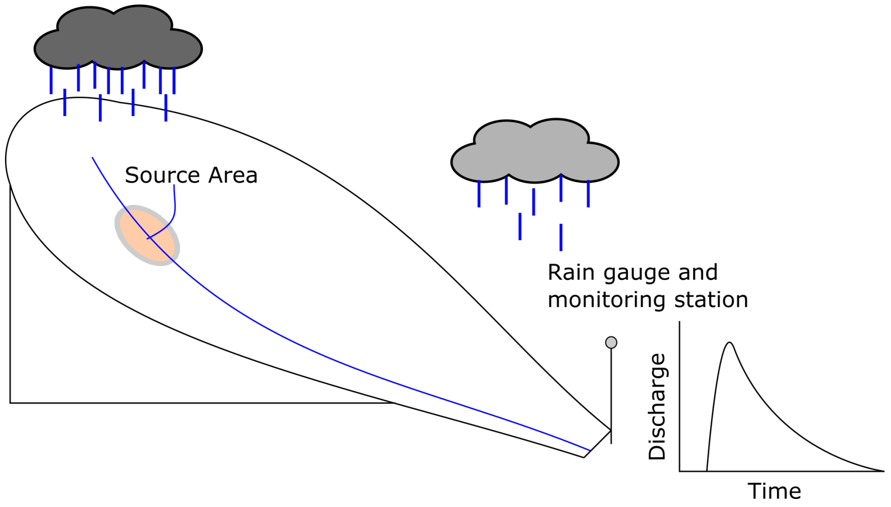
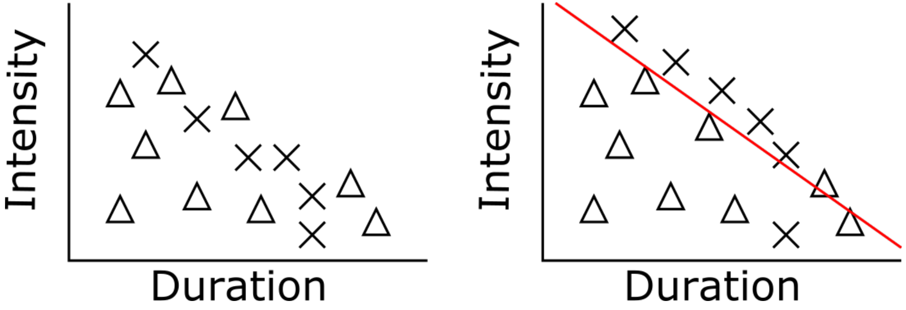
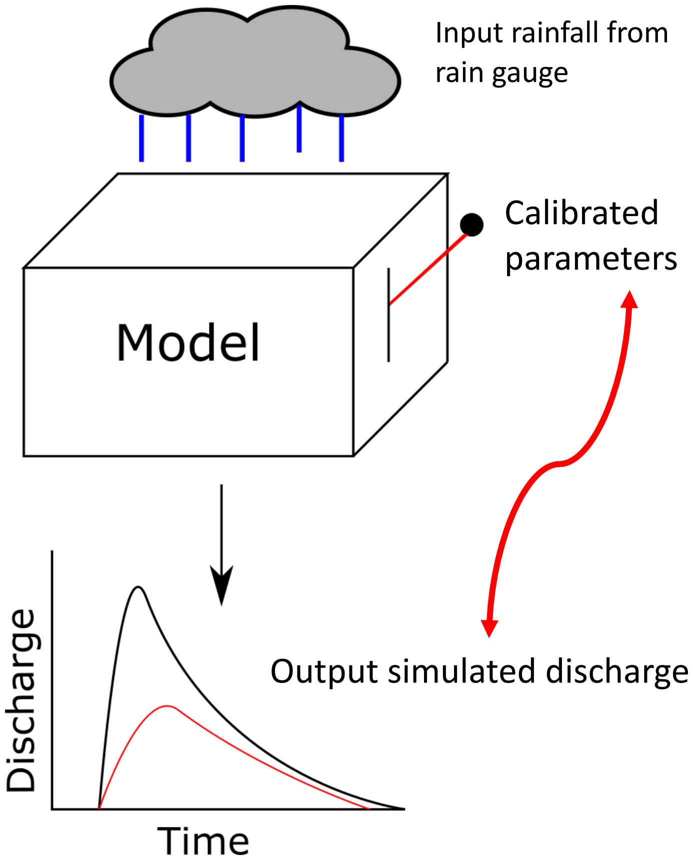
Rainfall Spatial variability, rainfall intensity–duration (ID) thresholds, and the initiation of debris flows in the eastern Italian Alps

