Supplement to "**Rockglaciers on the move – Understanding rockglacier landform evolution and recent change from numerical flow modeling**

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Supplement

S1 Perturbation Experiments

12 scenarios for each rockglacier were developed assuming three different initial thermal states of each rockglacier (-2°C, -1.5°C and -1°C). A potential warming of 1°C was combined with four different scenarios concerning the material input resulting from the suggested temperature increase:

Model run	Creep Rate change	Accumulation change
1.4*A and 0*Acc	1.4*A	0*a_r
1.4*A and 0.4*Acc	1.4*A	0.4*a_r
1.4*A and 1*Acc	1.4*A	1*a_r
1.4*A and 2*Acc	1.4*A	2*a_r
1.7*A and 0*Acc	1.7*A	0*a_r
1.7*A and 0.4*Acc	1.7*A	0.4*a_r
1.7*A and 1*Acc	1.7*A	1*a_r
1.7*A and 2*Acc	1.7*A	2*a_r
2.7*A and 0*Acc	2.7*A	0*a_r
2.7*A and 0.4*Acc	2.7*A	0.4*a_r
2.7*A and 1*Acc	2.7*A	1*a_r
2.7*A and 2*Acc	2.7*A	2*a_r

The following presents the evolution of surface along central flow line, thickness, thickness change and horizontal velocities of all experiments for the modelled time and both rockglaciers.

S1.1 Murtèl perturbation experiments

S1.1.1 Initial rockglacier temperature -2°C, therefore 1.4*rate factor A for a 1°C warming.

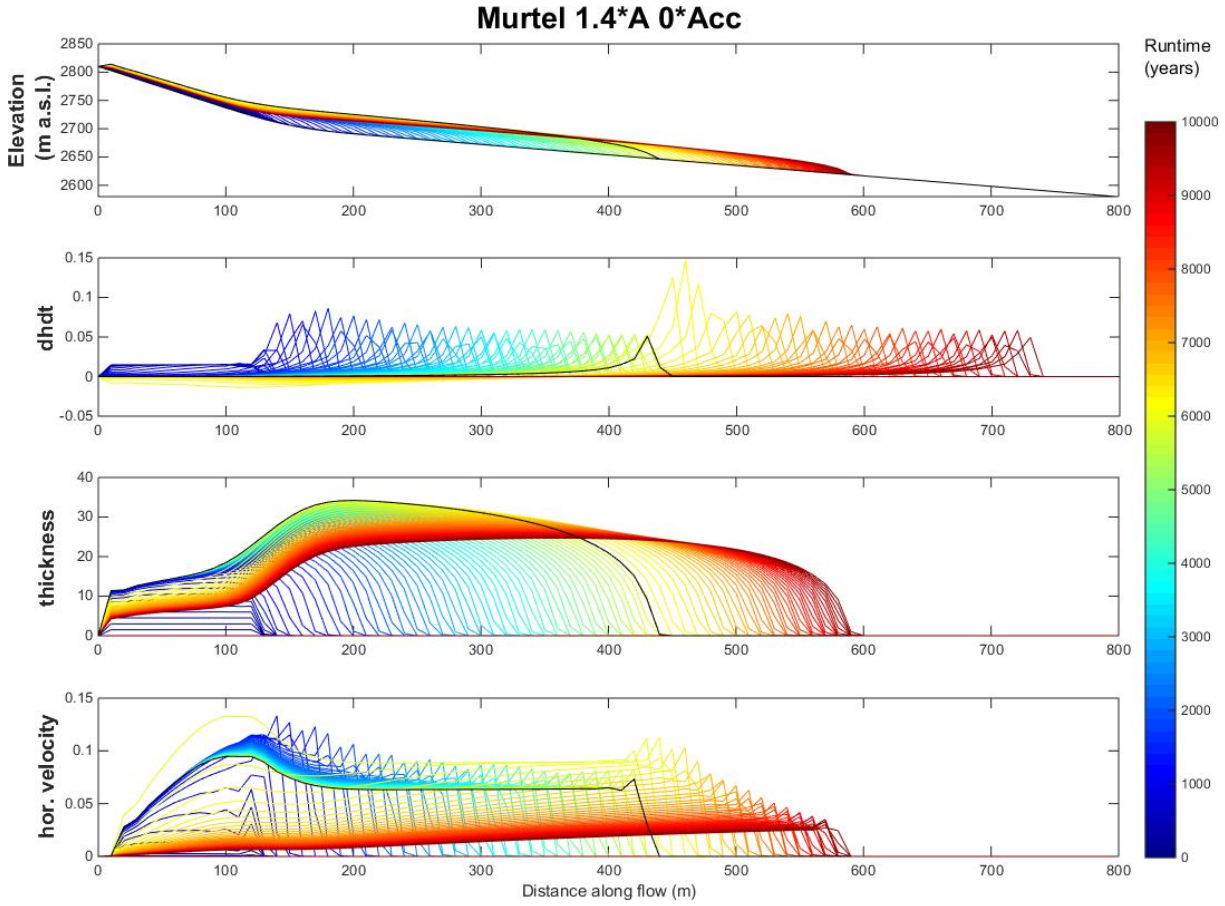


Figure S1: The evolution of surface geometry, thickness change (dhdt) absolute thickness in m horizontal velocity along the central flow line for rockglacier built-up (6000 years runtime / black line) and complex perturbation experiment (temperature increase of 1°C for a -2°C rockglacier and no material input after 6000 years). The lines are plotted in 100yr steps. Colour scale applies to all following Figures.

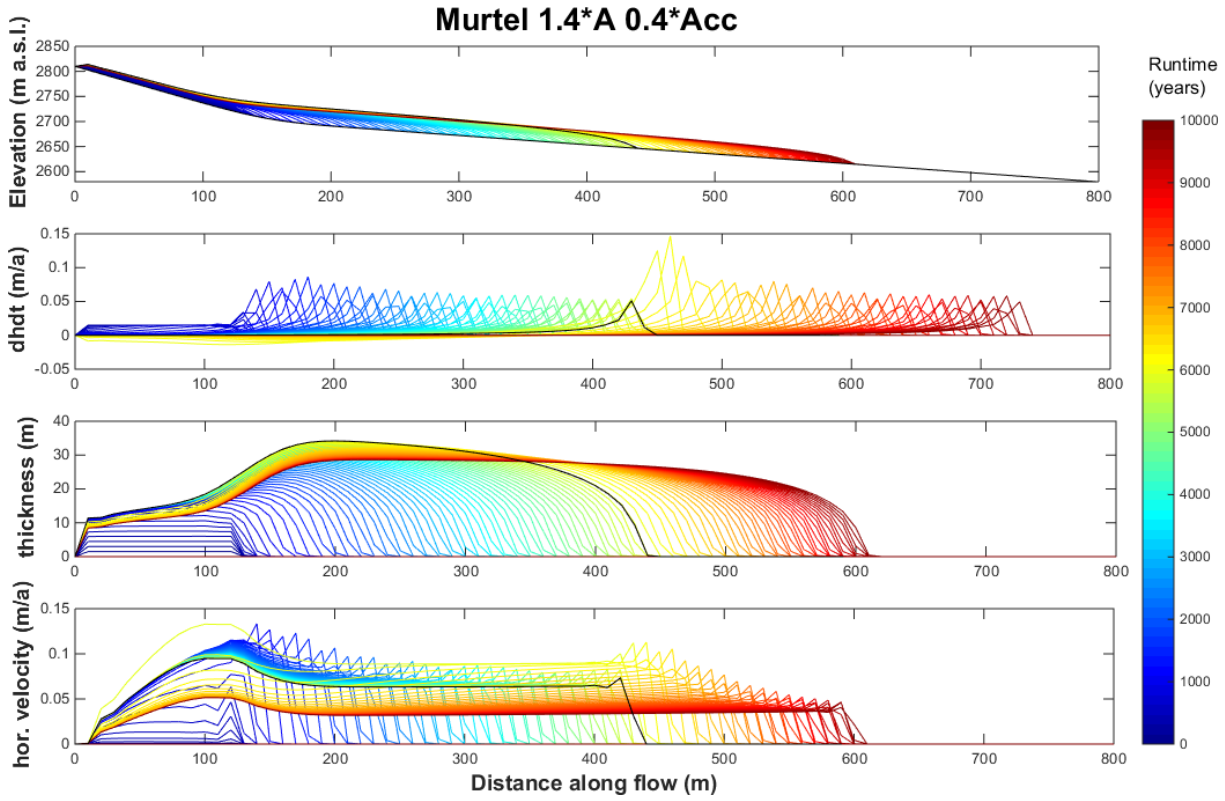


Figure S2: The evolution of surface geometry, thickness change (dhdt) absolute thickness in m horizontal velocity along the central flow line for rockglacier built-up (6000 years runtime / black line) and complex perturbation experiment (temperature increase of 1°C for a -2°C rockglacier and reduced material input (40%) after 6000 years). The lines are plotted in 100yr steps. Colour scale applies to all following Figures

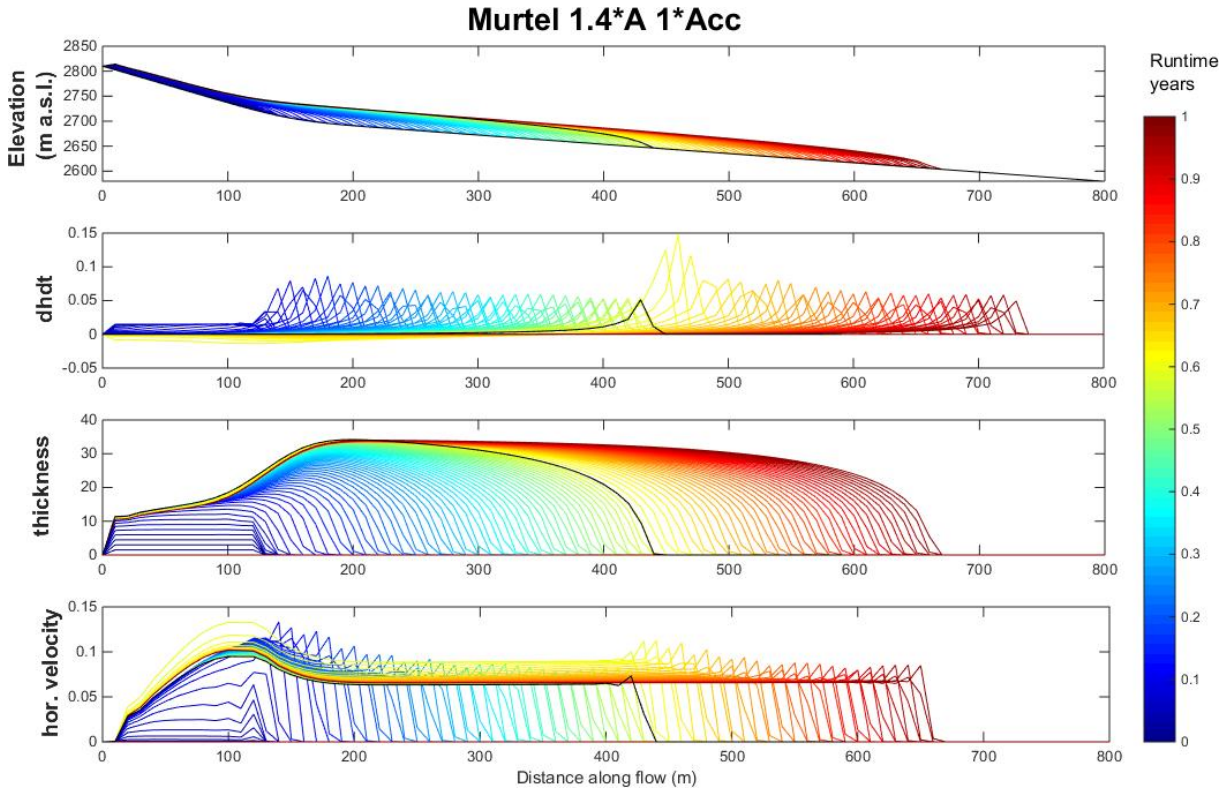


Figure S3: The evolution of surface geometry, thickness change (dhdt) absolute thickness in m horizontal velocity along the central flow line for rockglacier built-up (6000 years runtime / black line) and complex perturbation experiment (temperature increase of 1°C for a -2°C rockglacier and no change in material input after 6000 years). The lines are plotted in 100yr steps.

