Rockglacier Rheology – Recent developments in modeling approaches and future perspectives

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Rockglacier Rheology Modelling

Homogenous Ice Assumption

- Shallow Ice Assumption

- Rheology based on Glen's flow law
  →Temperature dependent rate factor A

Coupling of air temperature and energy fluxes in the rockglacier

Rate Factor A accounts for the higher viscosity

Frauenfelder (2005)
Kääb et al. (2007)
Whalley and Azizi (1996)

Process - based

- Representation of the actual rock-ice melange

- representation of mechanical stability, ground thermal regime and water flow

→ Data availability

→Highly complex

→Interactions not completely understood

→Account for morphology and rheology

Arenson & Springman 2005
Jansen et al. 2006
Naters et al. 2008

Physically - based model

Small scale physical model of the rockglacier in the laboratory.

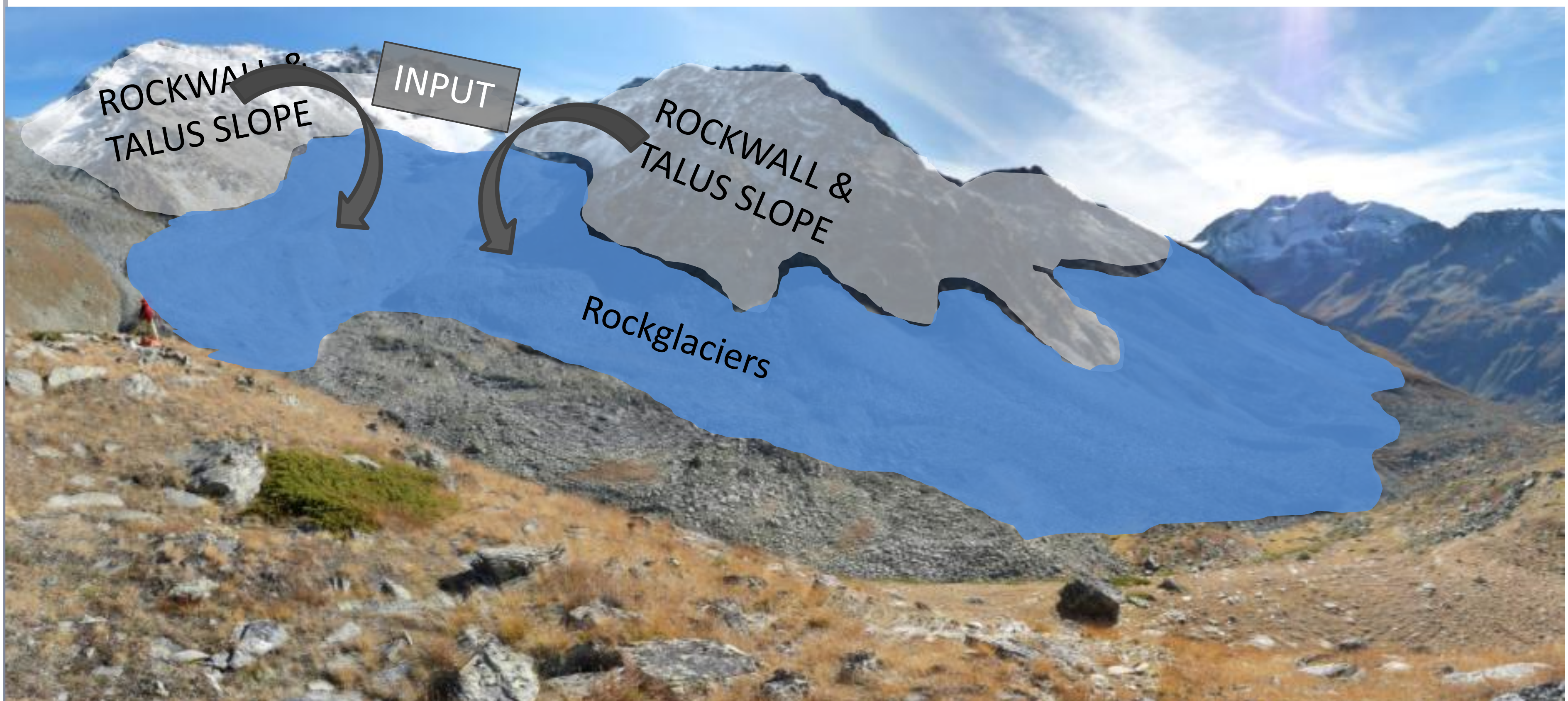
Kääb et al. (2002)

Challenges to the rockglacier models

Haeberli et al. 2006

- Rockwall - rockglacier coupling
- Freezing processes and ice formation
- Coupled thermohydro-mechanical modelling
- Kinematics of surface/subsurface from headwall to terminus
- Explanation of the surface morphology (furrow and ridges)

Modell Concept



Modell Concept: Conservation of mass for surface evolution

Rockglacier profile represented by discrete number of points (10 m apart)