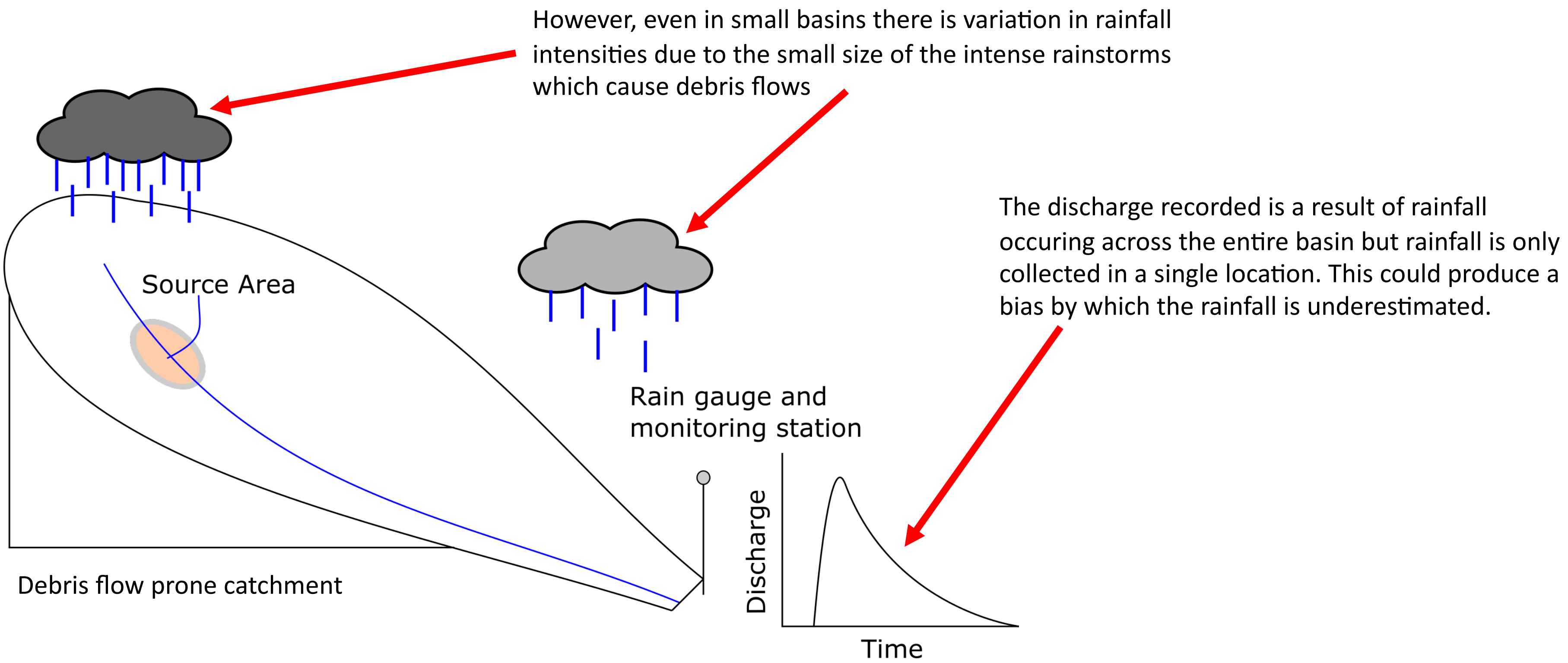
Oliver Francis, Hui Tang, Carlo Gregoretti, Matteo Berti, Martino Bernard, and Alessandro Simoni



