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Erosional modification of cinder cones explored using non-linear diffusion with spatially variable diffusivity and applied to the 2002-2003 scoria cone complex (C2002) at Mount Etna, Italy

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The temporal evolution of volcanic edifices is an important aspect of geological and geomorphological studies. Recent volcanic features like scoria cones offer the opportunity to monitor and model the processes and development of the volcano-geomorphic setting. Scoria (or cinder) cones are the most common of all volcanic landforms worldwide, commonly occurring in volcanic fields or on the flanks of large polygenetic volcanoes. Long-term erosional modifications of their relatively simple morphology are ideally suited for study by field and computer-simulation methods. Numerical simulations of the evolution of cinder cones over time were carried out using a non-linear slope dependent transport model. The model is based on the assumption that the average sediment mass flow rate can be approximated by topographic attributes (such as the slope), and that these attributes need to be only measured at a single point in order to predict the mass flow rate at that point. Furthermore, we assumed that the dominant mass transport processes are driven by a non-linear dependence on local slope. Low slopes have a nearly linear dependence, but increasing slope to a threshold value near the angle of repose scales the transport rates to nearly infinite. These assumptions are consistent with observed processes dominated by mass movements not driven by focused runoff, and led us to a nonlinear diffusion model, based on the Exner equation for the conservation of the mass. An iterative Alternating Direction Implicit (ADI) scheme has been applied to solve numerically the two-dimensional nonlinear diffusion equation with spatially variable diffusivity. While one dimensional non-linear approaches have been applied previously, the two dimensional approach provides significant flexibility with respect to non-axisymmetric and non-coaxial topographic elements. Adding spatially variable diffusivity allows us to simulate landscape evolution modulated by aspect dependent affects such as insulation and wind. We applied this approach to evolution of the 2002–2003 scoria cone complex (C2002) at Mount Etna, Italy, officially named "Monte Barbagallo". We explored the geomorphic modification of this complex and compared our results to erosional changes documented from a set of high resolution (1 m) digital elevation models (DEMs) derived from light detection and ranging (LIDAR) data collected during four different airborne surveys (2004, 2005, 2006, and 2007). To account for the asymmetric erosion and deposition patterns, the diffusivity was varied as a function of wind exposure at each pixel. The numerical results show a good agreement with the time-space erosional modifications observed for the C2002 cones, and the simulations allowed to better constraint the parameters of the model.