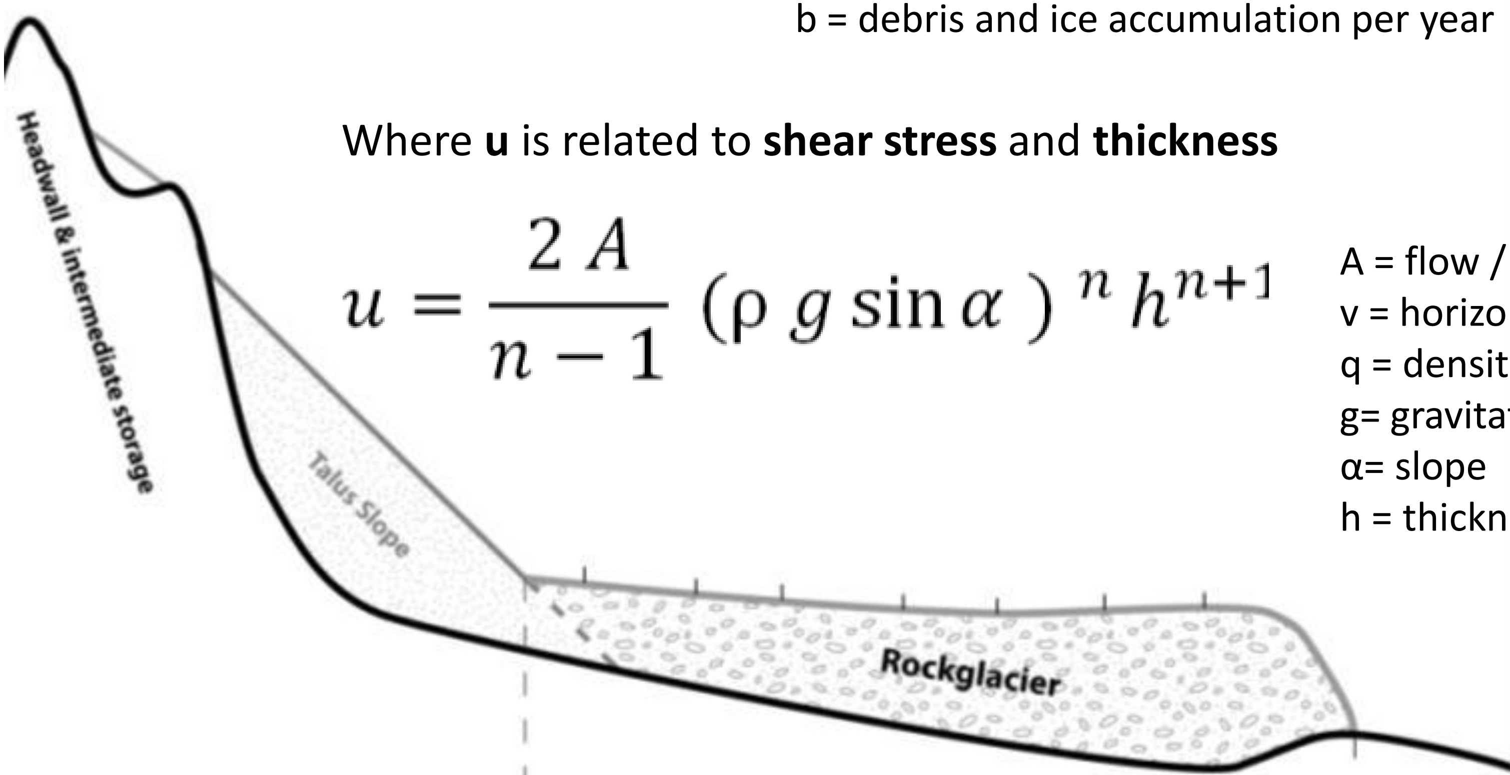
$$\frac{\partial h}{\partial t} = b - \frac{1}{w}\,\frac{\partial(u * w * h)}{\partial x}$$

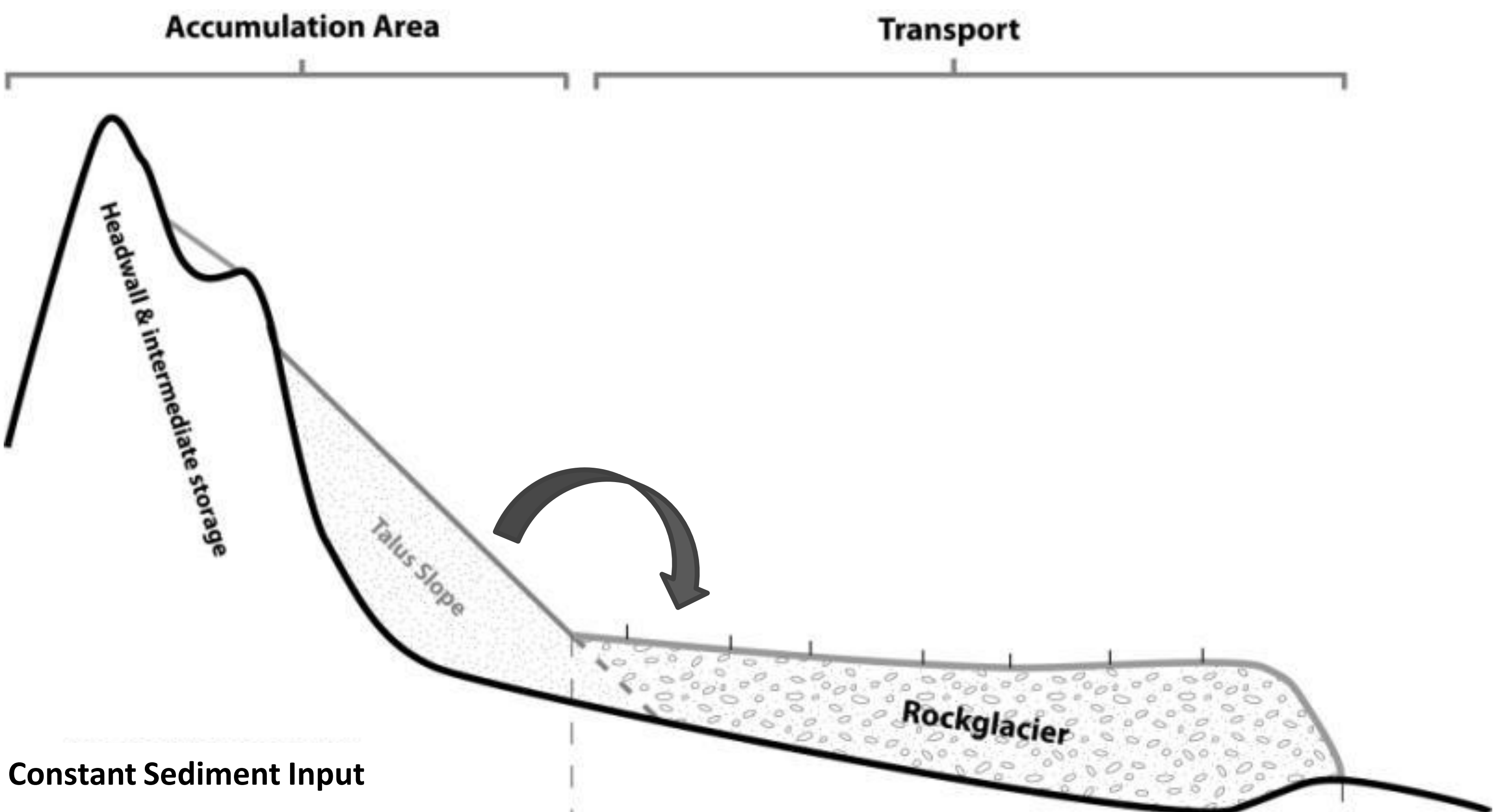
h = RG thickness at each point
u = horizontal velocity
w = width
b = debris and ice accumulation per year

