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Investigating the self-organization of debris flows: theory, modelling, and empirical work

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Here we present the conceptual framework of an interdisciplinary project on the theory, empirics, and modelling of the self-organisation mechanisms within debris flows. Despite the fact that debris flows are causing severe damages in mountainous regions such as the Alps, the process behaviour of debris flows is still not well understood. This is mainly due to the process dynamics of debris flows: Erosion and material entrainment are essential for their destructive power, and because of this destructiveness it is nearly impossible to measure and observe these mechanisms in action. Hence, the interactions between channel bed and debris flow remain largely unknown whilst this knowledge is crucial for the understanding of debris flow behaviour. Furthermore, while these internal parameter interactions are changing during an event, they are at the same time governing the temporal and spatial evolution of a given event. This project aims at answering some of these unknowns by means of bringing theory, empirical work, and modelling of debris flows together. It especially aims at explaining why process types are switching along the flow path during an event, e.g. the change from a debris flow to a hyperconcentrated flow and back. A second focus is the question of why debris flows sometimes exhibit strong erosion and sediment mobilisation during an event and at other times they do not. A promising theoretical framework for the analysis of these observations is that of self-organizing systems, and especially Haken's theory of synergetics. Synergetics is an interdisciplinary theory of open systems that are characterized by many individual, yet interacting parts, resulting in spatio-temporal structures. We hypothesize that debris flows can successfully be analysed within this theoretical framework. In order to test this hypothesis, an innovative modelling approach is chosen in combination with detailed field work. In self-organising systems the interactions of the system elements are local and simple, but are at the same time leading to a coordinated system-wide activity and pattern. Existing modelling approaches are very limited in reproducing this activity and pattern, which is why we apply an evolutionary design approach via the tool FREVO. It applies heuristic search methods to derive the microscopic interaction rules between agents, which produce the desired macroscopic behaviour. For a given behaviour, this approach can be used to fine-tune a manually given rule set or to search for possible rule sets in order to create a hypothesis of how micro-components interact. A CA model will serve as basis for this heuristic modelling approach. Theory application and development as well as the search for suitable parameter sets with an evolutionary algorithm will be accompanied, cross-checked and validated by field observations.