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Distinct Element modeling of geophysical signatures during sinkhole collapse

Djamil Al-Halbouni (1), Eoghan P. Holohan (2), Abbas Taheri (3), and Torsten Dahm (1)

(1) GFZ German Research Center for Geosciences, Physics of the Earth, Potsdam, Germany (halbouni@gfz-potsdam.de), (2) UCD School of Earth Sciences, University College Dublin, Belfield, Dublin 4, Ireland., (3) School of Civil, Environmental and Mining Engineering, The University of Adelaide, Australia

A sinkhole forms due to the collapse of rocks or soil near the Earth's surface into an underground cavity. Such cavities represent large secondary pore spaces derived by dissolution and subrosion in the underground. By changing the stress field in the surrounding material, the growth of cavities can lead to a positive feedback, in which expansion and mechanical instability in the surrounding material increases or generates new secondary pore space (e.g. by fracturing), which in turn increases the cavity size, etc. A sinkhole forms due to the eventual subsidence or collapse of the overburden that becomes destabilized and fails all the way to the Earth's surface. Both natural processes like (sub)surface water movement and earthquakes, and human activities, such as mining, construction and groundwater extraction, intensify such feedbacks. The development of models for the mechanical interaction of a growing cavity and fracturing of its surrounding material, thus capturing related precursory geophysical signatures, has been limited, however.

Here we report on the advances of a general, simplified approach to simulating cavity growth and sinkhole formation by using 2D Distinct Element Modeling (DEM) PFC5.0 software and thereby constraining pre-, syn- and post-collapse geophysical and geodetic signatures. This physically realistic approach allows for spontaneous cavity development and dislocation of rock mass to be simulated by bonded particle formulation of DEM.

First, we present calibration and validation of our model. Surface subsidence above an instantaneously excavated circular cavity is tracked and compared with an incrementally increasing dissolution zone both for purely elastic and non-elastic material.This validation is important for the optimal choice of model dimensions and particles size with respect to simulation time.

Second, a cavity growth approach is presented and compared to a well-documented case study, the deliberately intensified sinkhole collapse at Cerville-Buissoncourt in France. The outcomes of our model are compared with available extensiometer, surface-subsidence and microseismicity measurements during the pre- and syn-collapse period.

The proposed model development and a possible archive of modeled scenarios may, in combination with a geodetic and seismological sinkhole monitoring, contribute to an early-warning tool for end-users and decision makers in areas affected by natural (e.g. Dead Sea) or man-made sinkhole collapses (mines).