Where **u** is related to **shear stress** and **thickness**

$$u = \frac{2\,A}{n-1}\,(\rho\; g \sin\alpha\;)^{\,n}\, h^{n+1}$$

A = flow / rate factor
v = horizontal surface velocity
q = density of the material
g= gravitational acceleration
α= slope
h = thickness





Constant Sediment Input

Area supplying sediment from geomorphological mapping

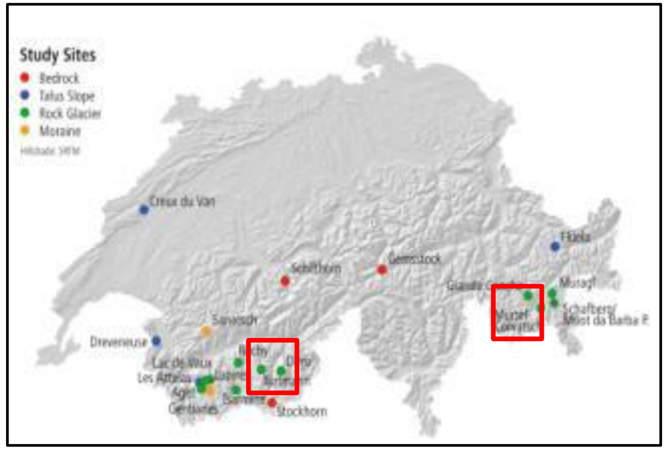
Backweathering rate of 2mm/a m2

Mean slope **Ice Content 60 %**
Barsch 1996, Roer 2012

(Thickness) **(Surface velocity)**

(For Sediment Input see Glade et al. 2005, Krautblatter et al. 2012 & Mueller et al. 2013)

Sites



Turtmanntal Rockglacier

Length: 310 m

Thickness: 12 m

Avg slope: 27°

Horiz. velocity: 0.75 – 1.55 m/a

Sediment Input: 0.022 m3/m2 a

Murtel Rockglacier

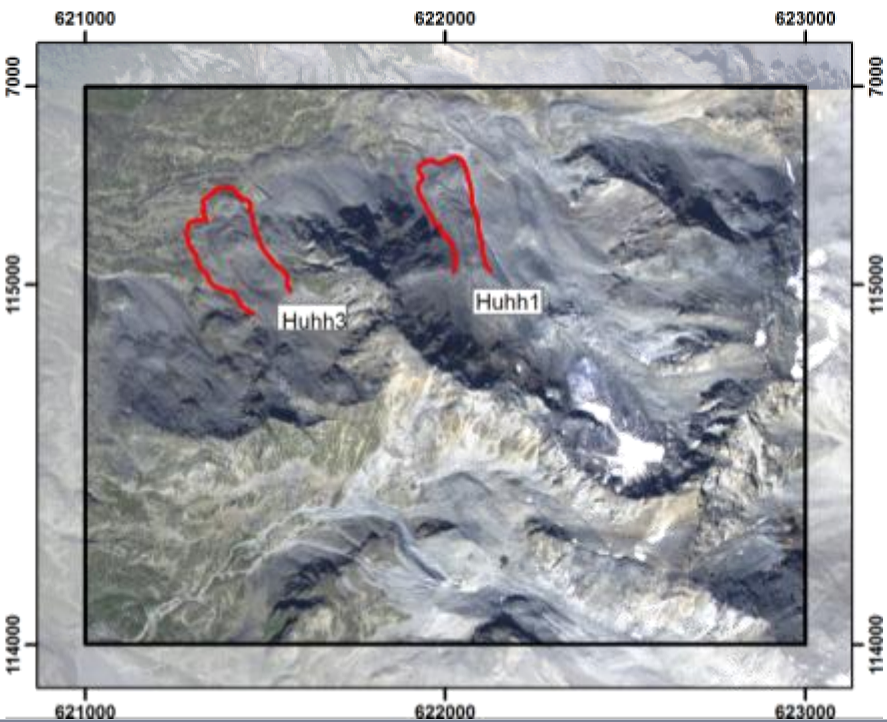
Length: 330 m

Thickness: 30 m (shear horizont)