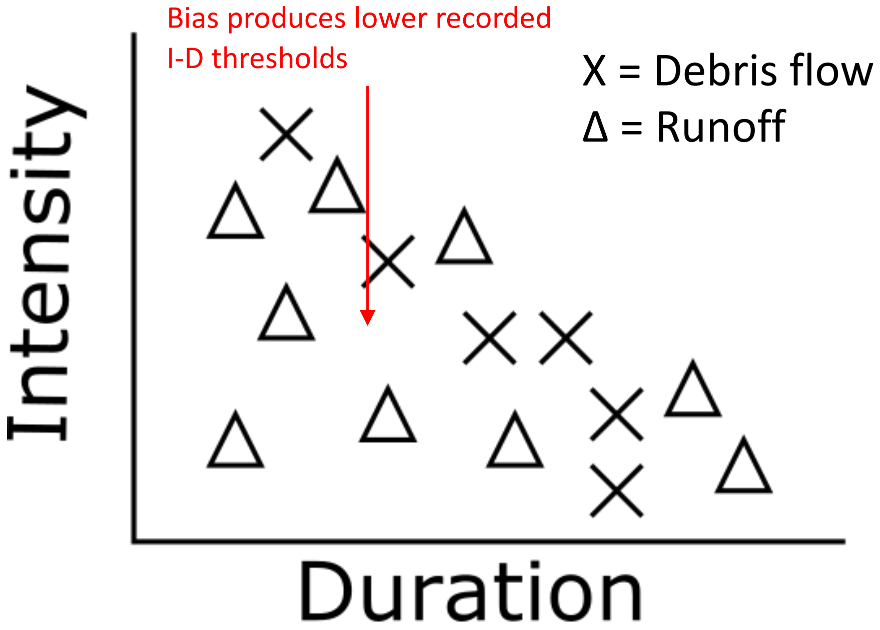




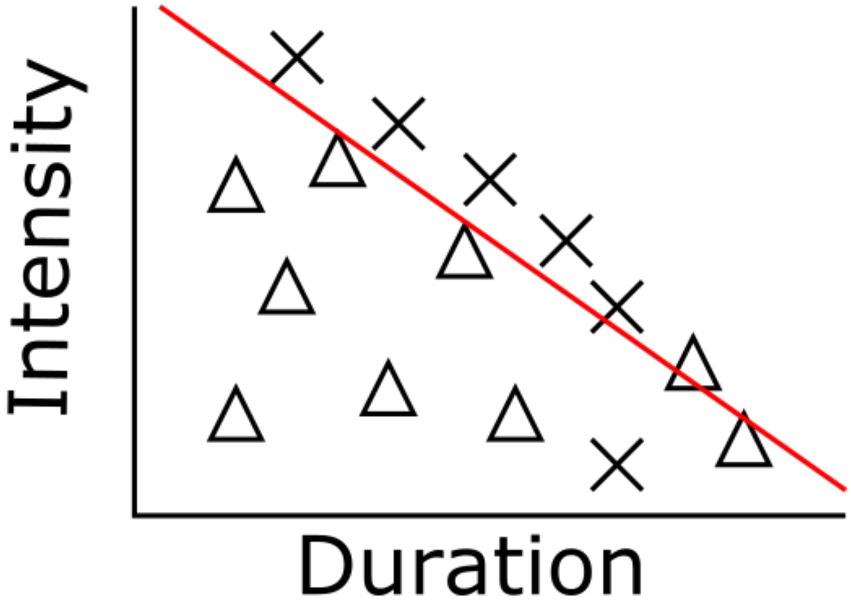
Debris flows in steep bedrock catchments initiate during short intense rainstorms. The rain produces runoff in these catchments which, once a critical threshold is exceeded, can entrain sediment and evolve into a debris flow. To identify this threshold debris flow prone catchments are monitored with a rain gauge to detect the intensity and duration of debris flow triggering rainstorms.



After recording multiple run off and debris flow triggering rain storms we can estimate the rainfall intensity-duration (I-D) threshold required to generate debris flow. Using rain gauges not directly in the source area of the debris flow can produce a bias in the estimated threshold preventing the threshold from being used for forecasting.



Marra et al 2016 demonstrated that this bias underestimates the I-D required for debris initiation. The bias is greatest when the storms are small and of short duration.



Without removing the bias it is impossible to separate the rainfall which triggers debris flows from those that just produce runoff. Using a numerical model which uses variable rainfall could help to remove the bias

