Modelling geomorphic responses to human perturbations: Application to the Kander River, Switzerland

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INTRODUCTION

Human perturbation to a river system

In the year 1714 the Kander river flowed into the Aare river causing flooding near Thun (Figure 1a). To resolve this problem the Kander river was deviated into lake Thun through the Kander correction (Figure 1a,b). Four years after the Kander correction underwent extreme channel erosion (Figure 1c).

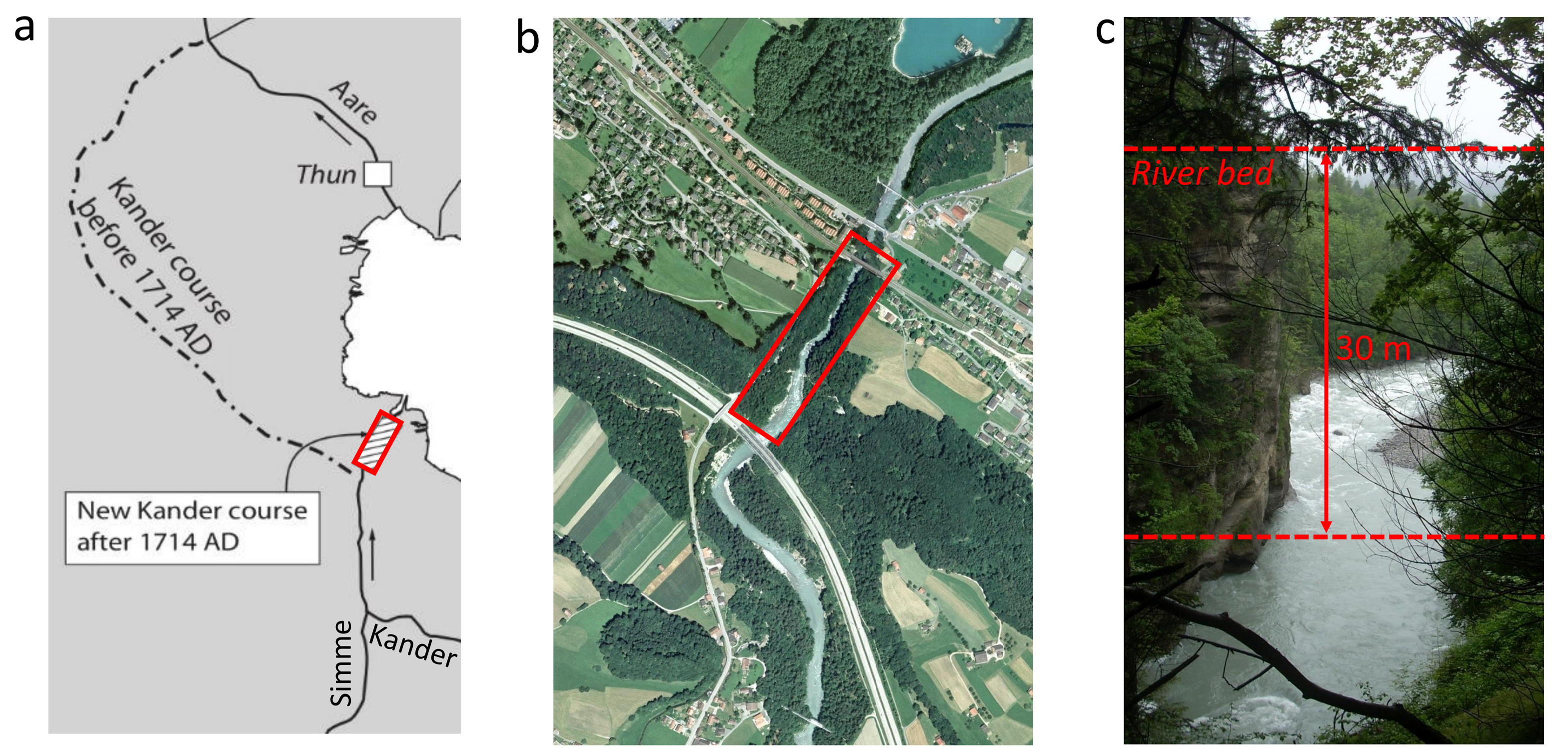

Figure 1. (a) Map of Kander and Simme rivers in 1714 (taken from [Wirth et al., 2011]). (b) Orthophoto and (c) oblique photo of Kander correction.

Are geomorphic models useful and stable in extreme situations?

