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Mathematical modelling of the transport of a poorly sorted granular mixture as a debris-flow. The case of Madeira Island torrential floods in 2010

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On the 20th February 2010, heavy rainfall was registered at Madeira Island, North Atlantic. Stony debris flows, mudflows and mudslides ensued causing severe property loss, 1.5 m thick sediment deposits at downtown Funchal including 16th century monuments, and a death toll of 47 lives. Debris-flow fronts propagated downstream while carrying very high concentrations of solid material. These two-phase solid-fluid flows were responsible for most of the infrastructural damage across the island, due to their significantly increased mass and momentum.
The objective of the present modelling work is to validate a 2DH model for torrential flows featuring the transport and interaction of several size fractions of a poorly-sorted granular mixture typical of stony debris flow in Madeira. The module for the transport of poorly-sorted material was included in STAV-2D (CERIS-IST), a shallow-water and morphology solver based on a finite-volume method using a flux-splitting technique featuring a reviewed Roe–Riemann solver, with appropriate source-term formulations to ensure full conservativeness. STAV-2D also includes formulations of flow resistance and bedload transport adequate for debris-flows with natural mobile beds (Ferreira et al., 2009) and has been validated with both theoretical solutions and laboratory data (Soares-Frazão et al., 2012; Canelas et al., 2013).
The modelling of the existing natural and built environment is fully explicit. All buildings, streets and channels are accurately represented within the mesh geometry. Such detail is relevant for the reliability of the validation using field data, since the major sedimentary deposits within the urban meshwork of Funchal were identified and characterized in terms of volume and grain size distribution during the aftermath of the 20th February of 2010 event. Indeed, the measure of the quality of the numerical results is the agreement between simulated and estimated volume of deposited sediment and between estimated and modelled grain-size distribution of the deposits.
The formulations expressing closures for size fraction interaction and active layer dynamics are discussed. The simulation tool resulting from this modelling effort is expected to help the establishment of new methodologies and parameters for hydraulic design and hazard assessment in the Island of Madeira.

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