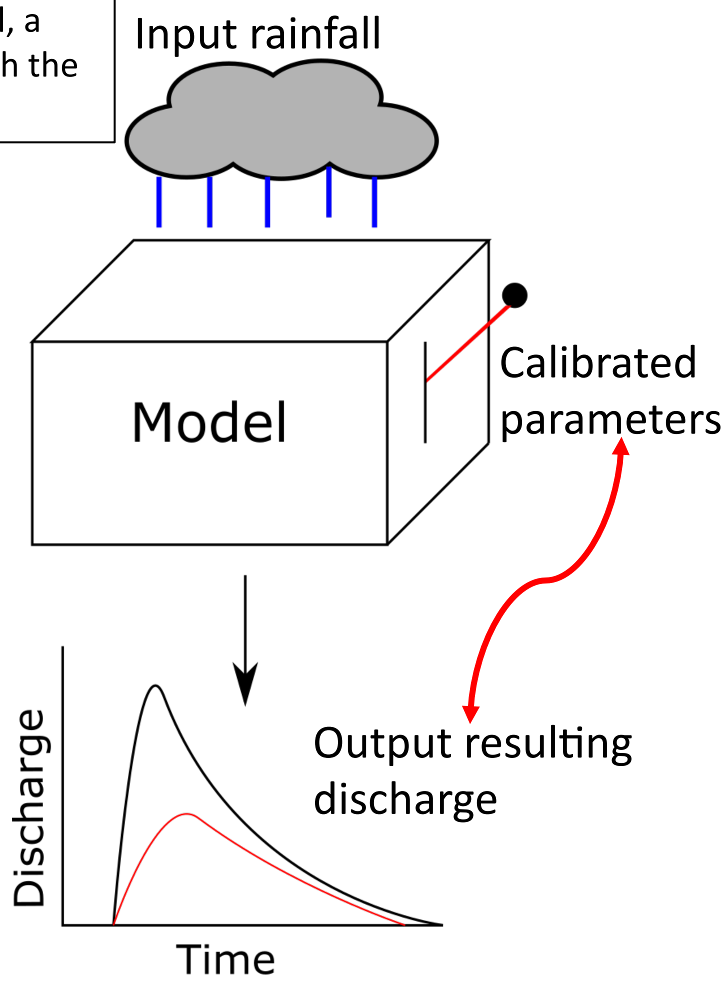
Most numerical models which simulate run off use a combination of rainfall, a DEM, some hydrological parameters and a discharge record to compare with the model output.

Rainfall is typically input as a single value which varies through time but not across the catchment area.

The models then calculate the runoff using the rainfall and hydrological parameters which are estimated from field and model observations.

Finally the output simulated discharge is then compared to the discharge record. The parameters are then calibrated until the simulation matches the discharge record.

However, assuming the rainfall does not vary over the catchment could introduce errors into the model through this calibration process