To answer this research question we:

- Use historic maps and documents to develop a detailed geomorphic model of the Kander river starting in the year 1714
- Simulate the extreme geomorphic events that preceded the deviation of the Kander river into Lake Thun
- Test our model by replicating long term impacts to the river that include:
  - Rates of incision
  - Knickpoint migration
  - Delta formation

METHODS

CAESAR Lisflood model combines:

- Landscape evolution model simulating erosion and deposition within river reaches (CAESAR) [*Coulthard et al.*, 2013]
- A hydrodynamic 2D flow model (based Lisflood FP model) that conserves mass and partial momentum

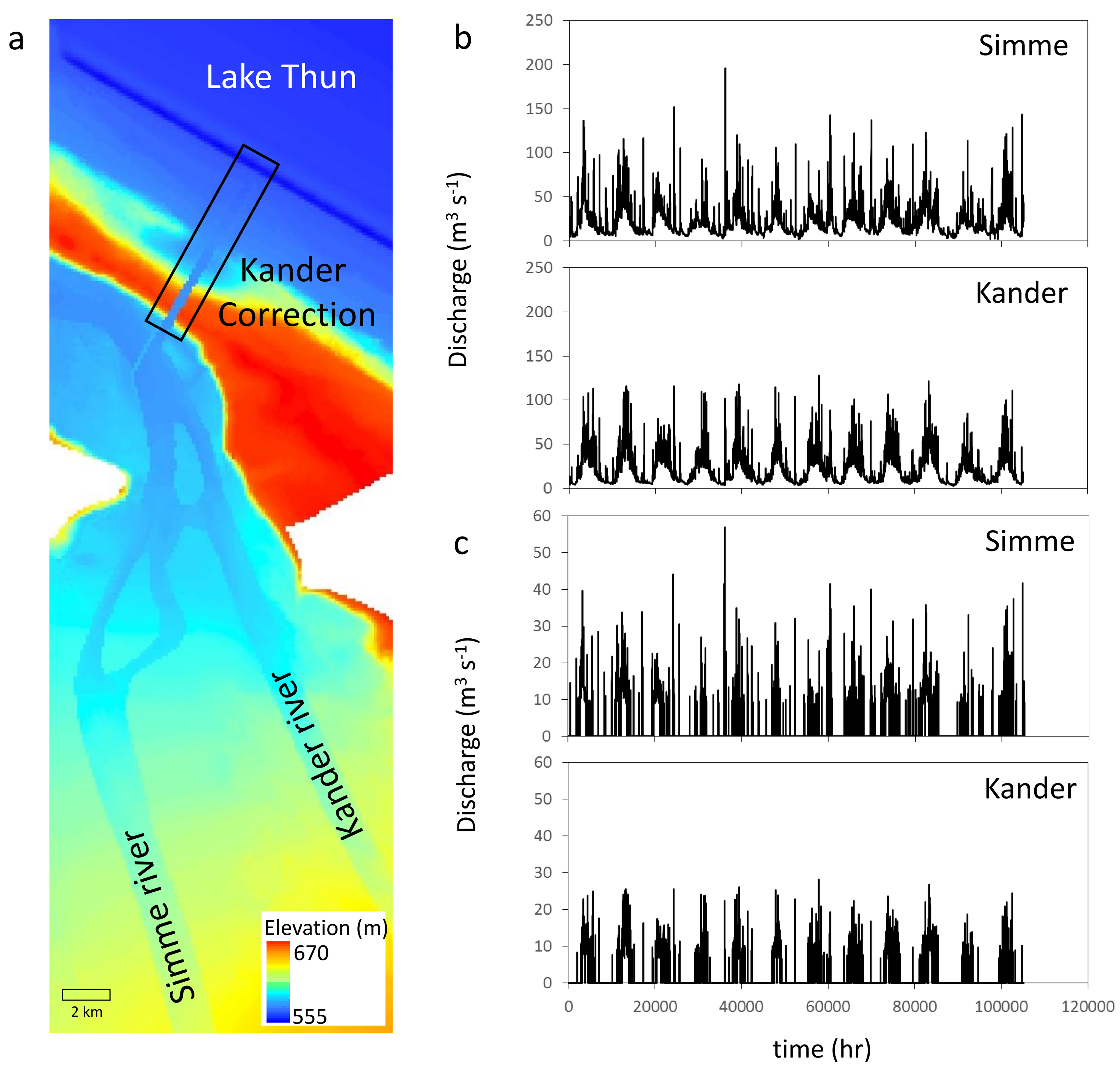

Figure 2. (a) Digital elevation model of the Kander correction. (b) Hourly discharge and (c) sediment inputs for the Simme and Kander rivers.

