Reviewer 1

Reviewer Point P 1.1 — I find the revised version of the manuscript much improved, and the additional figures and video are valuable. I still have serious doubts about the realism of such large velocities propagating on millennial timescales over such large distances into the ice-sheet interior. However, I would not be opposed to publication. The origin of Laurentide ice sheet surges is still an open question, and these results can provide further insight to the community. I only have one more general comment below that I would like to see addressed, as well as one very minor specific comment.

Reply: We are glad for the positive assessment from the reviewer of our revised manuscript.

Reviewer Point P 1.2 — I appreciate the reference to surging glaciers, and that such magnitudes of velocities (10s of kilometers per year) can be reached in reality. However, these glaciers span no more then several kilometers, not hundreds of kilometers, and the surges are usually seasonal. Thus, the analogy may break down. My doubts are further enhanced when looking at Figure 4 or Figure 6. The surface elevation of the ice sheet appears to become quite noisy, particularly at higher velocities. This is apparent in the curves of driving stress in the right-hand panels. I find this noise very unusual, as the ice sheet tends to act as a smoother to any perturbative stresses. In my experience, this is more indicative of numerical instability of the model. So I would ask that the authors confirm that this reflects a physical phenomenon as opposed to numerical noise. If it cannot be fully ruled out to be numerical, perhaps this is fine, but in either case, this surprising behavior should also be commented on somewhere in the text.

Reply: We agree that the modelling of the surges due to the high velocities are numerical challenging and impose high stability demands on the employed linear solvers. However, there is no evidence of numerical instability in either the stress balance solution or the ice thickness evolution solution in any of our simulations as both solvers always converge. The time stepping criterion in our PISM version is additionally even more stringent than in the base version to exactly avoid the situation raised by the reviewer. We have added a sentence to the revised manuscript that acknowldeges the numerical challenging nature of the Heinrich events. It reads: "The modelled high ice velocities and large velocity gradients during the surges pose a formidable challenge for the model numerics. However, in all presented simulations, solutions to the stress balance and ice thickness evolution equation always converge, confirming the robustness of our results."

Specific comments

Reviewer Point P 1.3 — L115-120: It would be more intuitive to frame this in the opposite way, by stating that "... basal sliding is further enhanced in regions where sediment is present ..."

Reply: Agreed. Changed accordingly.