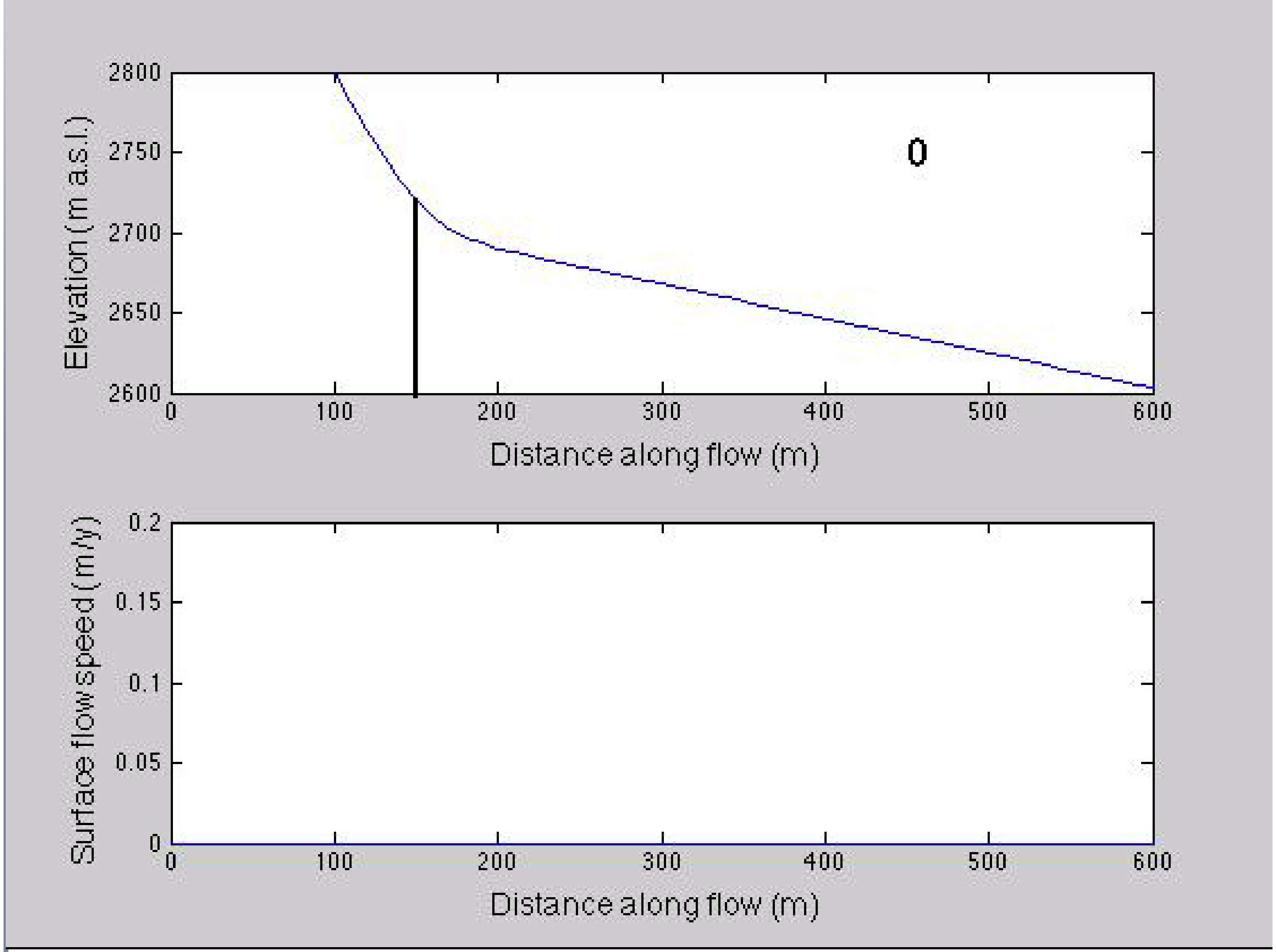
Avg slope: 12°

Horiz. velocity: 0.06 – 0.13 m/a

Sediment Input: 0.006 m3/m2 a



Modelling Results Rockglacier Murtel



Modell Setup:

Runtime: 6000yrs

(Kääb et al. 1998)

Thickness: 30m

Slope: 12°

SedInput:

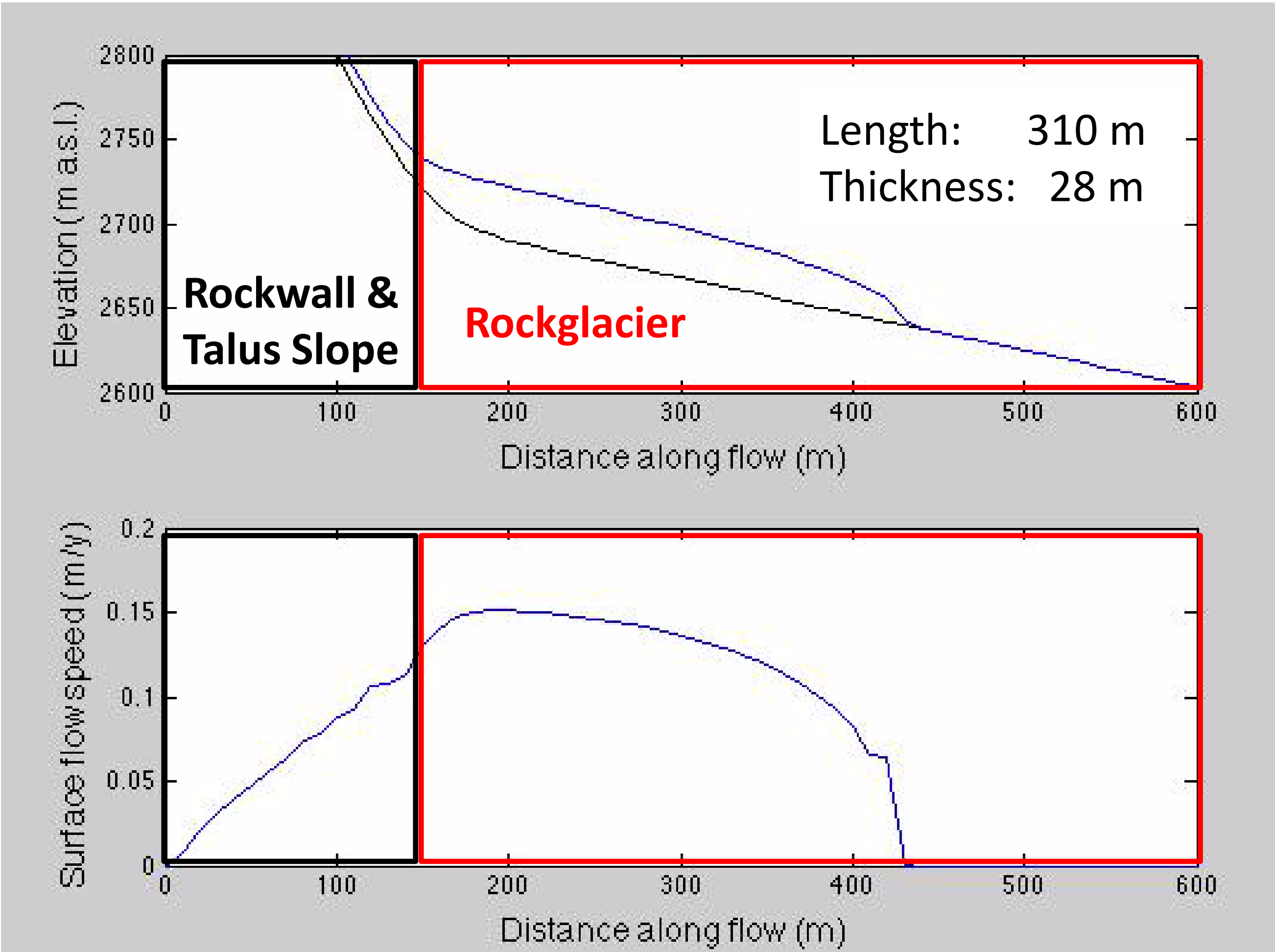
0.006 m3/m2 a

A= $4.5*10^{-18}$ Pa^{-3}/y

Timesteps: 50yrs

Pointspacing: 10m

Modelling Results Rockglacier Murtel



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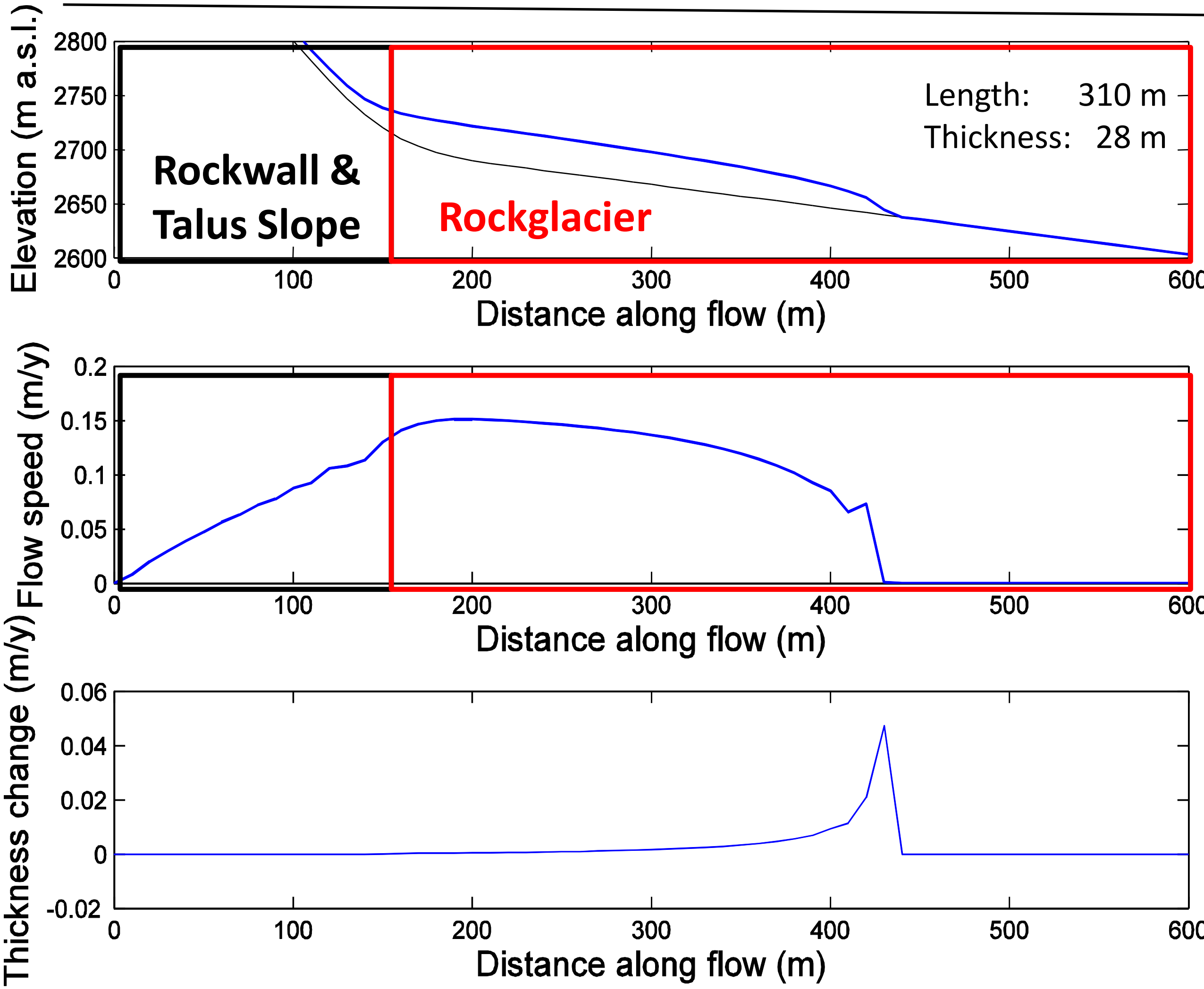
Modelling Results Murtel