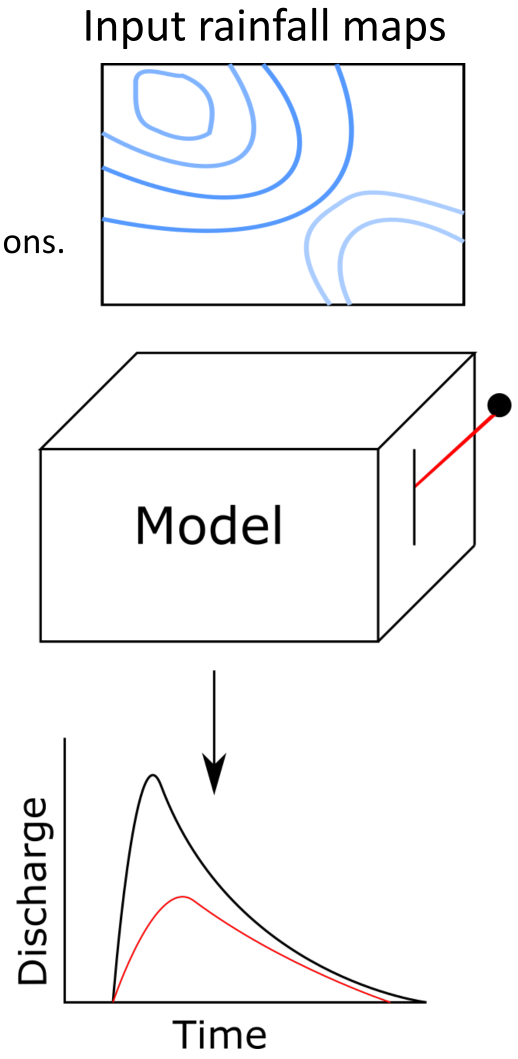


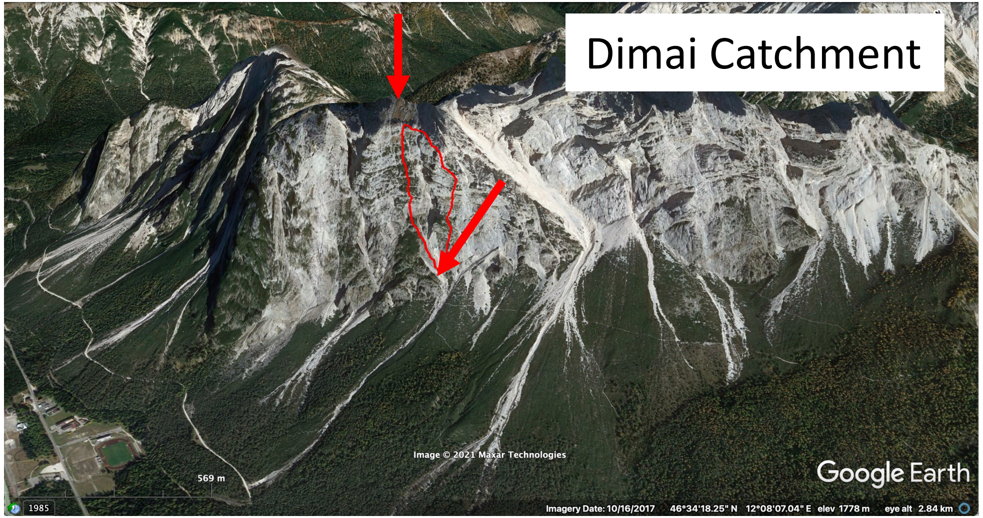
Our project: Using catchments with mulitple rain gauges we can investigate the impact of spatially variable rainfall on debris flow triggering.

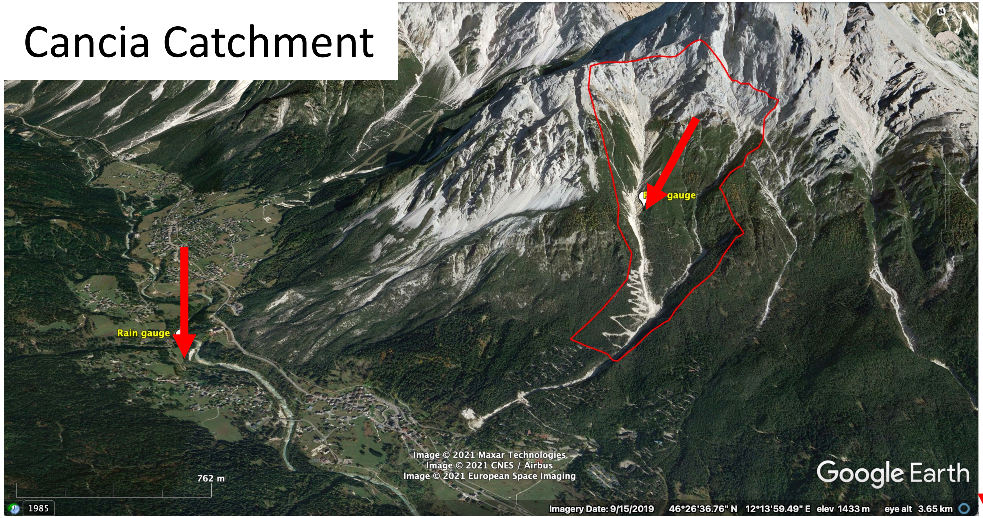
Rainfall maps can be produced from rain gauge networks, rainfall radar, or simulations.

By calibrating the model with the spatially variable rainfall map we can then determine the uncertainity in the parameters by a comparasion with a model using uniform rainfall.

Finally we use the fully calibrated model to generate a new I-D threshold and test whether this modelled threshold improves the forecasting of debris flows.