Kander correction model was developed using:

- Present day topography for river banks and historical data for river channel and Kander correction (Figure 2a)
- Observed hourly discharge from 1986-1998 (Figure 2b)
- Present day sediment estimates (20,000 m^3 yr^{-1}), added proportionally to discharge (figure 2c) [Soom, 2004]

RESULTS

Incision of Kander correction

- 29 m of modelled erosion within 4 years (Figure 3)
- 2 m difference with todays river channel elevation

Historical records indicate that 30 m of incision occurred in 4 years

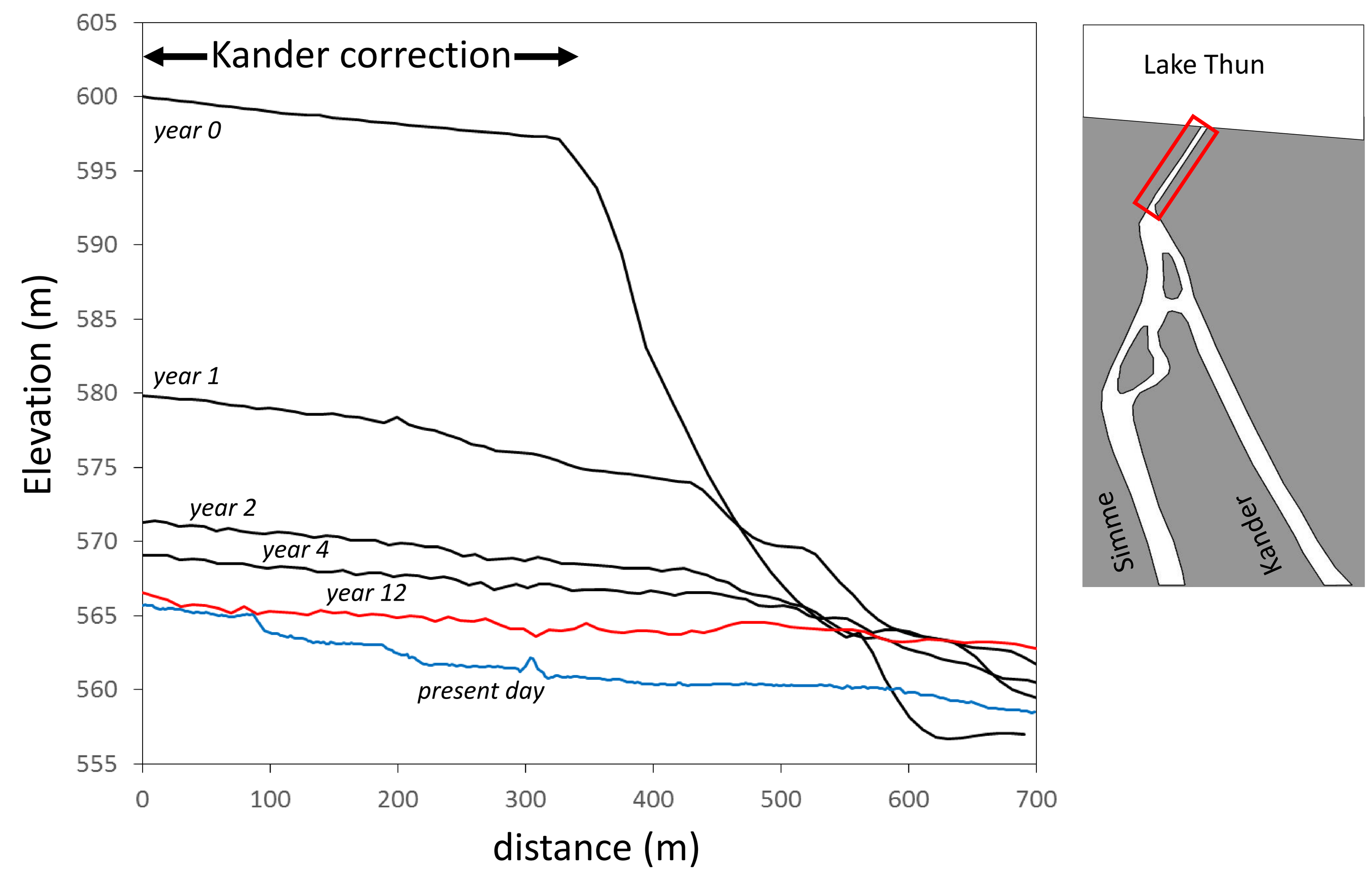

Figure 3. Kander correction elevation profile for present day (in blue) and modelled incision for several snapshots in time (black and red lines).