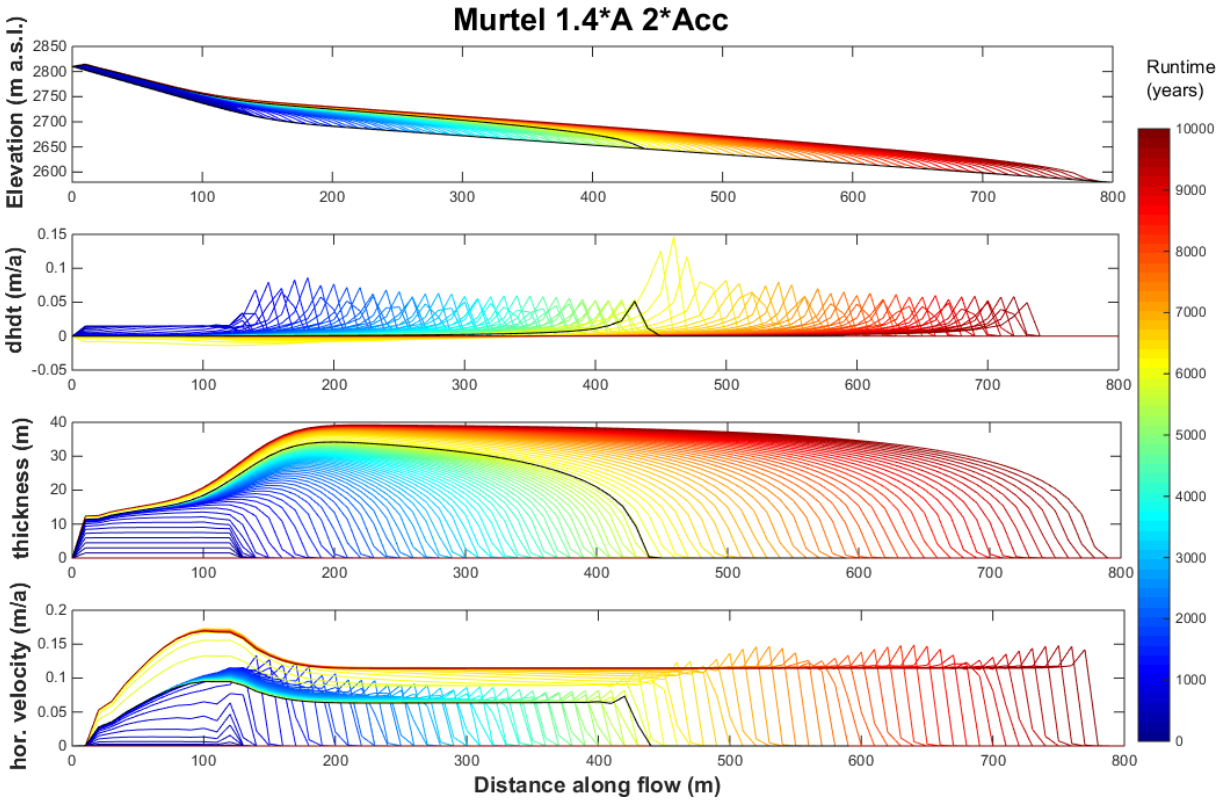


Figure S4: The evolution of surface geometry, thickness change (dhdt) absolute thickness in m horizontal velocity along the central flow line for rockglacier built-up (6000 years runtime / black line) and complex perturbation experiment (temperature increase of 1°C for a -2°C rockglacier and doubled material input after 6000 years). The lines are plotted in 100yr steps.

S1.1.2 Initial rockglacier temperature -1.5°C, therefore 1.7*rate factor A for a 1°C warming.

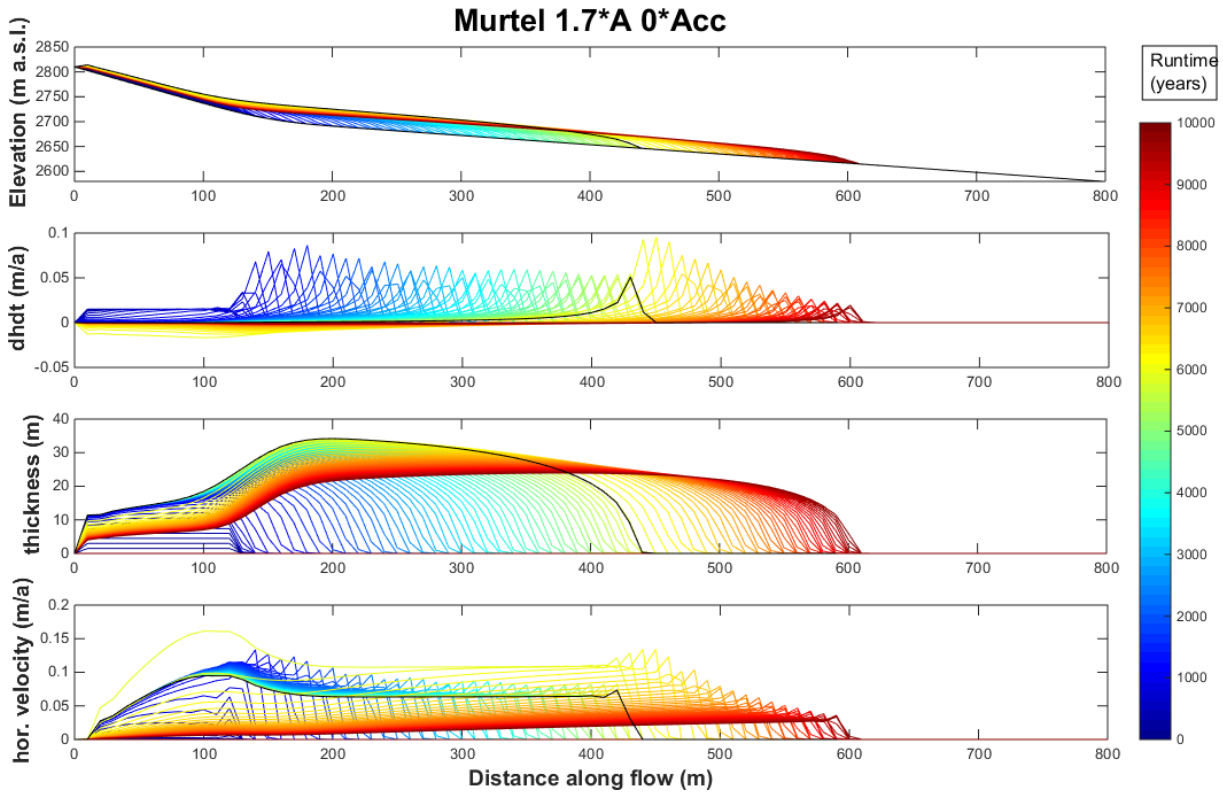


Figure S5: The evolution of surface geometry, thickness change (dhdt) absolute thickness in m horizontal velocity along the central flow line for rockglacier built-up (6000 years runtime / black line) and complex perturbation experiment (temperature increase of 1°C for a -1.5°C rockglacier and no material input after 6000 years). The lines are plotted in 100yr steps.

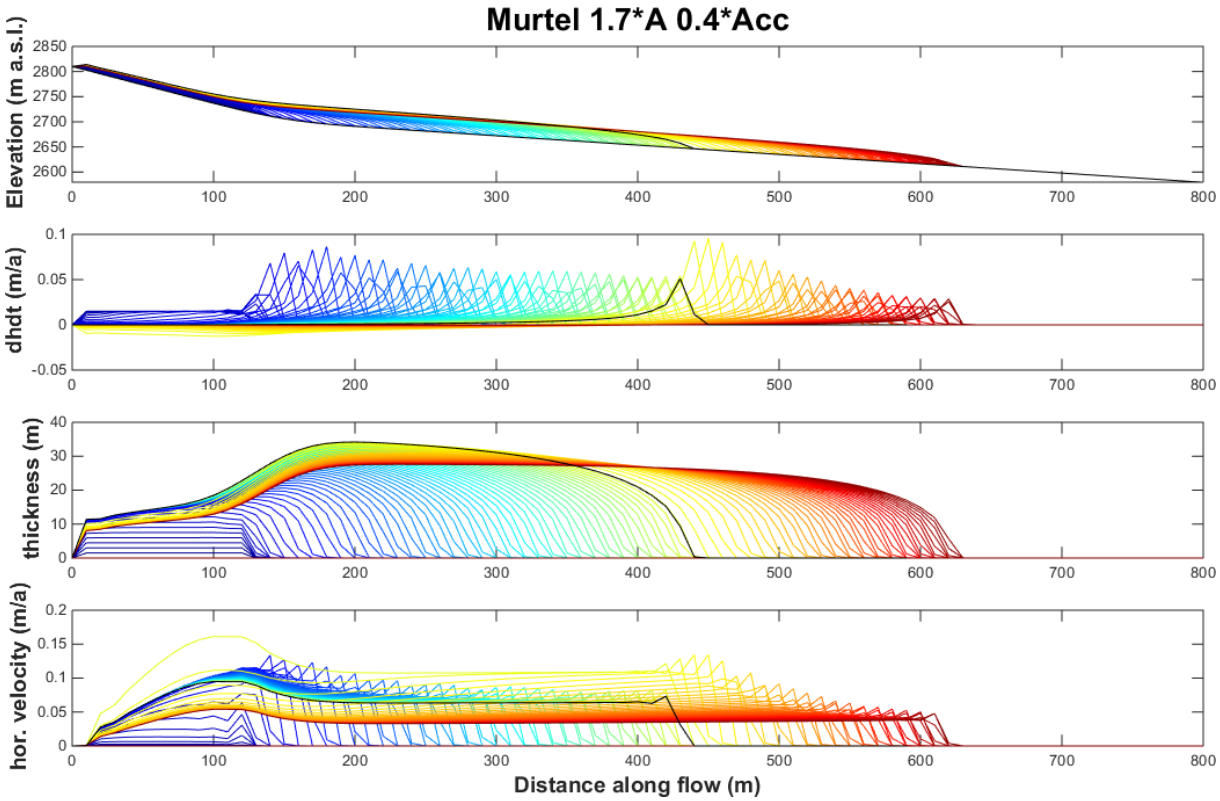


Figure S6: The evolution of surface geometry, thickness change (dhdt) absolute thickness in m horizontal velocity along the central flow line for rockglacier built-up (6000 years runtime / black line) and complex perturbation experiment (temperature increase of 1°C for a -1.5°C rockglacier and reduced material input (40%) after 6000 years). The lines are plotted in 100yr steps. Colour scale applies to all following Figures

