Challenges of modelling recent, very large lahars at Nevado del Huila Volcano, Colombia

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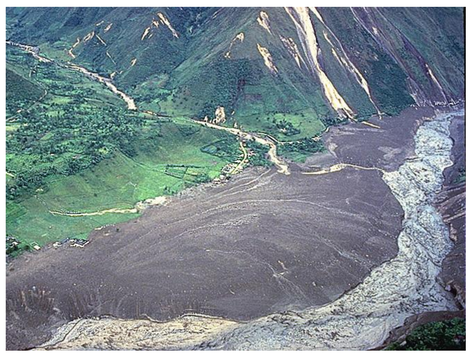
Introduction

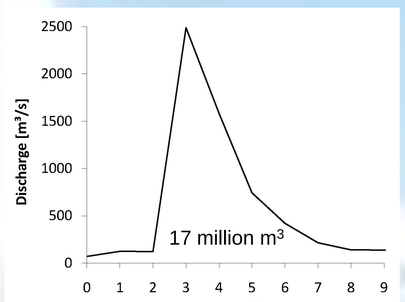




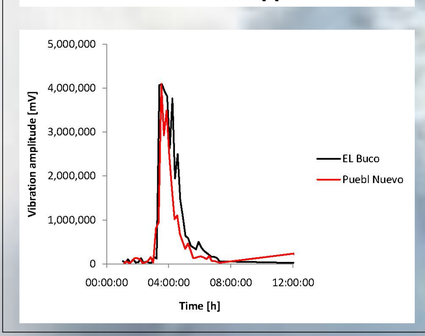
Large amounts of released water in steep mountain areas pose a major hazard for populated areas in downstream valleys. Events like volcanic debris flows (lahars) or outburst floods like GLOFs can be particularly destructive because large volumes of water are often released during such processes over a short period. Peak discharges generally are many times larger than the peak flows of rainfall and snowmelt floods in the same basin. Drain volumes in excess can easily attain tens to hundreds million m³ and run-out distances of 200 km have been documented.

In this study, we aim at analyzing the recent lahars from Nevado del Huila Volcano to better understand related hazards and to support prevention activities. We used lahar inundation depths, extent and reach, measured hydrographs and geophone seismic sensors to constrain the lahar dimensions. FLO-2D and LAHARZ programs were calibrated on the basis of past lahar events at Nevado del Huila and were then used for scenario-defined lahar modelling.

Reconstruction of the April 2007 lahar hydrograph

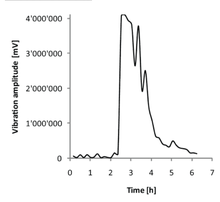


Discharge was measured 90 km downstream from Nevado del Huila where a lot of material has been deposited. As discharge was only measured in a one-hour interval this hydrograph underestimates the total lahar volume.

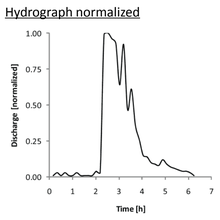


Geophone recordings were used to define an appropriate hydrograph for the upper river sections. Geophones measure the vibration amplitude of the passing lahar and provide the form of the hydrograph.

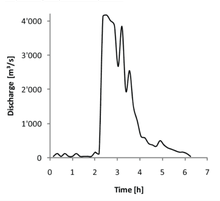
Measured data



Hydrograph normalized

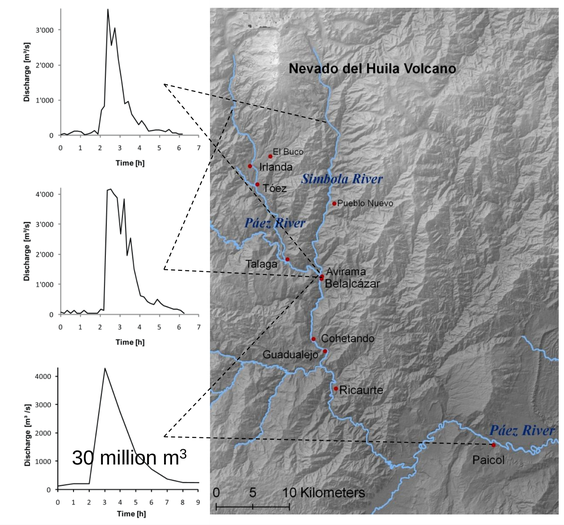


Hydrograph adapted



FLO-2D was used to define the April 2007 lahar volume. The model input volume that best represented inundation depths measured in the field was 30 million m³, which is assumed to be the lahar volume. This volume was then implemented in the hydrograph from discharge measure-ments and geophone recordings. Therefore the y-axis was normalized to values between 0 and 1 and then multiplied with the necessary discharge so as to obtain the specified lahar volume under the curve.