Knickpoint migration

- 900 m of modelled upstream knickpoint migration in 12 years (Figure 4)

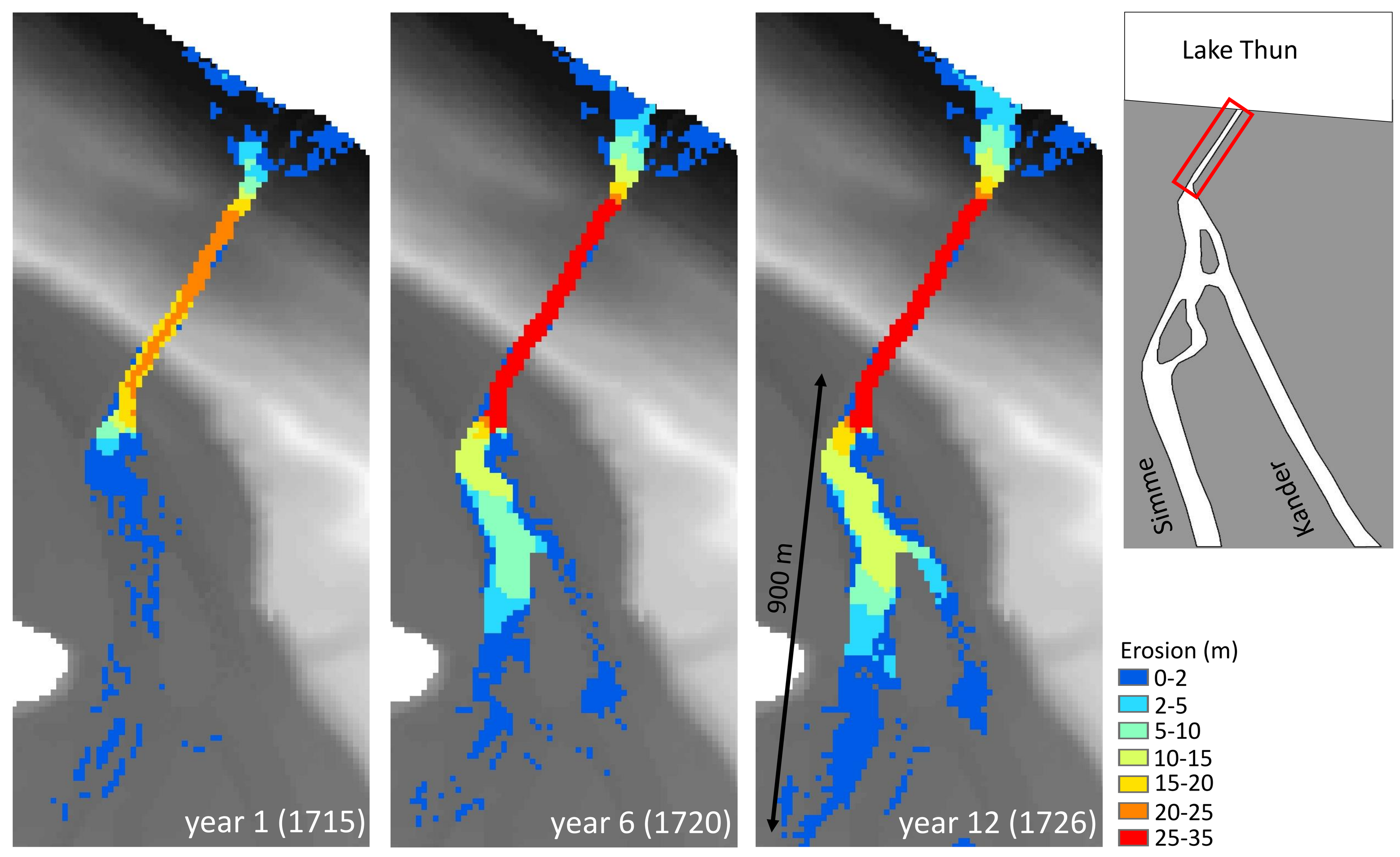

Figure 4. Modelled erosion of Kander and Simme river channel

Delta formation

- Model formed 40 % of the delta in 12 years (Figure 5)

