5-6 Monitoring and Modelling the Aftermath of Landslide Events

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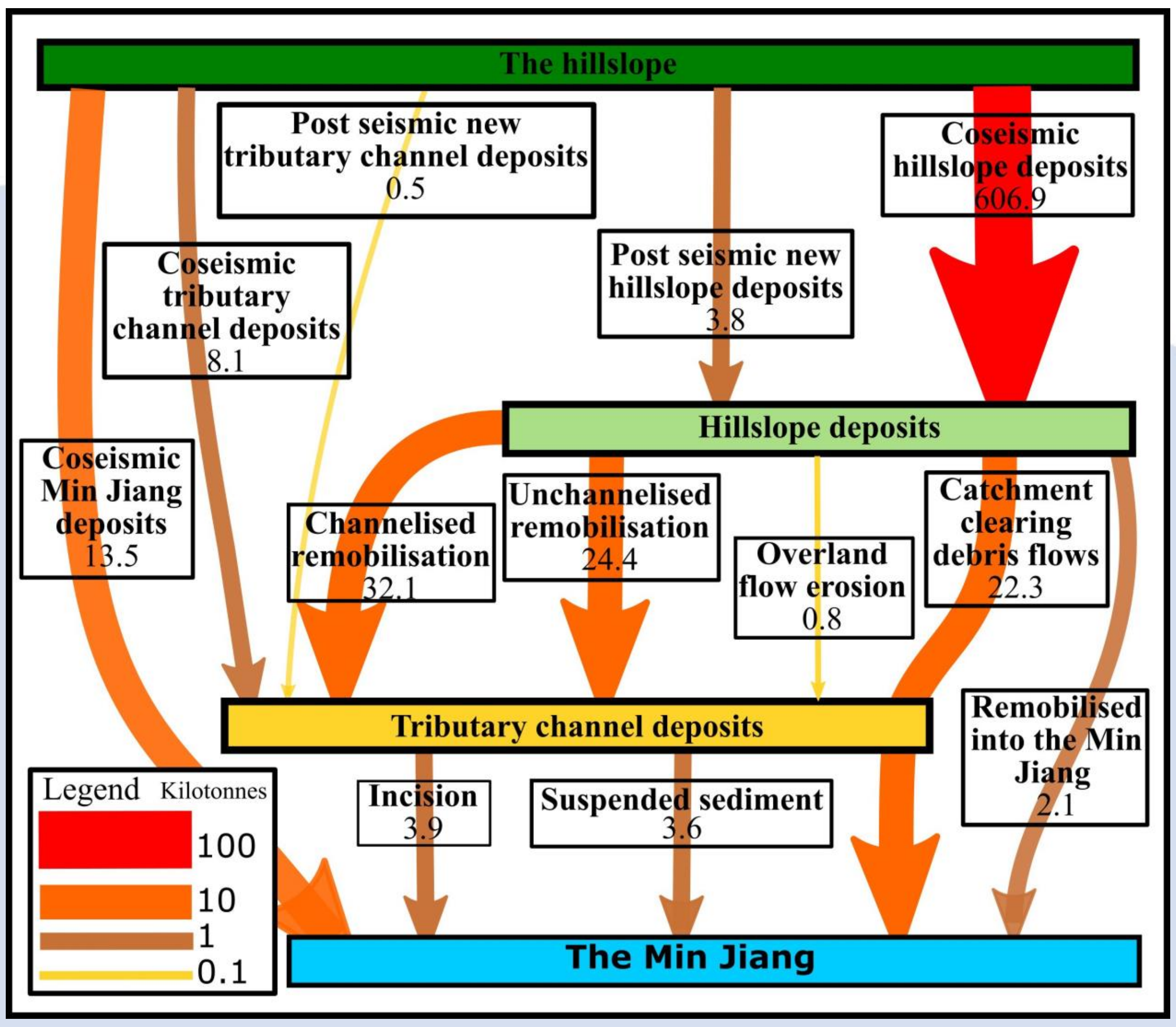
A sediment cascade: The Wenchuan Earthquake

Coarse sediment moves through mountain catchments via a cascade of interconnecting processes. Landslides generate the majority of coarse sediment in mountain ranges but only transports it a short distance, either further downslope or into the channel network. This sediment is then remobilised by debris flows and deposited further downstream before it is finally transported out of the catchment by riverine processes.
These cascades are typically studied in the aftermath of large earthquakes or in monitored catchments over long timescales. Here we present a quantified cascade of the 2008 Wenchuan earthquake and discuss a modelling framework for investigating the impact of climate change on these systems.

The processes linked to the sediment cascade are also very hazardous. For example following the 2008 Wenchuan earthquake large debris flows, such as the 2010 Qingping debris flow (right), devastated the nearby town and destroyed vital infrastructure just as it was recovering from the earthquake.