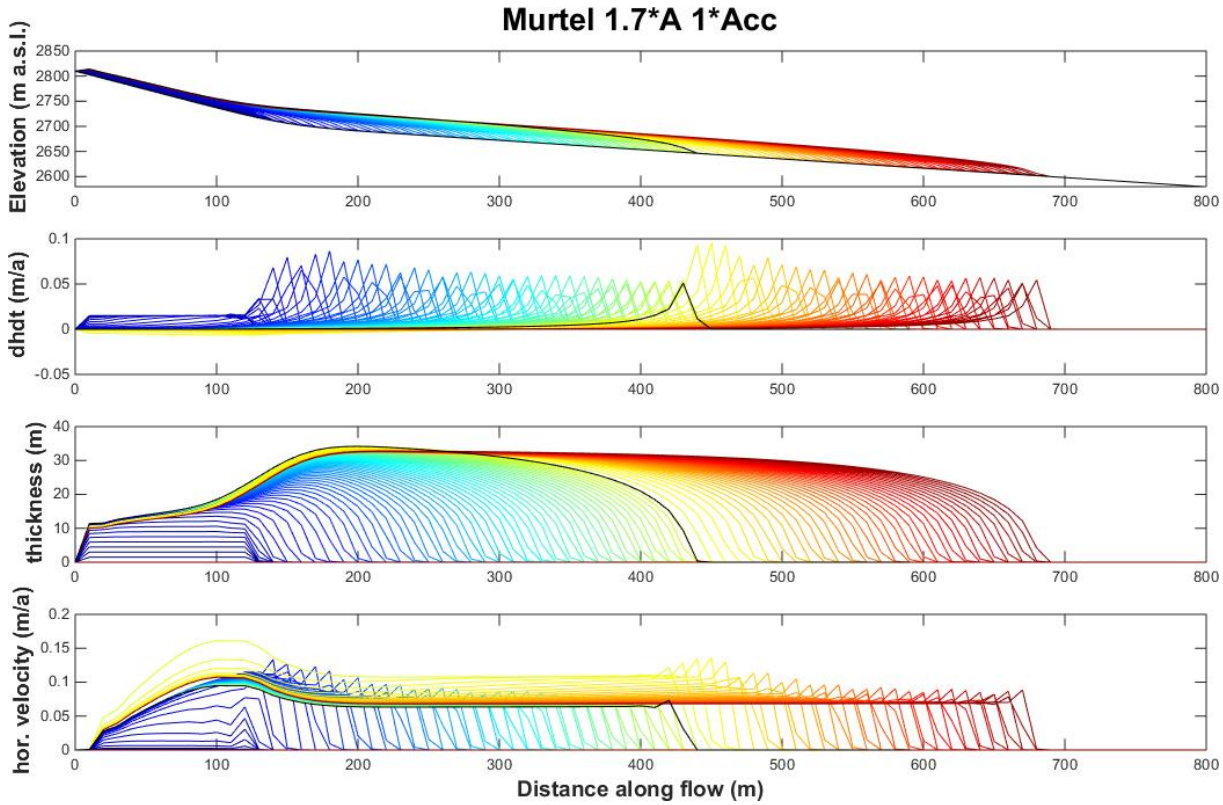


Figure S7: The evolution of surface geometry, thickness change (dhdt) absolute thickness in m horizontal velocity along the central flow line for rockglacier built-up (6000 years runtime / black line) and complex perturbation experiment (temperature increase of 1°C for a -1.5°C rockglacier and no change in material input after 6000 years). The lines are plotted in 100yr steps.

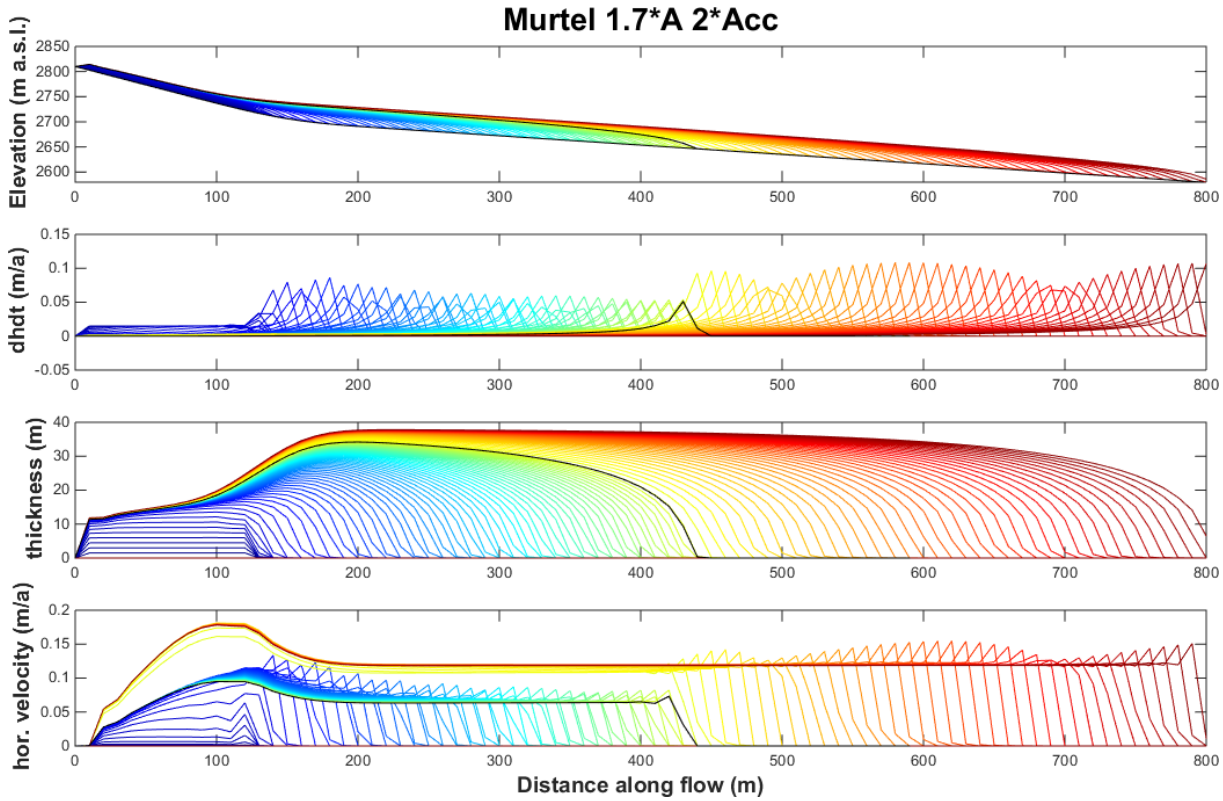
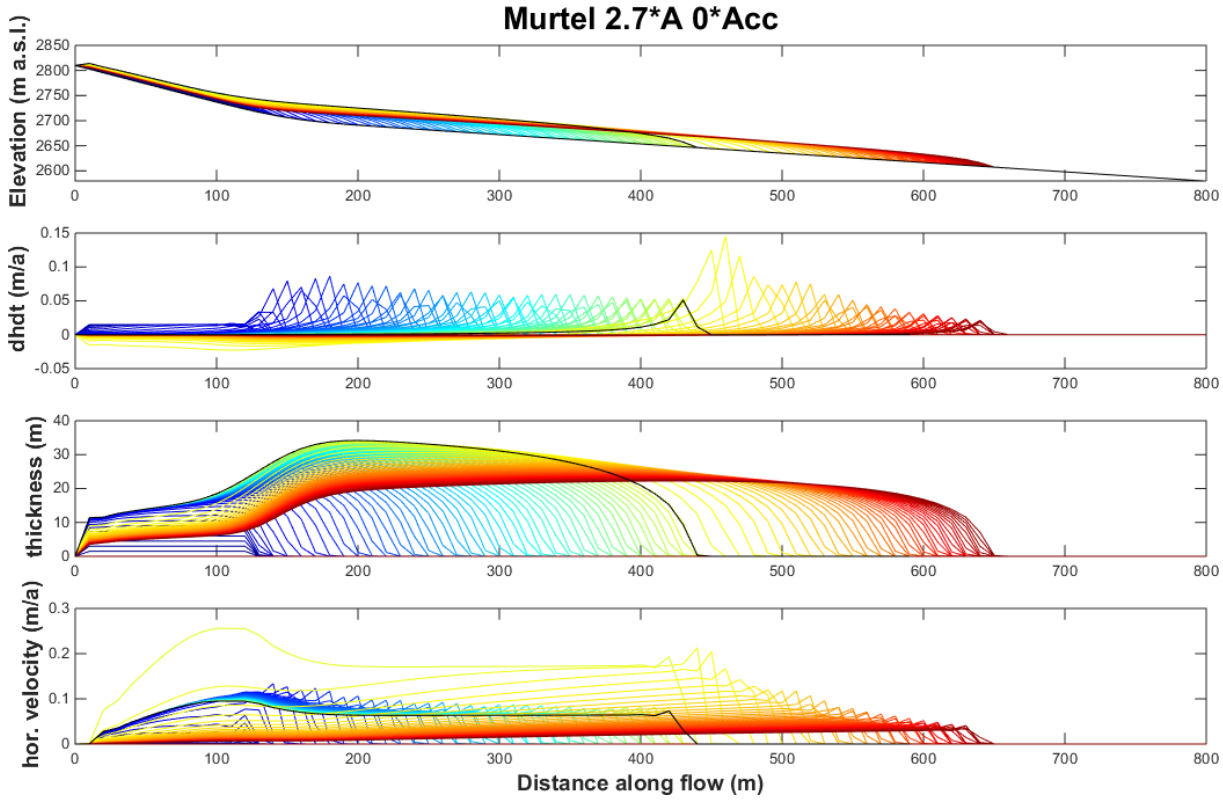


Figure S8: The evolution of surface geometry, thickness change (dhdt) absolute thickness in m horizontal velocity along the central flow line for rockglacier built-up (6000 years runtime / black line) and complex perturbation experiment (temperature increase of 1°C for a -1.5°C rockglacier and doubled material input after 6000 years). The lines are plotted in 100yr steps.