Model



Reference

Length: 330 m

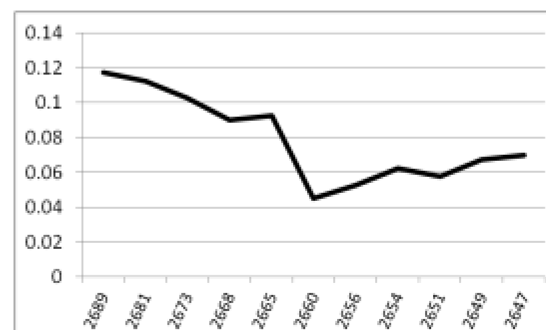
Thickness: 30 m

Avg slope: 12

Sed. Input (40%)
0.006 m3/m2 a

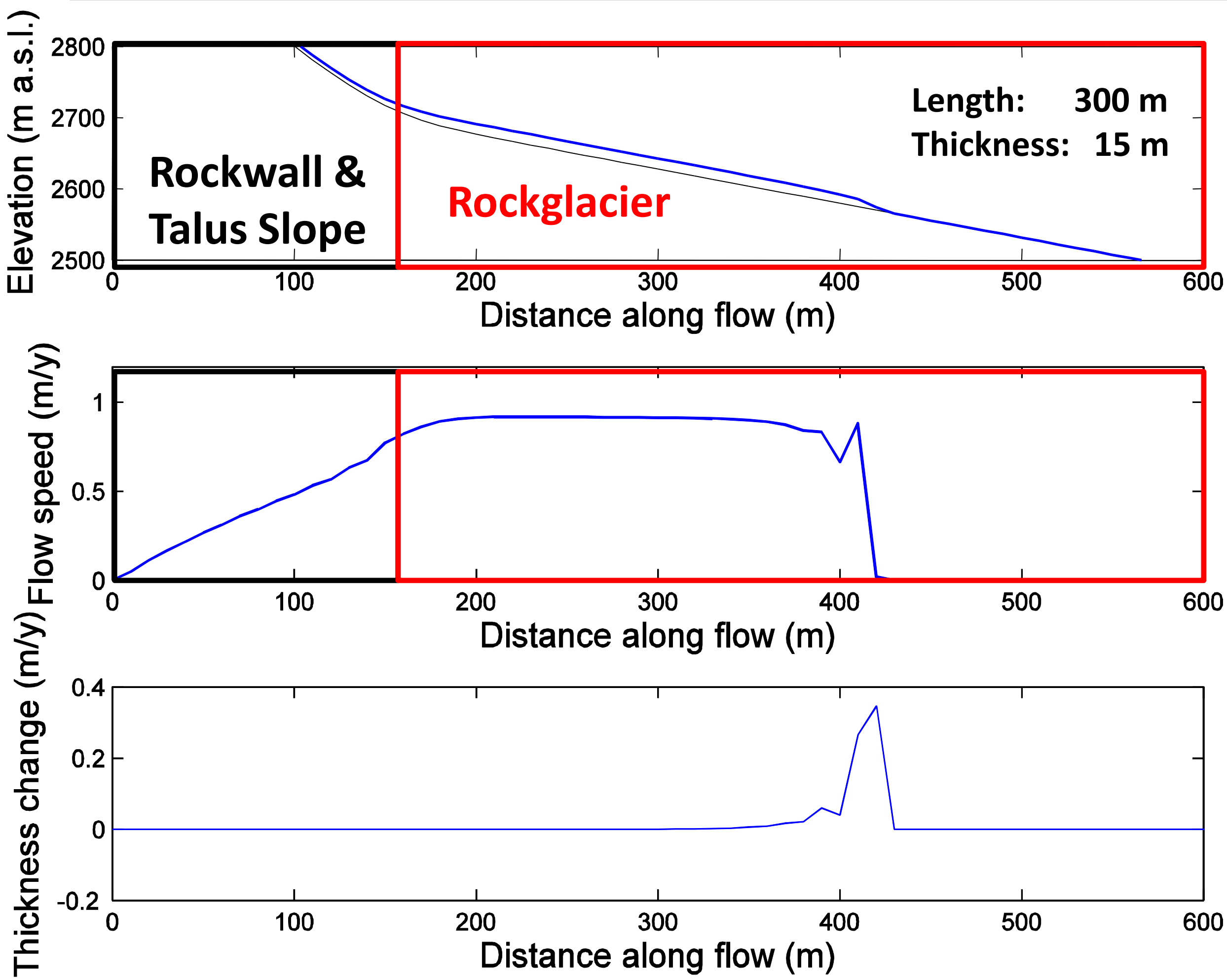
Ice Input (60%)
0.009m3/m2 a

$A = 4.5 * 10^{-18}\ Pa^{-3}/y$



Modelling Results Hungerli Valley

Model



Reference

Length: 310 m

Thickness: 12 m

Avg slope: 27

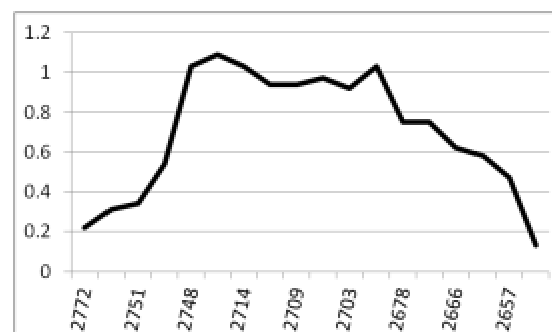
Sed. Input (40%)

0.022 m3/m2 a

Ice Input (60%)