Quantifying a sediment cascade: the Wenchuan Earthquake



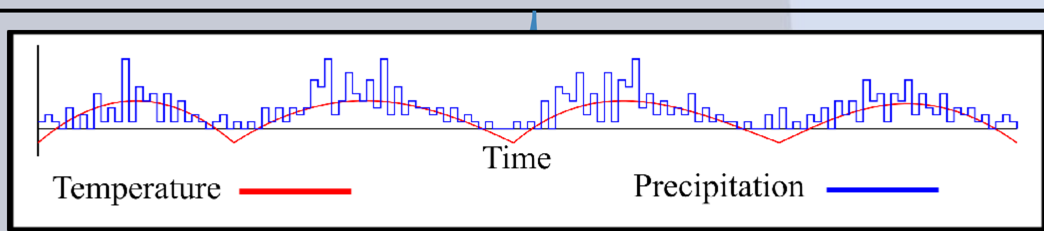
See Francis, O.R. et al. 2021. The Fate of Sediment After a Large Earthquake. Earth and Space Science Open Archive . doi: https://doi.org/10.1002/essoar.10507543.2. for more detail on the methodology of this study

We quantified the sediment cascade in the epicentral area of the 2008 M_w7.9 Wenchuan earthquake using satellite imagery and a literature review (*Francis et al., Under Review JGR Earth Surface*). We found that after the earthquake the majority of sediment mobilised from the hillslope was derived from unstable coseismic landslide deposits. These deposits were primarily eroded by debris flows (channelised remobilisation) the largest of which, catchment clearing debris flows (such as the Qingping debris flow) are the dominant process by which sediment enters the Min Jiang main trunk which drains the epicentral area.
After the earthquake all sediment transport is triggered by rainfall (i.e. the climate).

A modelling framework for investigating the impact of climate change on sediment cascades

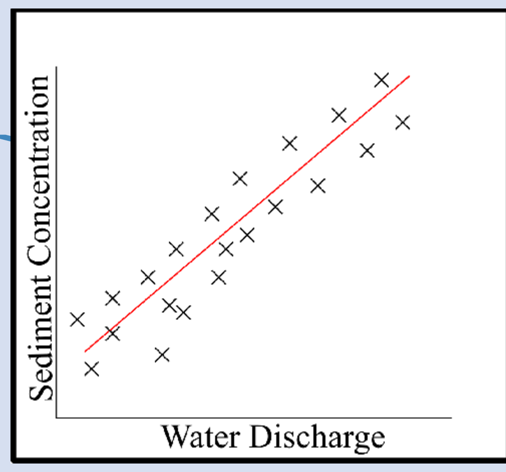
It has long been suggested that anthropogenic climate change will increase the frequency of landsliding in mountainous landscapes due to an increase in the intensity and frequency of rainstorms (Gariano and Guzzetti 2016). However it is not clear how the secondary parts of the sediment cascade will respond. Each process in the sediment cascade has its own rainfall threshold which may be different to the landsliding threshold. Any mismatch between the thresholds of the different processes could alter how natural hazards and the sedimentary system is impacted by climate change. Here we propose a simple modular framework of models which can interact with each other and a climate model to investigate the impact of climate change on mountainous catchments.

A climate model – Each component of the sediment cascade is driven by the output of a simple climate model. Most of the processes are driven by precipitation but other outputs, such as temperature, could also be important.



The climate model can return temperature and precipitation statistics which can be altered by possible forcing scenarios.

A Landsliding model – Landslide susceptibility models combine slope stability and hydrology models to determine the likelihood of a pixel failing during a given rainstorm. Susceptibility can be converted into probability by considering the return period of rain storms (Rosso et al. 2006). The triggering model can be combined with estimates of failure plane depths to determine the volume of sediment generated in the studied catchment (Campforts et al. 2020).



The sediment concentration of a river is related to the availability of sediment in its reach. Connectivity and the effectiveness of the sediment cascade will likely determine how and when the sediment flux of the river responds to a change in climatic forcing.

Debris flow model – Debris flows in previously deposited sediment are typically triggered by runoff. Surface runoff can trigger debris flows by channel bed failure or by a progressive increase in sediment concentration (McGuire et al. 2017). Debris flow initiation is thresholded which is controlled by the hydraulic conductivity of the ground and by the properties of the mobilised sediment. The model will determine the frequency and magnitude of sediment entering the channel network from otherwise disconnected landslide deposits.

River transport – Landslide derived sediment is deposited into the river network either directly by well connected landslides or by debris flows. The majority of sediment is mobilised during flooding, therefore accurate sediment transport modelling must include variable discharge (Perron 2017). The variability of the discharge will be driven by the climate model.

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