S1.1.3 Initial rockglacier temperature -1°C, therefore 2.7*rate factor A for a 1°C warming.



Figre S9: The evolution of surface geometry, thickness change (dhdt) absolute thickness in m horizontal velocity along the central flow line for rockglacier built-up (6000 years runtime / black line) and complex perturbation experiment (temperature increase of 1°C for a -1°C rockglacier and no material input after 6000 years). The lines are plotted in 100yr steps

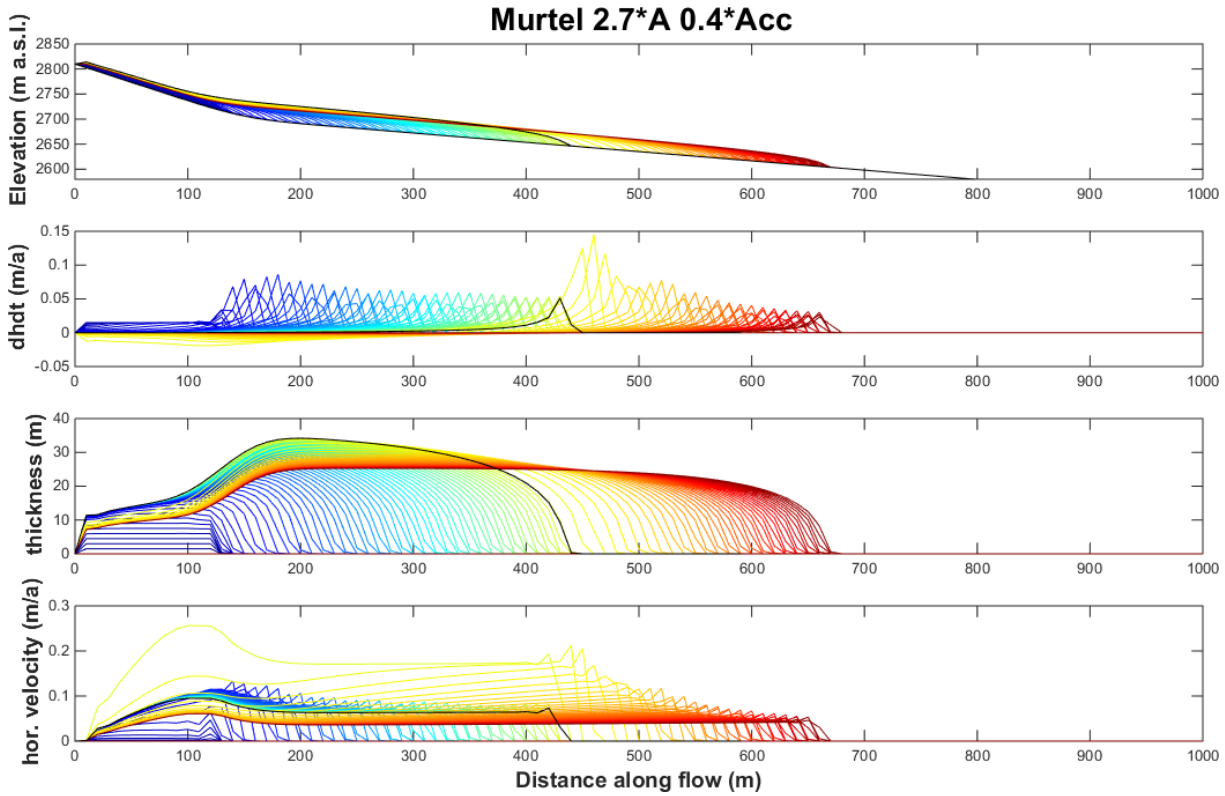


Figure S10: The evolution of surface geometry, thickness change (dhdt) absolute thickness in m horizontal velocity along the central flow line for rockglacier built-up (6000 years runtime / black line) and complex perturbation experiment (temperature increase of 1°C for a -1°C rockglacier and reduced material input (40%) after 6000 years). The lines are plotted in 100yr steps. Colour scale applies to all following Figures

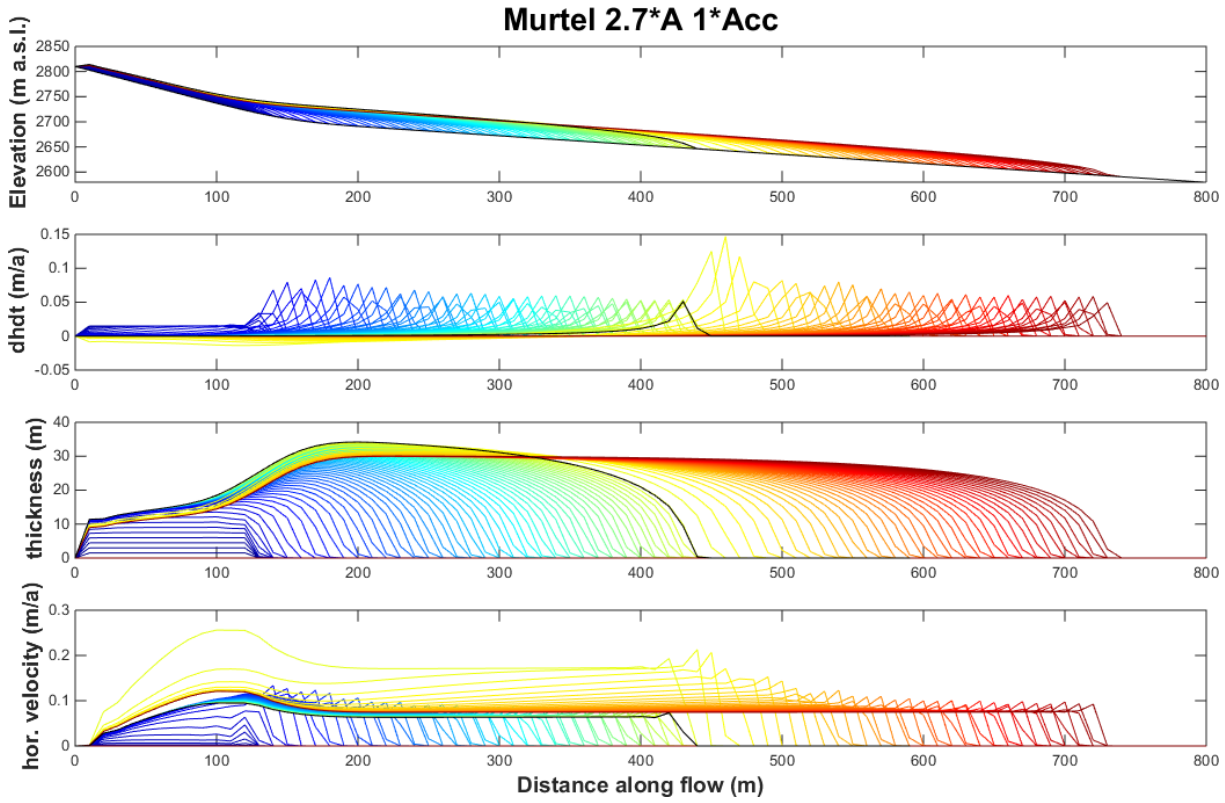


Figure S11: The evolution of surface geometry, thickness change (dhdt) absolute thickness in m horizontal velocity along the central flow line for rockglacier built-up (6000 years runtime / black line) and complex perturbation experiment (temperature increase of 1°C for a -1°C rockglacier and no change in material input after 6000 years). The lines are plotted in 100yr steps.

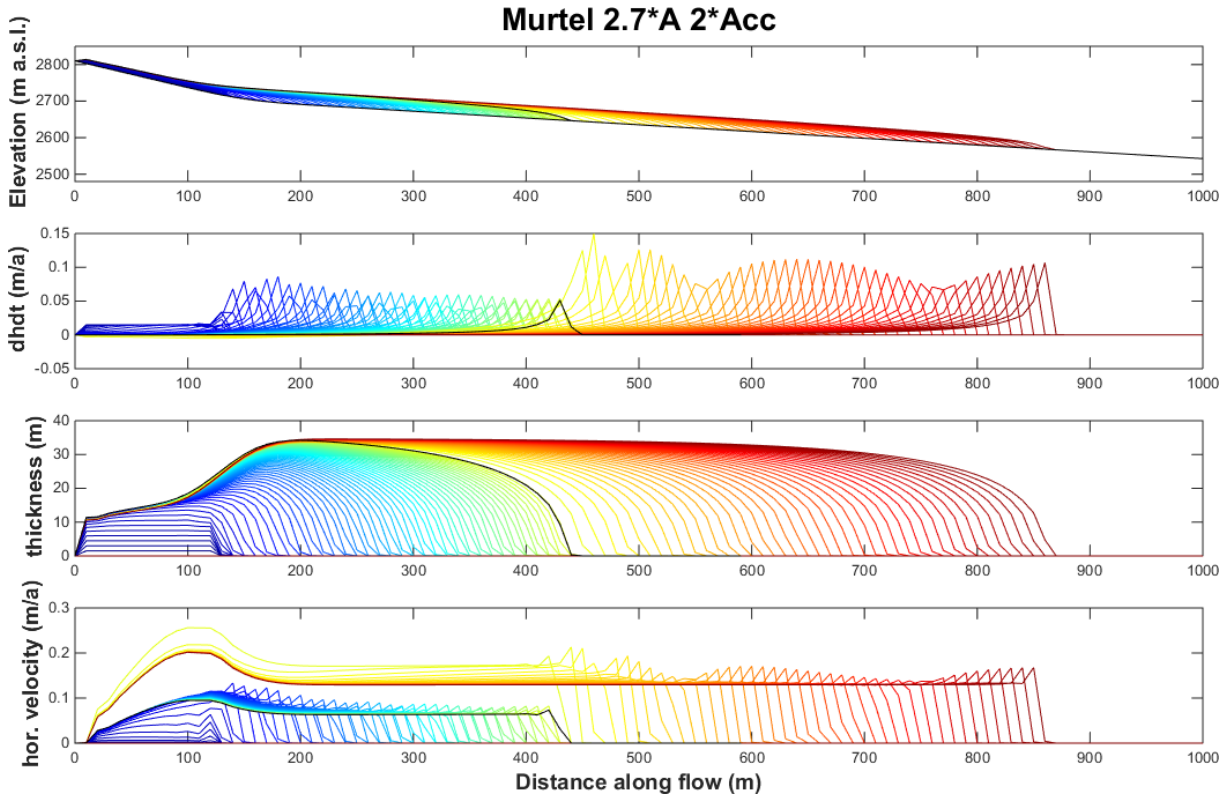


Figure S12: The evolution of surface geometry, thickness change (dhdt) absolute thickness in m horizontal velocity along the central flow line for rockglacier built-up (6000 years runtime / black line) and complex perturbation experiment (temperature increase of 1°C for a -1°C rockglacier and doubled material input after 6000 years). The lines are plotted in 100yr steps.