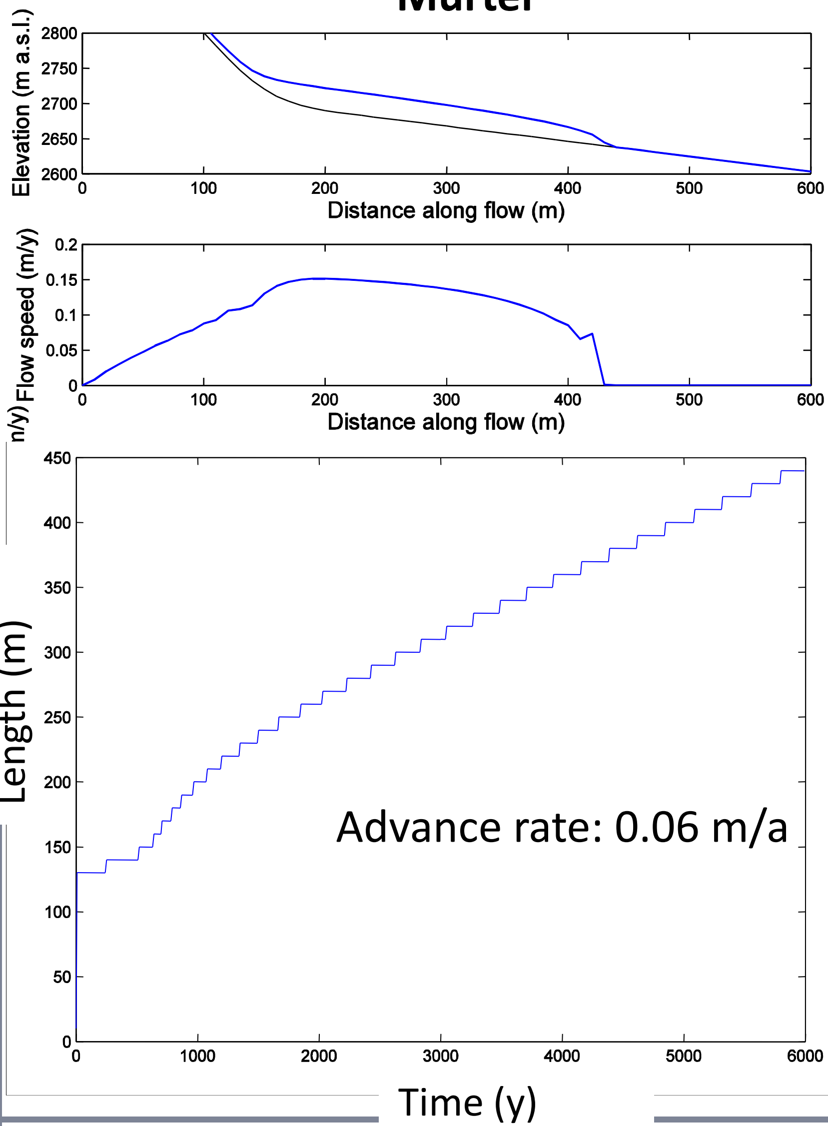
0.033 m3/m2 a

Flow rate A = $7*10^{-17}$ Pa^{-3}/y

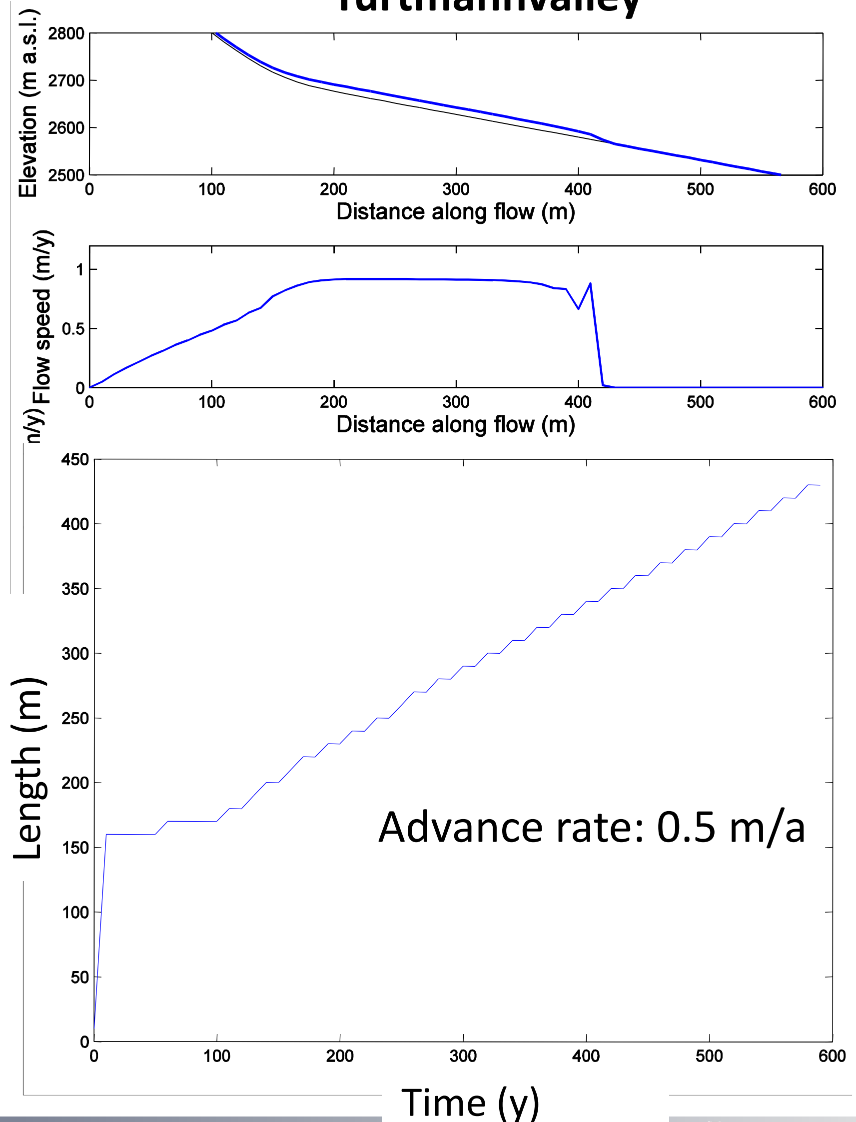


Surface velocity vs. Advance rates

Murtel



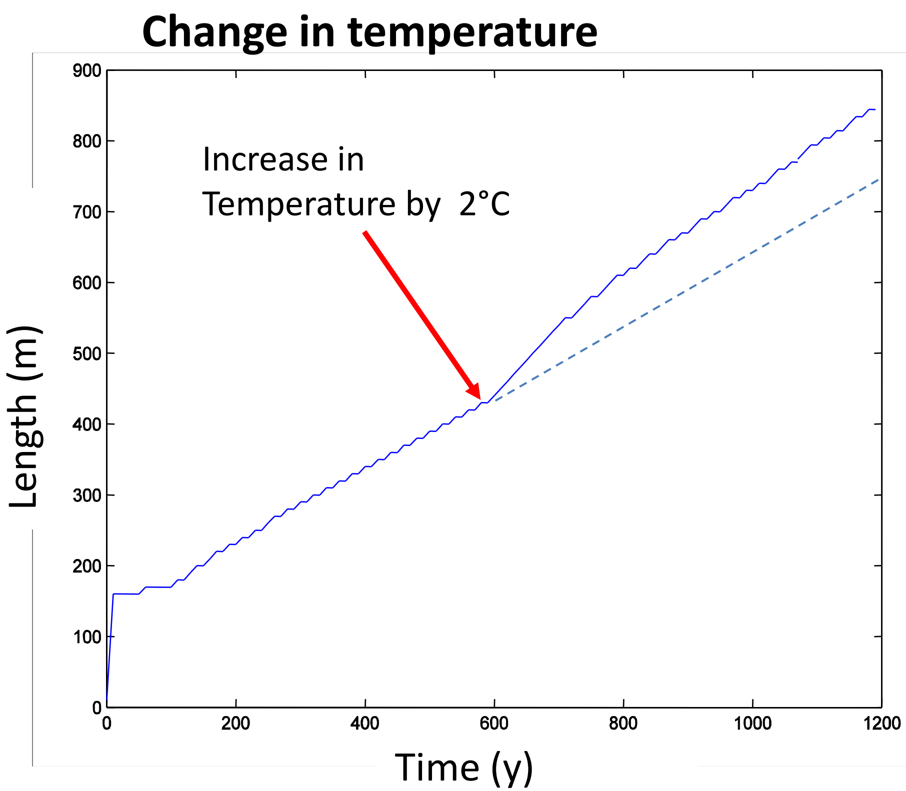
Turtmannvalley

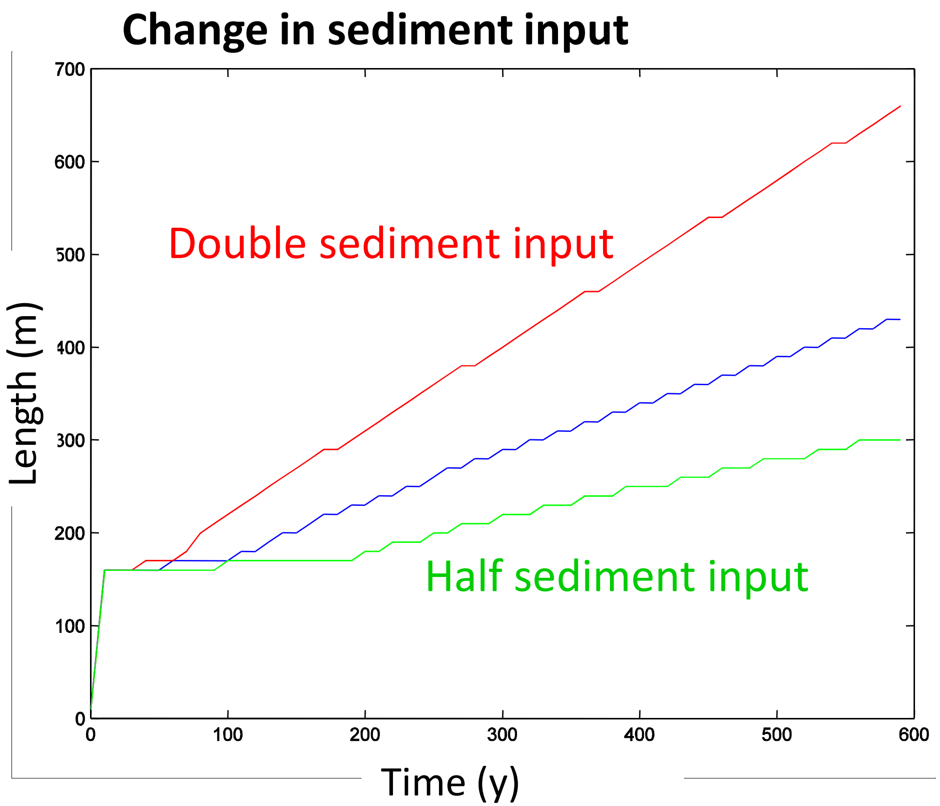


Conclusion

- Surface evolution of rockglaciers based on a mass conservation model
