High-resolution InSAR Constraints on subsidence mechanisms and geotechnical parameters of sediments along the Dead Sea shores

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Sinkholes and sinkhole-related land subsidence constitute a severe geo-hazard along the Dead Sea in Israel and Jordan, affecting both human activities and infrastructure. To discriminate between potential subsidence mechanisms (dissolution, viscoelastic creep, consolidation) and to constrain some of the mechanical properties of the subsurface granular sediments, we examine a 5-year long subsidence record using high-resolution InSAR measurements from the COSMO SkyMed satellites. In particular we study: (a) sinkhole precursory subsidence, which show gradual acceleration before sinkhole collapse; (b) Land subsidence in response to surface loading, which is characterized by a quasi-exponential decay; and (c) Subsidence following flash-flood events, which is characterized by an abrupt increase immediately after the flood and a quasi-exponential decay thereafter. Precursory subsidence duration correlates with the sediment type and can thus constrain sediment properties. Quasi-exponential subsidence decay after flash-floods can be explained by: (a) A decay in salt dissolution rates due to an exponential drop of the groundwater hydraulic head after a flash flood; (b) Viscoelastic creep; (c) A combination of these two mechanisms. The Kelvin-Voigt creep model can explain the entire observed subsidence decay pattern, constraining the viscosity and elastic modulus of the consolidated gravel to 1e+15 - 1e+16 Pa s and ~175 MPa, respectively. However, constraining the elastic moduli to values reported in previous studies (600-4700 MPa), only 10-30% of the subsidence can be explained by viscoelastic creep. This implies that more than 70% of the post-flood subsidence decay should be attributed to decreasing dissolution rates due to the observed exponential drop of groundwater head. The viscosity values obtained by our calculations agree well with numerical simulations of sinkhole formation along the Dead Sea, whereas the elastic moduli are generally on the lower end of previous estimates.