S1.2 Huhh1 perturbation experiments

S1.2.1 Initial rockglacier temperature -2°C, therefore 1.4*rate factor A for a 1°C warming.

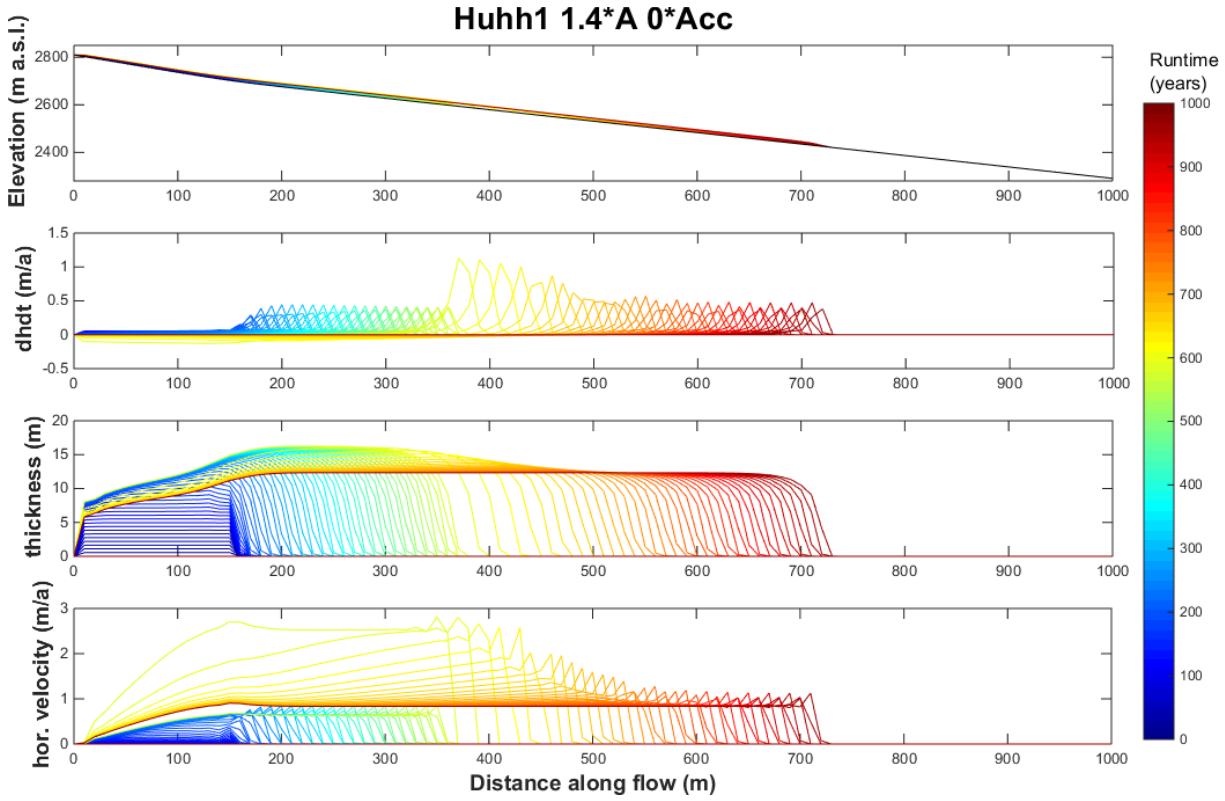


Figure S13: The evolution of surface geometry, thickness change (dhdt) absolute thickness in m horizontal velocity along the central flow line for rockglacier built-up (600 years runtime) and complex perturbation experiment (temperature increase of 1°C for a -2°C rockglacier and no material input after 600 years). The lines are plotted in 10yr steps. Colour scale applies to all following Figures.

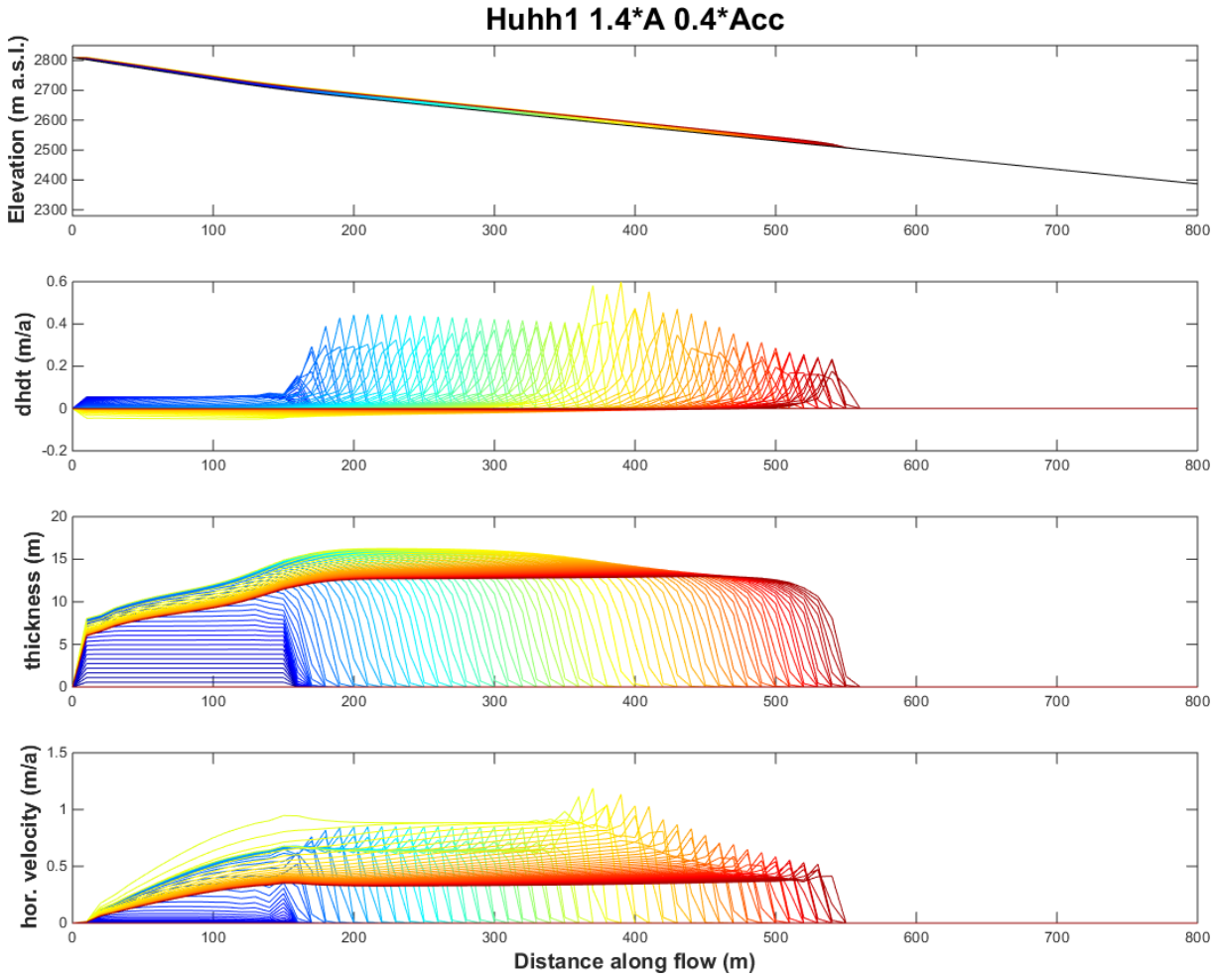


Figure S14: The evolution of surface geometry, thickness change (dhdt) absolute thickness in m horizontal velocity along the central flow line for rockglacier built-up (600 years runtime) and complex perturbation experiment (temperature increase of 1°C for a -2°C rockglacier and reduced material input (40%) after 600 years). The lines are plotted in 10yr steps.

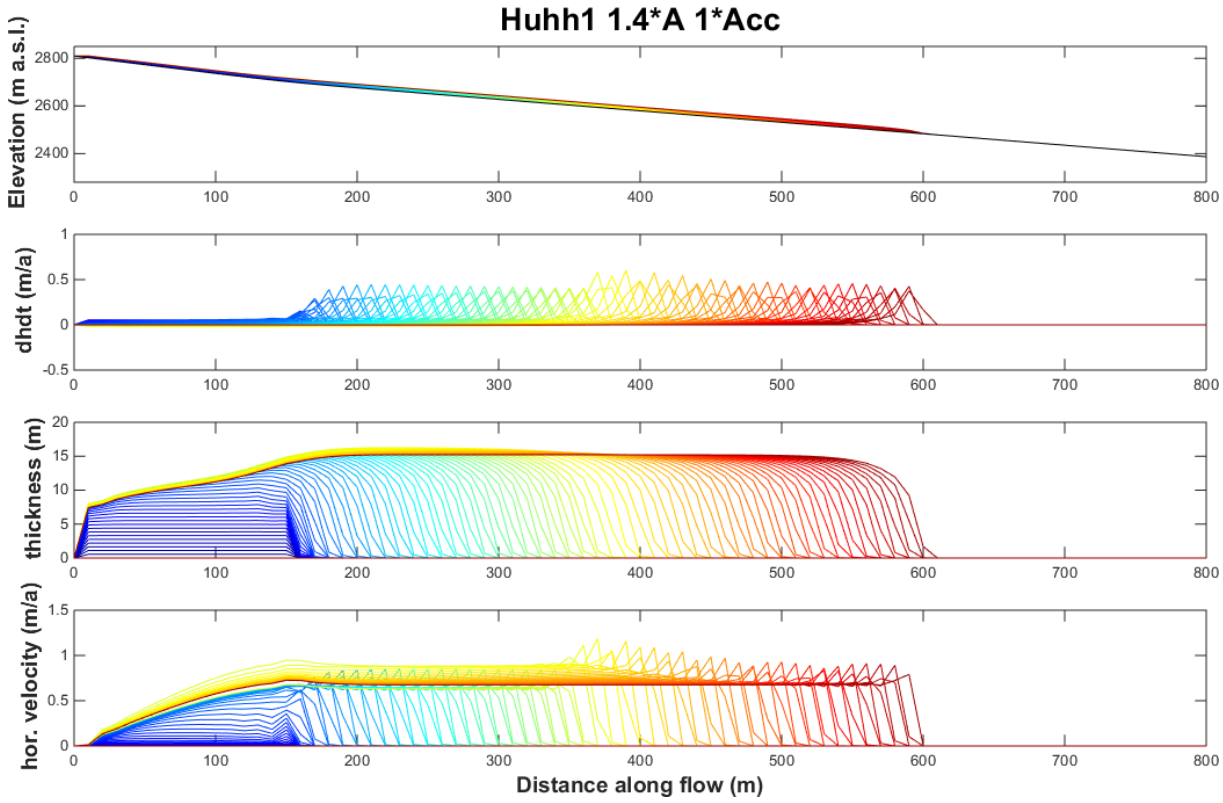


Figure S15: The evolution of surface geometry, thickness change (dhdt) absolute thickness in m horizontal velocity along the central flow line for rockglacier built-up (600 years runtime) and complex perturbation experiment (temperature increase of 1°C for a -2°C rockglacier and no change in material input after 600 years). The lines are plotted in 10yr steps.