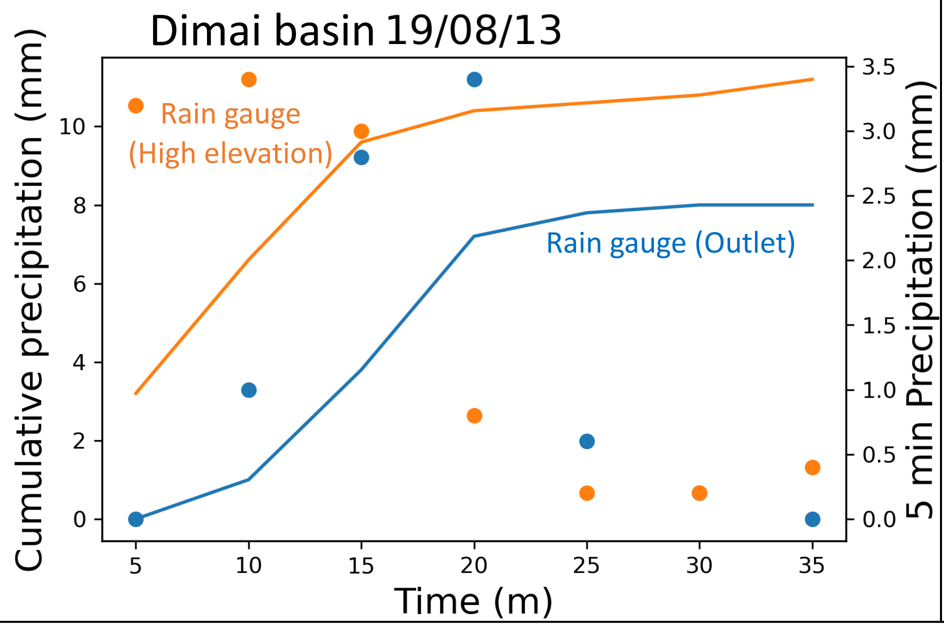




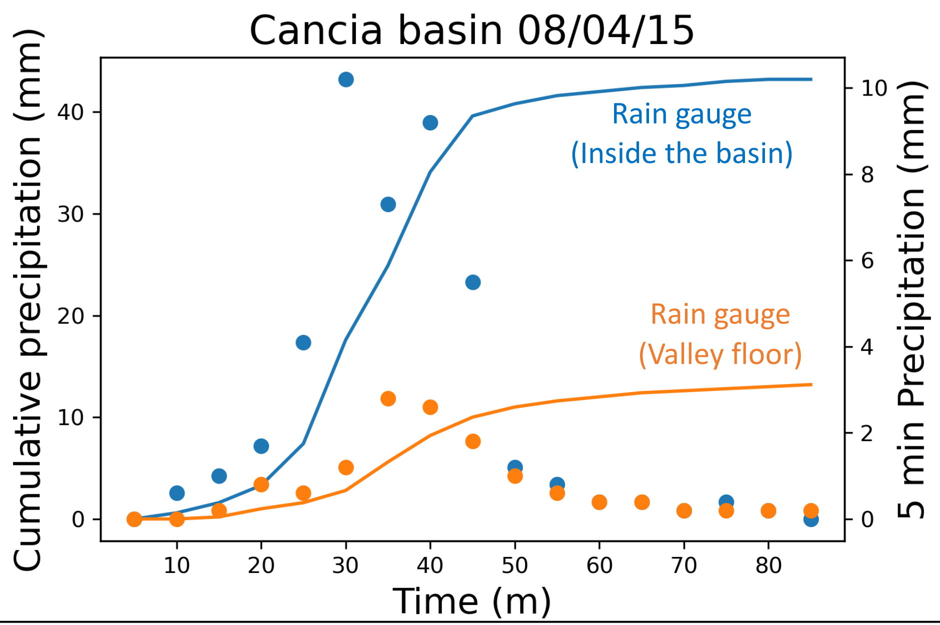
Our current study area is the North East of Italy in the Dolomites of the Italian Alps.
Here there are multiple montiored debris flow catchments with multiple rain gauges.
Currently we are working on the Dimai and Cancia catchments which are steep bedrock catchments of the Boite river valley.
Debris flows are triggered by runoff during small, short but very intense rainstorms.
These catchments are well studied and many of the hydrological parameters are constrained from field data.

Rain gauge

Despite the small size of these catchments significant differences in the rainfall recorded by the rain gauges can be observed. This likely highlights the small size of the storms which trigger debris flows. This difference may also be impacted by the recording time of the rain gauges, the longer the recording time the smaller the difference.

