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The Cryosphere Discussions

Interactive comment on "Modelling historical and recent mass loss of McCall Glacier, Alaska, USA" *by* C. Delcourt et al.

C. Delcourt et al.

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Reply to the interactive comments on "Modelling historical and recent mass loss of McCall Glacier, Alaska, USA", by C. Delcourt et al.

Reply to comments by J. Oerlemans

1. The major point that is raised here is the lack of the use of a 3D geometry in the model. Evidently this is a point that - from the moment the comment was posted on the TCD website - we investigated more closely and included in a new series of experiments. We opted for the common approach by taking into account width variations perpendicular to the flowline in the continuity equation for ice thickness, i.e. H_t = -1/W (UHW)_x + M (where the underscore stands for derivative). As such the model takes care of converging and diverging flow along the flowline. We therefore repeated

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all simulations with the inclusion of the width variations along the flowline. The results are therefore altered. Nevertheless, while there are quantitative differences, qualitatively there are less differences with respect to the initial manuscript, i.e. the relative importance of the different parameters in the forcing remain the same. As for the parameterization of the width factor, we adopted different approaches, i.e. the width variation for the main glacier along the flowline as well as in a combination with the lower cirque. The latter puts higher constraints on the divergence and convergence and give not realistic results. Even the difference in ice thickness in the confluence area between modeled and observed was not really solved. However, also for this type of experiment, the qualitative behaviour of the glacier retreat experiments was still valid. The main reason for this is that the confluence area is not a real confluence of two separate glaciers, but of only a cirque, which does not represent such a large surface, compared to the rest of the main glacier. Future work with a three-dimensional model of the glacier should shed more light on this. The changes to the model are corrected in the manuscript and in the data section as well as in the discussion we explained the effect of width variations and inclusion of the LC.

2. It was also clear that the discussion on the difference between the use of a higher-order model (HOM) and the SIA approach was lacking in the initial manuscript. This discussion is added now. In fact, one of the main reasons why the difference between both approaches is so small is not in relation to the use of simple basal sliding laws. Whenever basal sliding is introduced (and is a function of the basal shear stress) the influence is clearly there. However, one needs rather large contributions of basal sliding in order to have the difference accounted for. Furthermore, another factor that influences the difference between HOM and SIA is glacier bed topography. McCall Glacier has a relatively gentle topography and a distinct lack of an ice fall. A similar comparison of HOM and SIA models is made in Pattyn (2002, JGLAC) applied to the geometry of Haut Glacier d'Arolla. Also here, the basal topography is gentle and the difference between both models is limited in a time dependency. However, large differences in the velocity field between both types of models do occur when the velocity field is calcu-

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lated in a diagnostic way, since small changes in surface slopes will - according to SIA - result in large changes in velocity, while in reality longitudinal stresses must develop. Such approach is presented in Pattyn et al. (2005) for McCall Glacier, and was one of the reasons why we pursued with the HOM in this study. This discussion is now included in the paper and added to the conclusions. Similar conclusions were obtained by Leysingier-Vieli and Gudmundsson (2004), but in that paper only very simple glacier geometries were considered.

3. See 2.

Reply to comments by M. Pelto

1. Internal accumulation: the issue of internal accumulation has been addressed to by Rabus and Echelmeyer (1998, JGLAC) in which they make estimates of internal accumulation based on the observed difference between the total volume loss of the glacier determined from GPS surveys and mass balance measurements. The main reason why the ratio increases so rapidly is because in the same period the ELA increased and the accumulation area was reduced significantly. A thorough discussion on the subject is given at length in that paper. However, internal accumulation has especially an influence on the model for the historical part of the simulations, based on the estimates by Rabus and Echelmeyer. For higher elevations of ELA (predictions) the accumulation area is so small that the impact on the whole glacier is minimal. The graphs show this clearly: the effect of internal accumulation result in a longer glacier and thicker ice for the whole time series; but after 2005, thinning rates are similar to those from the other experiments.

2. Most of these comments are been corrected for in the manuscript. The reason for the overestimates of ice thickness in the model near the terminus are due to the fact that the simulated retreat of the glacier does not exactly follow the observed retreat. The largest discrepancies are therefore found near the terminus.

Reply to comments by T. Johannesson

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1. See reply to comments by J. Oerlemans

2. See partly the response to M. Pelto: the model experiments that include internal accumulation are most influenced by the historical impact of internal accumulation, following the estimates by Rabus and Echelmeyer. However, after 2005, and according to the ELA evolution, the accumulation area is so small that the internal accumulation has hardly any effect anymore on the overall glacier dynamics and the simulated retreat rates are therefore similar to those of other experiments. Evidently, refreezing will have an effect on the heat balance, which is the reason why the temperatures in the accumulation area were altered in such a way that by fixing the temperatures at the surface the ice column becomes more or less isotherm over its total thickness, conform to observations that stem from boreholes. We added a comment on this in the manuscript.

3. This section has been removed.

4. this is corrected for

5. see also reply to comments by J. Oerlemans

6. Minor corrections are accounted for in the manuscript.

Interactive comment on The Cryosphere Discuss., 1, 385, 2007.