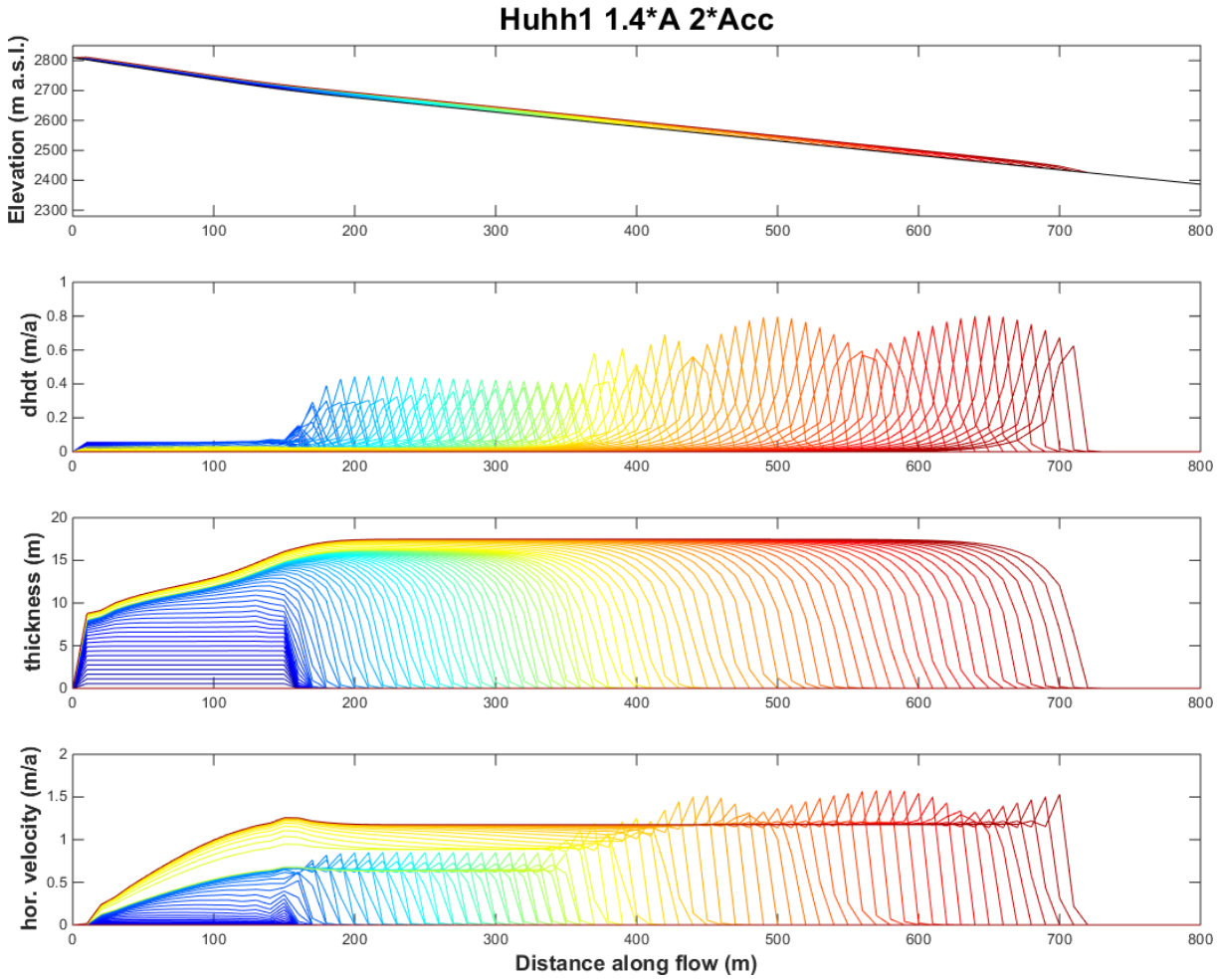


Figure S16: The evolution of surface geometry, thickness change (dhdt) absolute thickness in m horizontal velocity along the central flow line for rockglacier built-up (600 years runtime) and complex perturbation experiment (temperature increase of 1°C for a -2°C rockglacier and doubled material input after 600 years). The lines are plotted in 10yr steps.

S1.2.2 Initial rockglacier temperature -1.5°C, therefore 1.7*rate factor A for a 1°C warming.

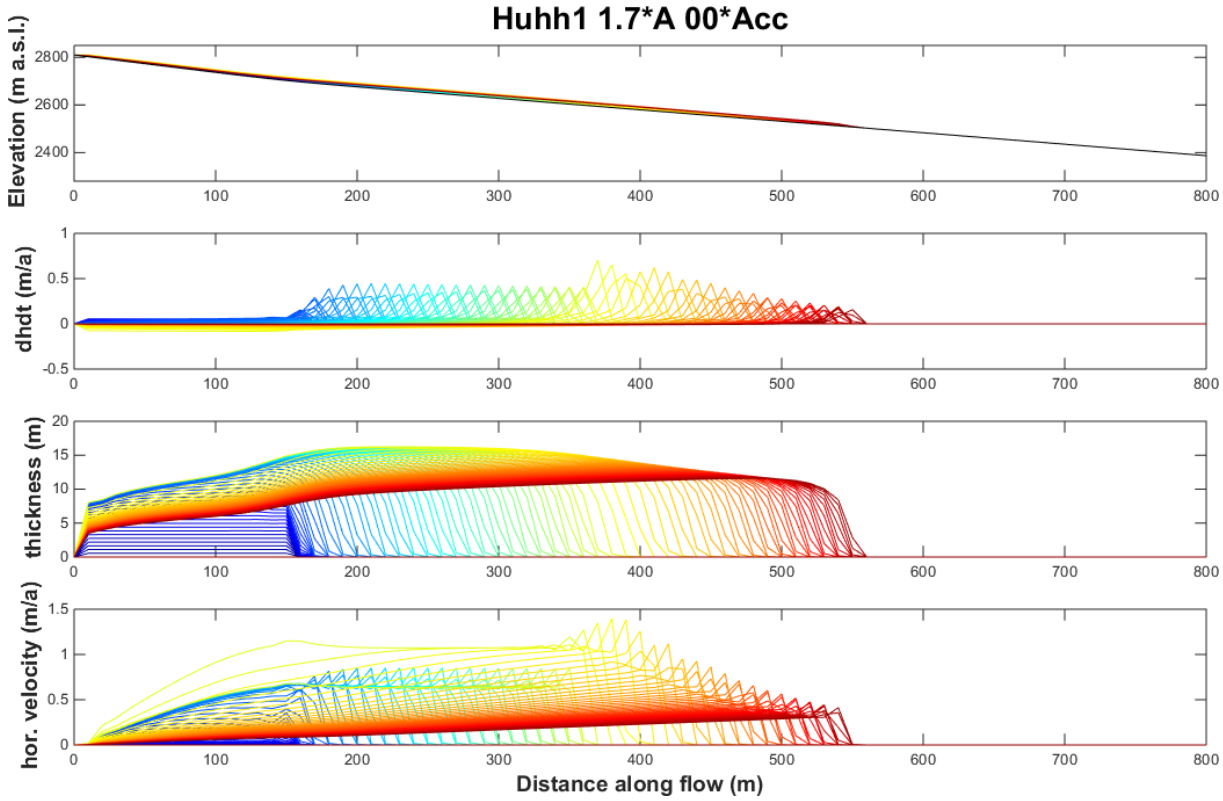


Figure S17: The evolution of surface geometry, thickness change (dhdt) absolute thickness in m horizontal velocity along the central flow line for rockglacier built-up (600 years runtime) and complex perturbation experiment (temperature increase of 1°C for a -1.5°C rockglacier and no material input after 600 years). The lines are plotted in 10yr steps. Colour scale applies to all following Figures.

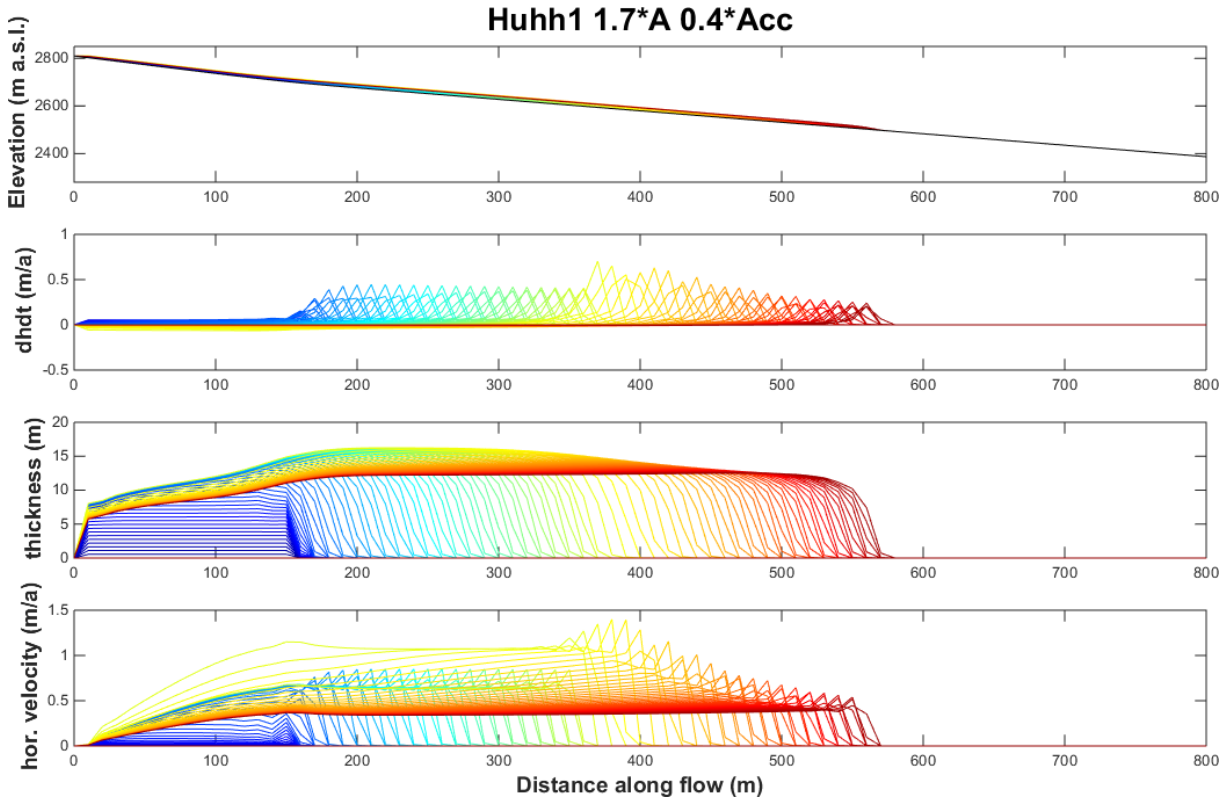


Figure S18: The evolution of surface geometry, thickness change (dhdt) absolute thickness in m horizontal velocity along the central flow line for rockglacier built-up (600 years runtime) and complex perturbation experiment (temperature increase of 1°C for a -1.5°C rockglacier and reduced material input (40%) after 600 years). The lines are plotted in 10yr steps.