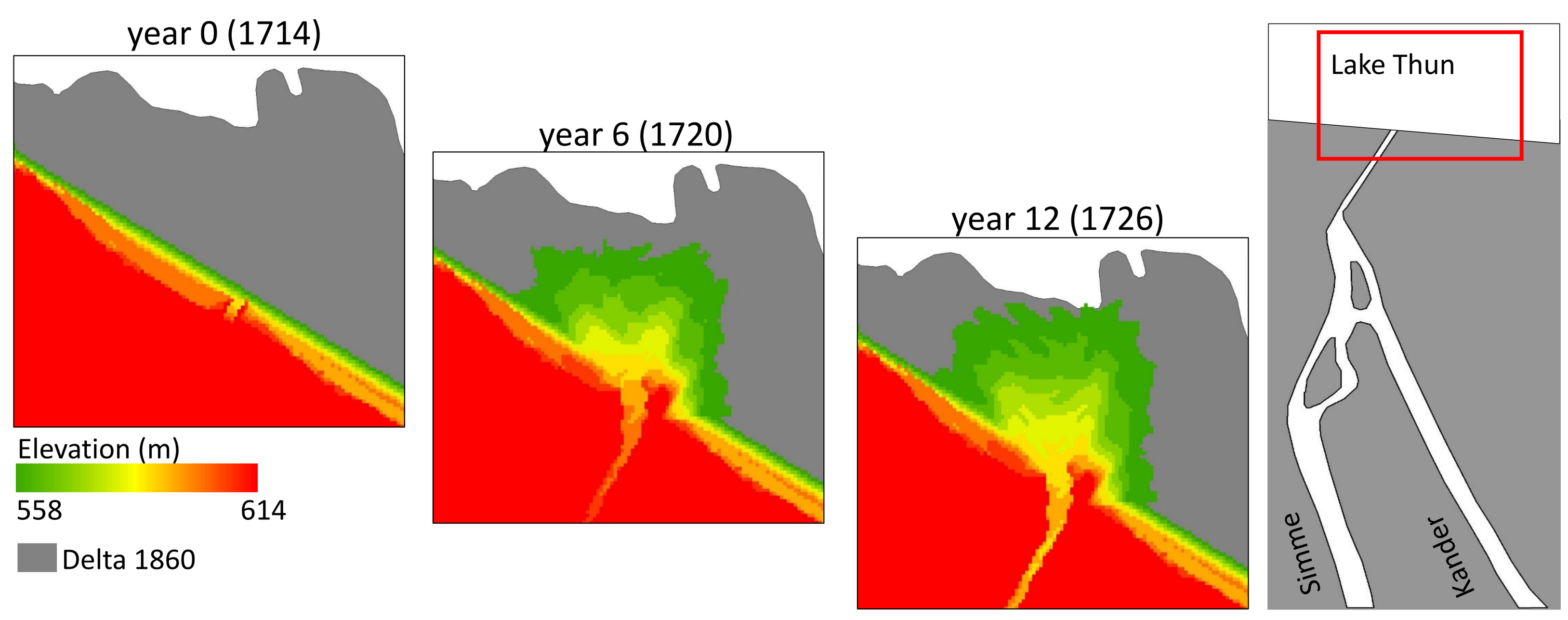

Figure 5. Modelled delta development within Lake Thun

CONCLUSIONS / FUTURE WORK

- CAESAR Lisflood can replicate geomorphic effects of human intervention in fluvial systems that include river bed incision, knickpoint migration, and delta formation.
- The model demonstrated stability in extreme geomorphic conditions by producing reasonable geomorphic changes. This underscores the models usefulness in predicting the response of rivers to human perturbations.
- Future work will model a longer time period and will attempt to replicate historical rates of knickpoint migration further upstream in the Kander river.

Coulthard, T. J., J. C. Neal, P. D. Bates, J. Ramirez, G. A. M. de Almeida, and G. R. Hancock (2013), Integrating the LISFLOOD-FP 2D hydrodynamic model with the CAESAR model: implications for modelling landscape evolution, Earth Surf. Process. Landforms, 38(15), 1897–1906, doi:10.1002/esp.3478.
Wirth, S. B., S. Girardclos, C. Rellstab, and F. S. Anselmetti (2011), The sedimentary response to a pioneer geo-engineering project: Tracking the Kander River deviation in the sediments of Lake Thun (Switzerland), Sedimentology, 58(7), 1737–1761.
Soom, M. (2004), Geschiebehaushalt Kander.