- Representation of geometry and surface velocity over long time scales
- Rockglacier development in relation to geomorphological setting
- Coupling of rockwall input & rockglacier rheology

The next step – Sensitivity Analysis





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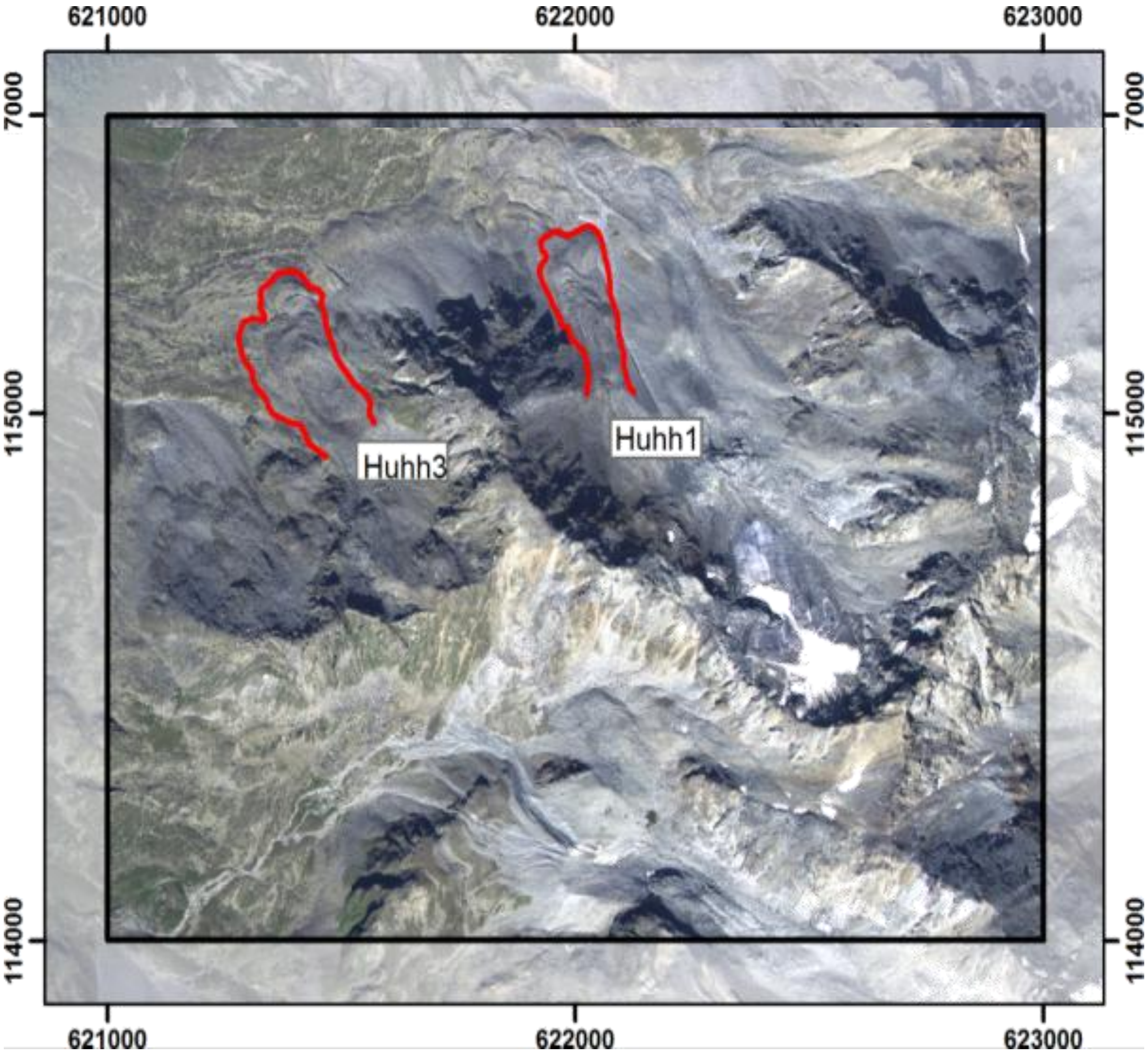
Turtmann Rockglaciers



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Rockglacier Degradation