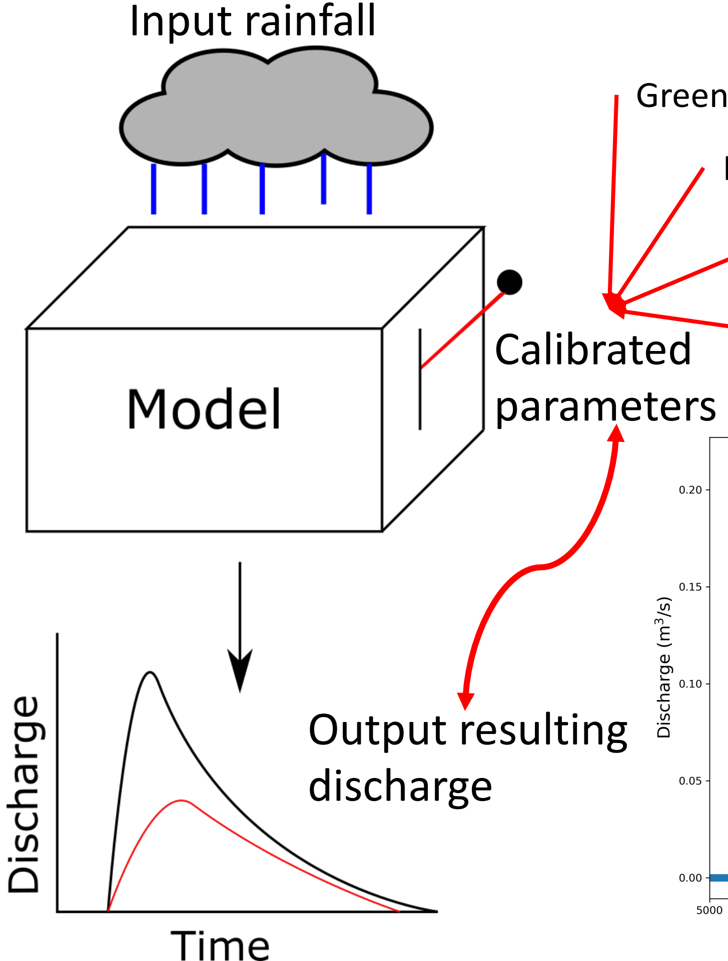


~500m between rain gauges



~3km between rain gauges

For this study we will be using an adapted version of the SWEHR model delevoped by McGuire et al 2016.

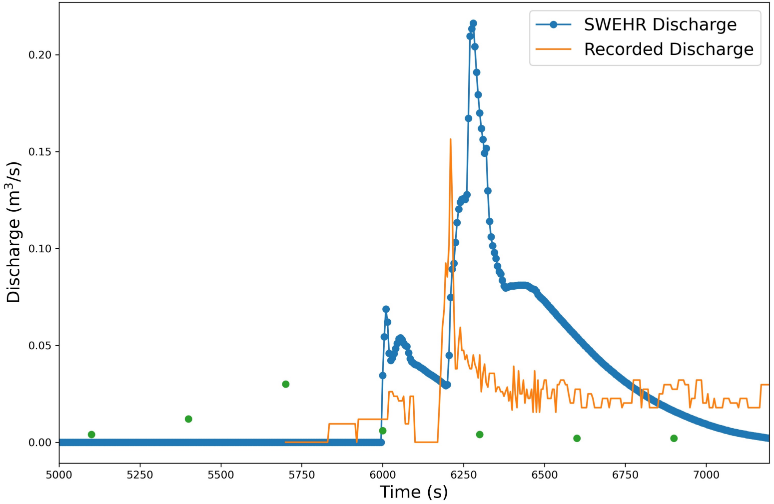


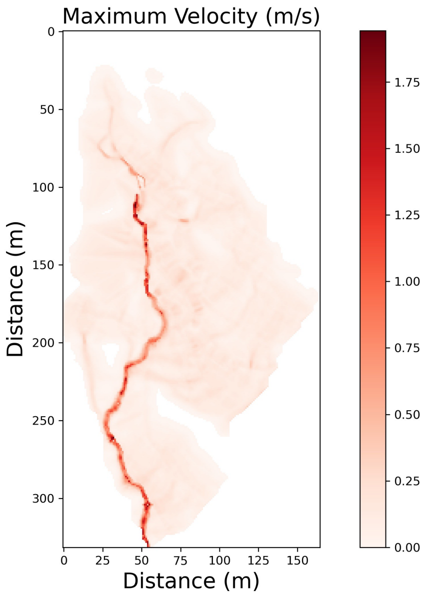
Green-Ampt Infiltration model

Harsine-Rose soil erosion model

Shallow water equations

Simplified debris flow model





Initial results of calibration of Dimai catchment, 14/08/2014 with uniform rainfall