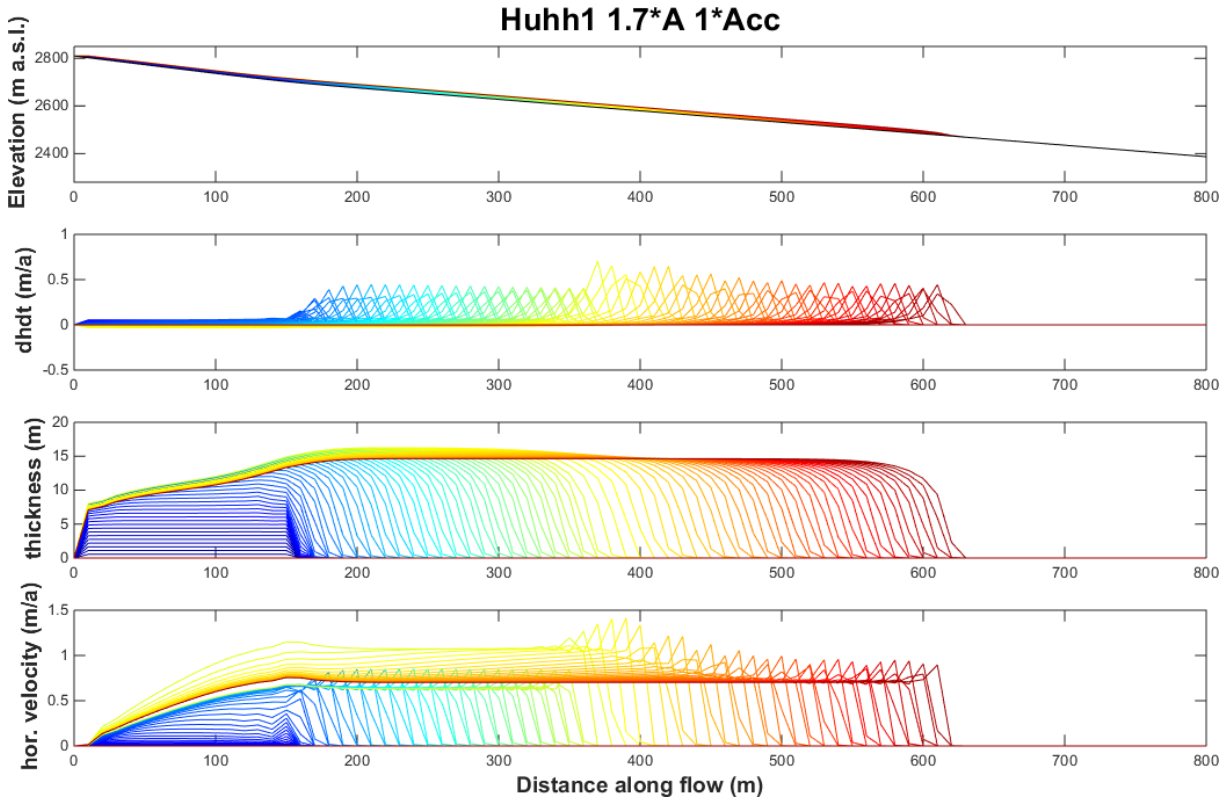


Figure S19: The evolution of surface geometry, thickness change (dhdt) absolute thickness in m horizontal velocity along the central flow line for rockglacier built-up (600 years runtime) and complex perturbation experiment (temperature increase of 1°C for a -1.5°C rockglacier and no change in material input after 600 years). The lines are plotted in 10yr steps.

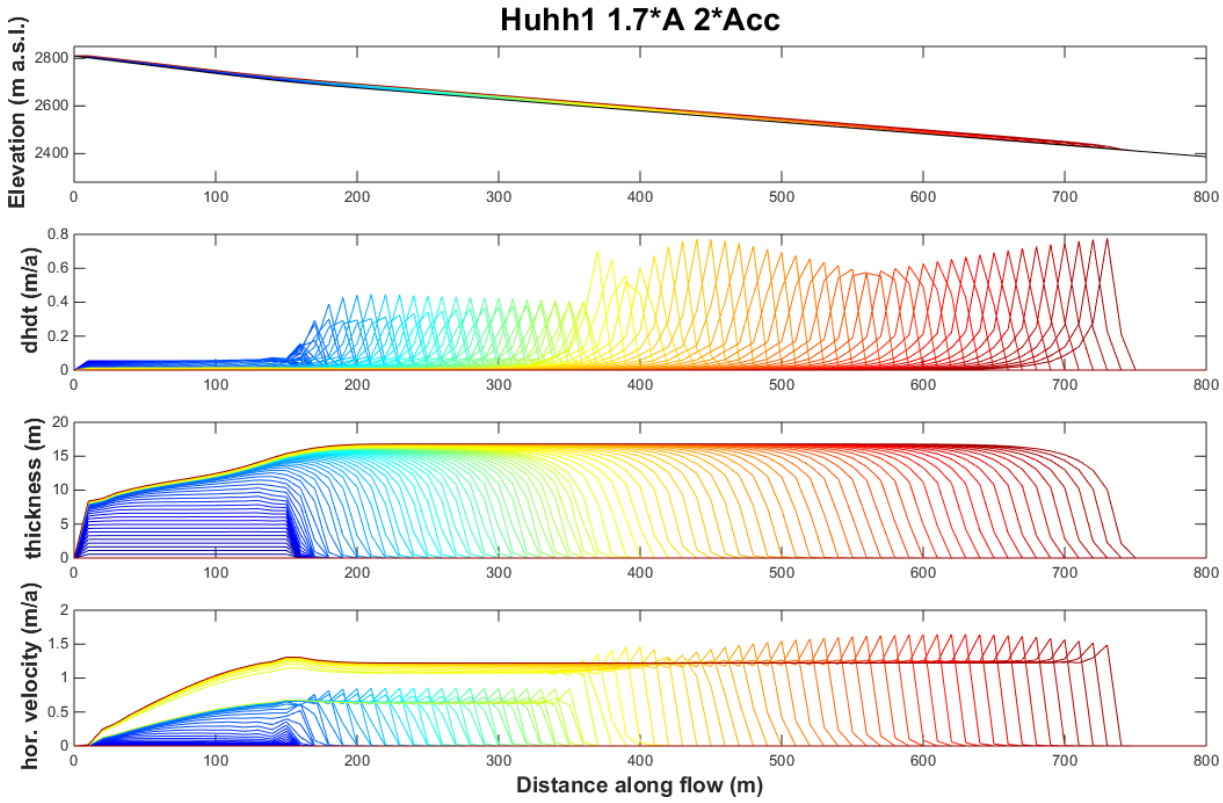


Figure S20: The evolution of surface geometry, thickness change (dhdt) absolute thickness in m horizontal velocity along the central flow line for rockglacier built-up (600 years runtime) and complex perturbation experiment (temperature increase of 1°C for a -1.5°C rockglacier and doubled material input after 600 years). The lines are plotted in 10yr steps.

S1.2.3 Initial rockglacier temperature -2°C, therefore 2.4*rate factor A for a 1°C warming.

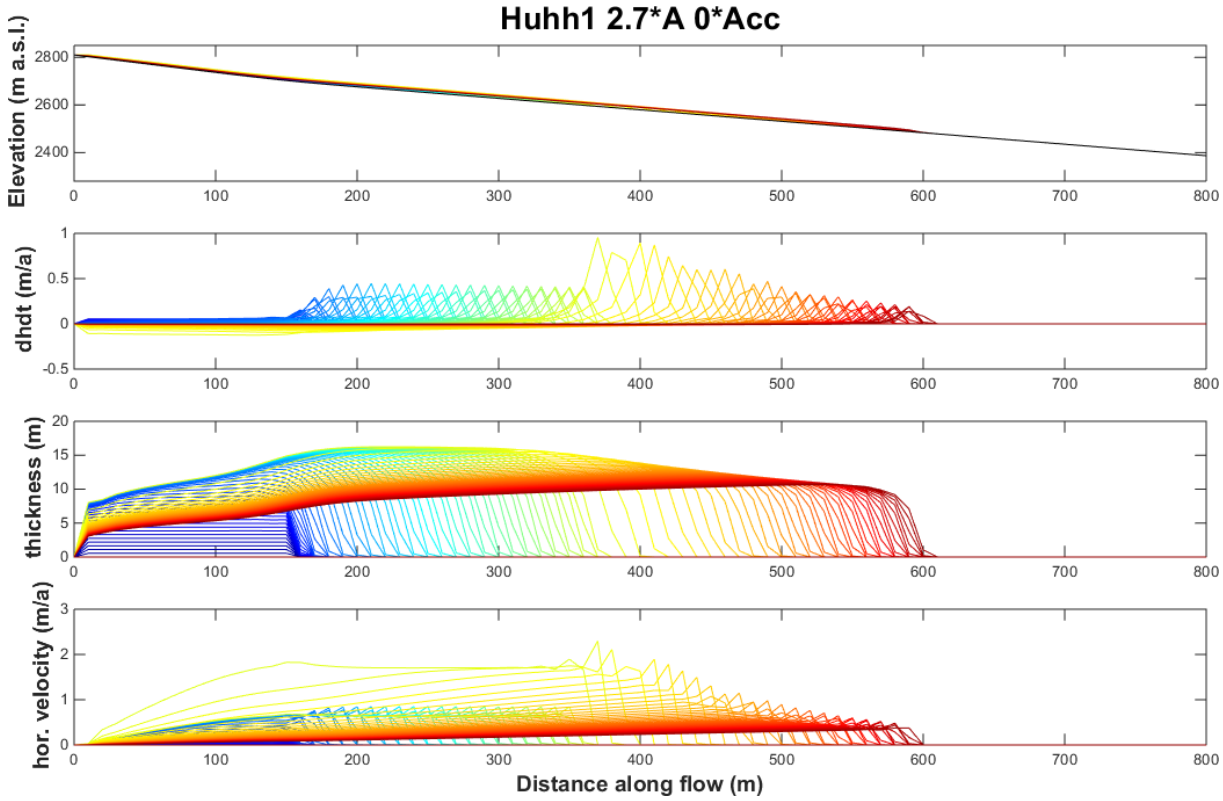


Figure S21: The evolution of surface geometry, thickness change (dhdt) absolute thickness in m horizontal velocity along the central flow line for rockglacier built-up (600 years runtime) and complex perturbation experiment (temperature increase of 1°C for a -1°C rockglacier and no material input after 600 years). The lines are plotted in 10yr steps. Colour scale applies to all following Figures.

