slab approximations.

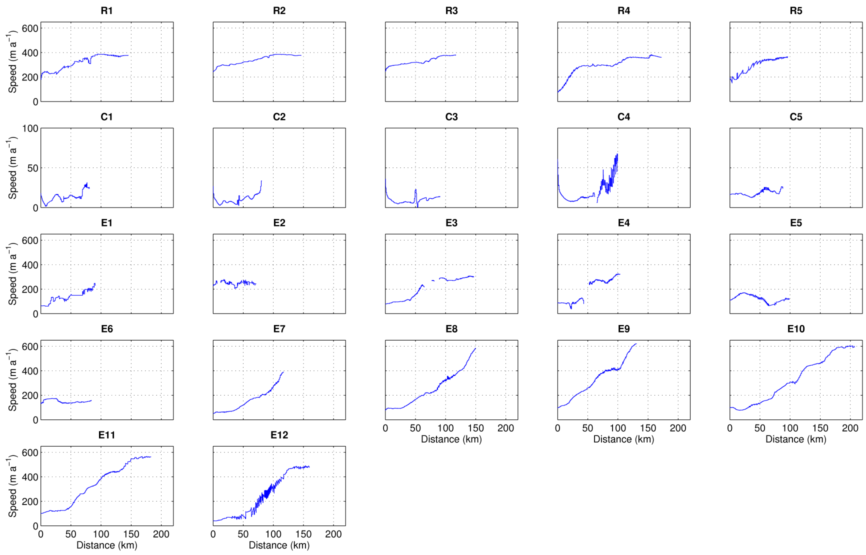

Fig. 2. Surface velocities. Note the different scale on the y-axis for profiles C1-C5.