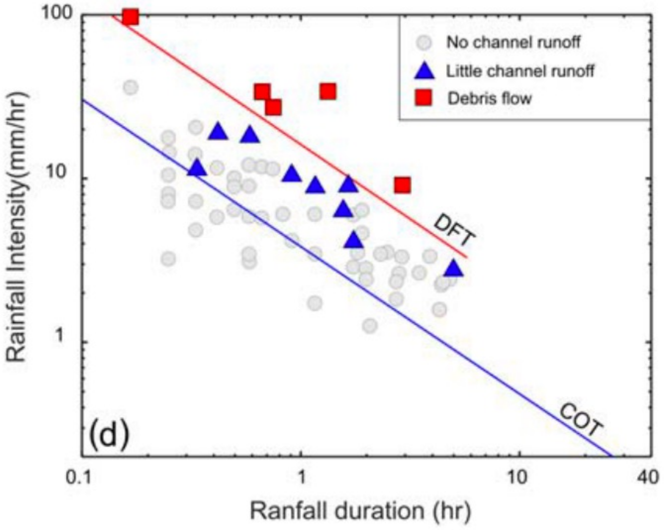
Next steps

Design or intergrate a storm generation model into the SWEHR model

Produce I-D thresholds from uniform and spatial variable rainfall models

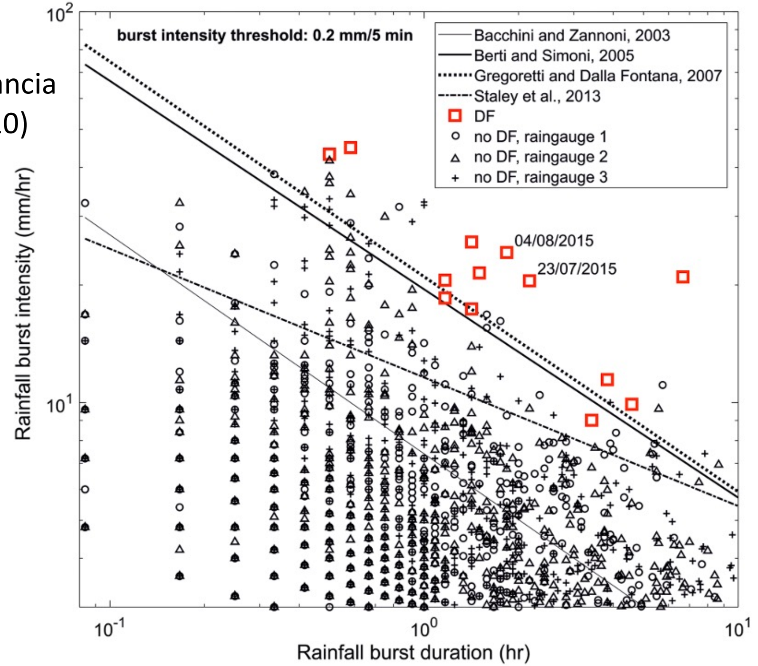
Locate larger catchments to investigate the effects of greater rainfall variability on I-D thresholds.

Contact details:
Oliver.francis@gfz-potsdam.de
Twitter: @GeomorphOllie



I-D Threshold of Dimai (Berti et al 2020)

I-D Threshold of Cancia (Simoni et al 2020)



References:

Marra, F., Nikolopoulos, E. I., Creutin, J. D. & Borga, M. Space–time organization of debris flows-triggering rainfall and its effect on the identification of the rainfall threshold relationship. *J. Hydrol.* **541**, 246–255 (2016).

McGuire, L. A., Kean, J. W., Staley, D. M., Rengers, F. K. & Wasklewicz, T. A. Constraining the relative importance of raindrop- and flow-driven sediment transport mechanisms in postwildfire environments and implications for recovery time scales. *J. Geophys. Res. Earth Surf.* **121**, 2211–2237 (2016).

Berti, M., Bernard, M., Gregoretti, C. & Simoni, A. Physical Interpretation of Rainfall Thresholds or Runoff-Generated Debris Flows. *J. Geophys. Res. Earth Surf.* **125**, 1–25 (2020).

Simoni, A. *et al.* Runoff-generated debris flows: Observation of initiation conditions and erosion–deposition dynamics along the channel at Cancia (eastern Italian Alps). *Earth Surf. Process. Landforms* **45**, 3556–3571 (2020).