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# SCIDDICA-SS1, a preliminary cellular model for combined subaerial-subaqueous flow-like landslides: first simulations of the 1997 Albano lake (Rome, Italy) debris-flow

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Complex dynamical systems, which evolve on the base of local interactions, may be modelled within a discrete space/time by Cellular Automata (CA). Flow-like landslides, whose behaviour is predominantly fluid-dynamical, match well this requirement.

A CA involves a regular division of the space in cells; the attributes of each cell (substates) represent physical characteristics of the real space part corresponding to the cell. Substates change according to a transition function, that depends on the neighbouring cells; transition function and neighbouring conditions are invariant in the space/time. At the step 0, the cell substates describe initial conditions, then the system evolves changing the substates of all the cells simultaneously. Each computation step corresponds to a fixed time interval. Our research group developed the family of semi-empirical deterministic CA models SCIDDICA (Simulation through Computational Innovative methods for the Detection of Debris flow path using Interactive Cellular Automata).

SCIDDICA-SS1 derives from SCIDDICA-S3hex, validated against the Sarno (Italy) subaerial landslides of 1998. The innovative points concern the modelling of complicated transition of the debris flow from the subaerial environment to the subaqueous one, the more accurate energy computation, necessary because of subaqueous conditions. SCIDDICA-SS1 is a two dimensional CA with hexagonal cells, where the third dimension is expressed by some substates. The cell substates are: cell altitude (in meters a.s.l.), thickness of landslide (in meters), depth of erodable regolith (in meters), outflows of landslide (in meters) from a cell toward the adjacent cells; kinetic head (in meters), kinetic energy (in joules) of the landslide. The different behaviour (subaerial/subaqueous) is automatically detected by the cell altitude together with the debris thickness and involves different values of the parameters of motion algorithms and energy dissipation. During the air/water transition, where both the behaviours coexist, interaction effects between the two parts are added and computed. The transition function involves the following "elementary" processes: 1) determination of debris outflows from the cell; 2) mixing of inflows and remaining debris inside the cell (new thickness and energy values); 3) mobilisation triggering with energy dissipation; 4) debris loss in first touching water and energy dissipation. Furthermore the features of the model permit to obtain time and intensity consideration from the simulations in the limits of the space-time discretisation.

SCIDDICA-SS1 was validated against the 1997 Albano lake event which is a rare case of combined subaerial-subaqueous debris-flow. This landslide occurred in the eastern slope of the Albano lake on the 7th of November 1997 after an intense rainfall event (128 mm in 24 hours), and it began as a soil slide, mobilizing about 300 $m^3$ of eluvial material; the so mobilized mass was channeled within a steeply dipping impluvium (about 40°) and thus evolved as a debris flow which entrained a large amount of debris material along the bottom of the channel and reached an estimated volume of some thousands of cubic meters at the coastline. A few amount of material deposited at coastline while a greater quantity entered in water generating a little tsunami wave. Detailed subaerial and submerged topographic data was acquired in 2005 and 2006 through aerial LiDAR and sonar multibeam swath bathymetric surveys, performed by the INGV (Italian National Institute of Geophysics and Volcanology) in the frame of a project sponsored by the Italian National Civil Protection Department. So, a 1m cell size DTLM (Digital Terrain and Lacustrine Model) was produced and allowed us to map in detail both the subaerial and the submerged detachment and deposition areas and to estimate their volumes.

Simulations permit to validate the general model and to calibrate adequately its parameters; results show a good agreement concerning erosion and deposits on both subaerial and subaqueous part. A comparison between the real event and the simulated one for both the environments is performed by a fitness function, that considers a normalised value between 0 (complete failure) and 1 (perfect simulation), computed by the following formula $\sqrt{((R \cap S)/(R \cup S))}$, where R is the set of cells affected by the landslides in the real event and S the set of cells affected by the landslides in the simulation.

First model results are encouraging: the value 0.72 was obtained for the fitness function and have confirmed a satisfying reliability of this preliminary model in reproducing the phenomenon; we consider this model a good base for a more complex model in the course of develop.