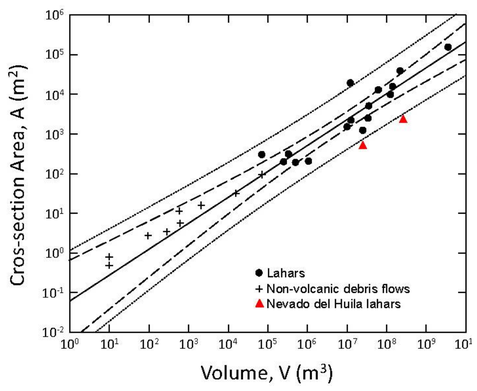
These hydrographs were applied for lahar modelling with FLO-2D, representing different river sections.

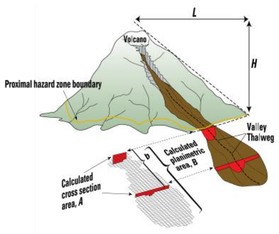


LAHARZ calibration

Iverson et al. (1998) linked in a semiempirical relationship wetted valley cross-sections (A) with flow volumes (V) based on 27 documented lahars and non-volcanic debris-flows. The resulting equation calculates in the LAHARZ program indirectly lahar inundation depths.

Cross section areas of Nevado del Huila lahars in 1994 and 2007 were plotted against the corresponding volumes. As resulting points lie outside of the confidence interval LAHARZ – equations were recalibrated.





Original equation

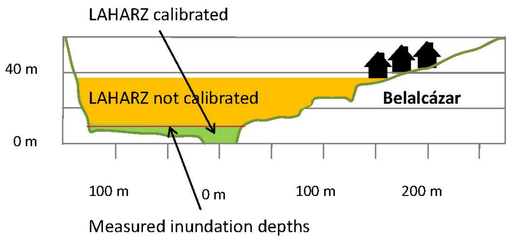
$$A = 0.05V^{2/3}$$

Calibrated equation

$$A = 0.0065V^{2/3}$$

A= wetted cross-section area
V= Lahar volume

Modelled cross-sections



FLO-2D and LAHARZ model outputs in Belalcázar, the biggest community in the valley.

- The applied volumes in the scenario-defined modelling are in a magnitude of past events and worst case scenarios which are e.g. partial collapses of the volcano.
- The communities of Tóez, Talaga, Belalcázar and Cohetando would be directly affected by any lahar bigger than 60 million m³ with the consequence of significant loss of infrastructure and lives.
- Highest inundation depths are calculated ca. 500 m downstream from Belalcázar, due to the steep and narrow valley form, the bend and backwater effects.
- In the Belalcázar region the minimal Froude number of 1 (supercritical flow) is exceeded for most of the midstream grid cells. In the transition zone with subcritical flow hydraulic jumps can occur.

- Maximum modelled inundation depths for a lahar volume of 60 million m³ would hit Belalcázar in the periphery.
- Calculating inundation depths with a volume of 320 million m³ affects Belalcázar to a major extent.
- Modelled maximum flow depths exceed 40 m and 50 m, for lahar scenarios of 600 and 1000 million m³, respectively. These volumes could not be modelled with FLO-2D, due to the required long computation times. Lahar scenarios with such dimensions would heavily harm Belalcázar.

Conclusion

Considering the huge hazard potential emanating from high-magnitude water-driven processes such as lahars, outburst floods or debris flows, it is of great importance to improve our fragmentary understanding of involved processes and dynamics. However, due to the difficulty of directly measuring high-magnitude floods it is challenging to approach this lack of quantification. To face this problem, a detailed study of well-characterised events is the base to gain knowledge about flow physics and flow parameters.

Numerical modelling provides a valuable tool for quantitative prediction of large-scale floods. However, the possibility must exist to adjust and calibrate flow parameters and perhaps even more importantly, models have to be fully validated with adequate field studies.