Climate change impacts on sediment yield and debris-flow activity at the Illgraben, Switzerland

Jacob Hirschberg$^{1,2}$, Simone Fatichi$^2$, Georgie Bennett$^{3,4}$, Brian McArdell$^1$, Stuart Lane$^5$, and Peter Molnar$^2$

$^1$Swiss Federal Institute for Forest, Snow and Landscape Research WSL, Birmensdorf, Switzerland (jacob.hirschberg@wsl.ch)
$^2$Institute of Environmental Engineering, ETH Zurich, Zurich, Switzerland
$^3$School of Environmental Sciences, University of East Anglia, Norwich, United Kingdom
$^4$Geography, University of Exeter, Exeter, United Kingdom
$^5$Institute of Earth Surface Dynamics, University of Lausanne, Lausanne, Switzerland

Debris flows are rapid mass movements composed of a mixture of water and sediments and often pose a danger to humans and infrastructure. In the Alpine environment, they are mostly triggered by intense rainfall, snowmelt or a combination thereof, and conditioned by sediment availability. Their occurrence is expected to increase in a warmer climate due to changes in the hydrological regime (e.g. higher rainfall intensity, lower duration of snow cover). Furthermore, sediment production is likely to accelerate due to permafrost thawing and changes in freeze-thaw cycles, resulting in increased sediment availability. For the purpose of climate change impact assessment on sediment yield and debris-flow activity, interactions and feedbacks of climate and the aforementioned processes need to be considered jointly.

In the study presented here, we address this challenge by forcing a sediment cascade model (SedCas$^1$) with precipitation and temperature from a stochastic weather generator (AWE-GEN$^2$) producing ensembles of possible climate in the present and for the future. The chosen study site is the Illgraben, a debris-flow prone catchment in the Swiss Alps which currently produces 3-4 debris flows yearly on average. SedCas conceptualizes a geomorphic system in which hillslopes produce and store sediments from landslides and eventually deliver them to the channels. From there, sediments can be mobilized by concentrated surface runoff and transferred out of the catchment in form of bedload, hypereconcentrated flow, or debris flows, depending on the surface runoff magnitude and the sediment availability. AWE-GEN operates at the hourly scale and is trained for the current climate with observed data and for the future climate using the newest climate change projections for Switzerland CH2018 developed by the National Center for Climate Services$^3$.

Preliminary results reveal a likely increase in debris-flow occurrence in the Illgraben in the future. Such an increase can be attributed to an extension in the debris-flow seasonal changes in the discharge regime. Furthermore, the number of landslides filling the sediment storage increases because they are affected by a shorter duration of snow cover and thus greater exposure to freeze-
thaw weathering. However, projections are subject to large uncertainties, stemming not only from uncertainty in climate scenarios, but also from internal climate variability. Furthermore, the simplified hillslope weathering and debris-flow triggering mechanisms contribute to the overall uncertainty. Nevertheless, the methodology is thought to be transferable to any sediment-cascade-like catchment where dominant processes are driven by climate. Lastly, this work highlights the importance of considering stochasticity in climate and sediment history for projections of magnitudes and frequencies of relative rare events as debris flows. This allows us to explicitly separate climate change signals in geomorphic processes from fluctuations induced by internal natural variability.

REFERENCES