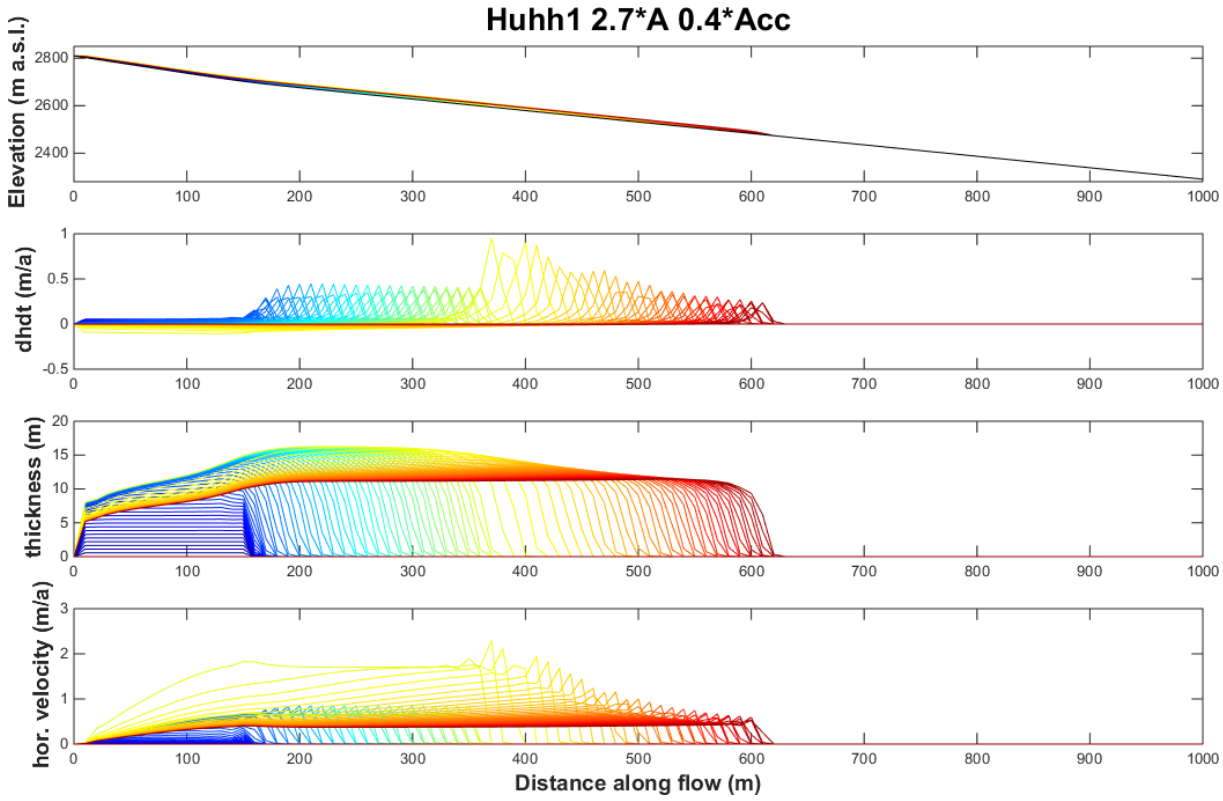


Figure S22: The evolution of surface geometry, thickness change (dhdt) absolute thickness in m horizontal velocity along the central flow line for rockglacier built-up (600 years runtime) and complex perturbation experiment (temperature increase of 1°C for a -1°C rockglacier and reduced material input (40%) after 600 years). The lines are plotted in 10yr steps.

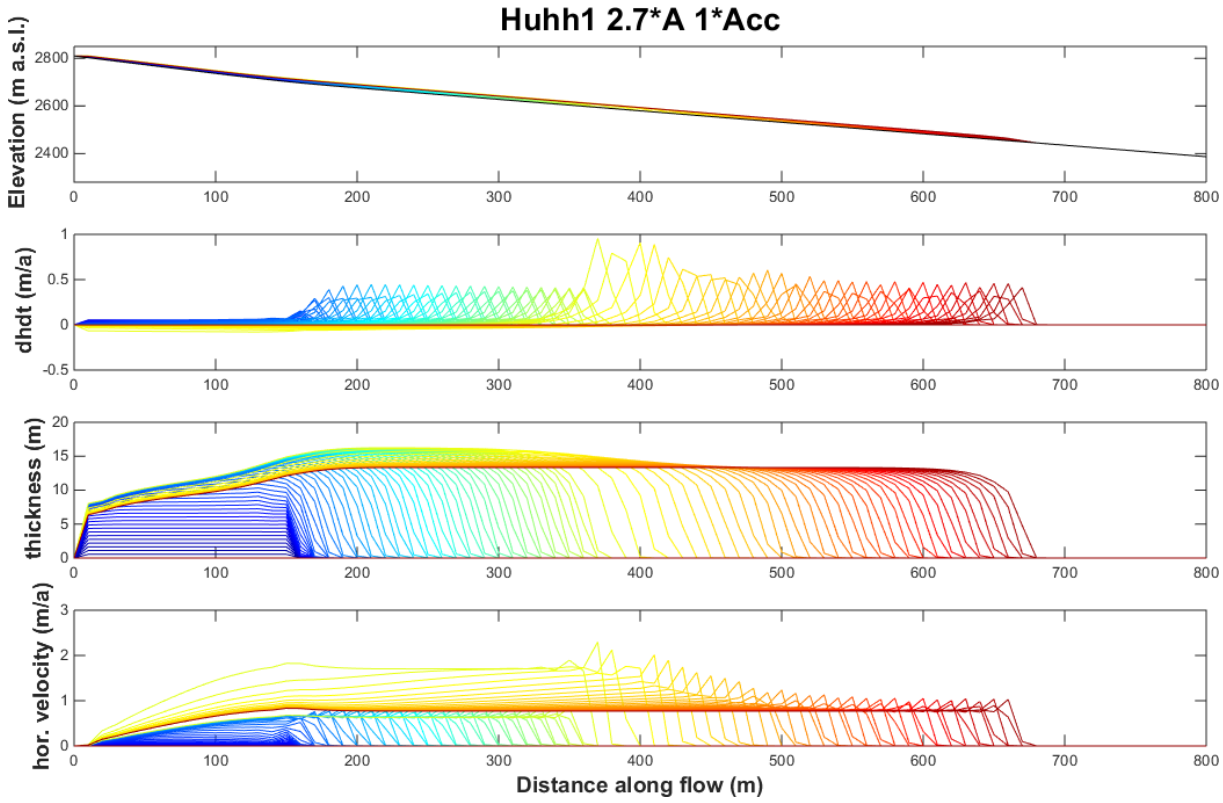


Figure S23: The evolution of surface geometry, thickness change (dhdt) absolute thickness in m horizontal velocity along the central flow line for rockglacier built-up (600 years runtime) and complex perturbation experiment (temperature increase of 1°C for a -1°C rockglacier and no change in material input after 600 years). The lines are plotted in 10yr steps.

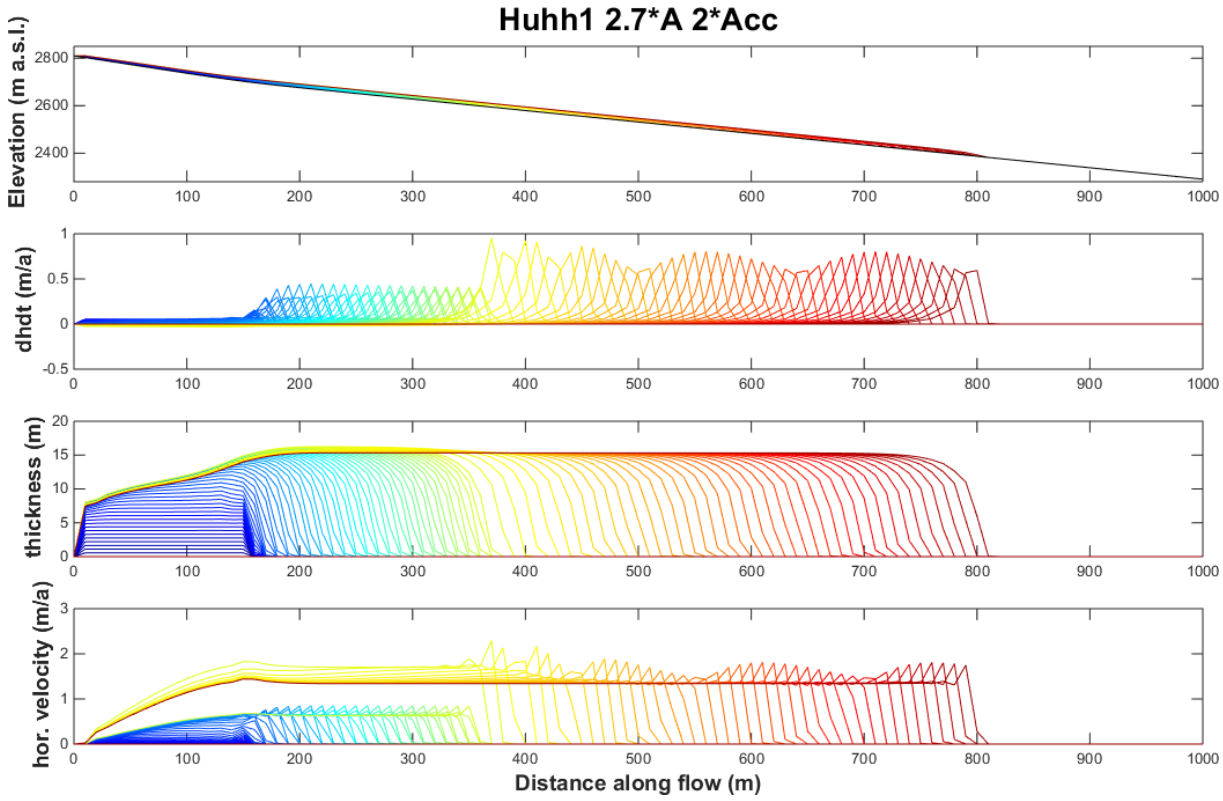


Figure S24: The evolution of surface geometry, thickness change (dhdt) absolute thickness in m horizontal velocity along the central flow line for rockglacier built-up (600 years runtime) and complex perturbation experiment (temperature increase of 1°C for a -1°C rockglacier and doubled material input after 600 years). The lines are plotted in 10yr steps.