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Modeling surface deformation of geothermal environments with high-fidelity finite element models

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The geothermal environment is an assembly of heterogeneous geological settings and complex interactions among different phases of rock and fluid medium. The artificial activities of energy production could further interplay with the on-going natural processes within volcanos, hotspots, and other geothermal areas to result in spatiotemporal signatures of displacements near the surface. Here, we study the temporal ground deformation near a geothermal site through processing Interferometric Synthetic Aperture Radar (InSAR) time-series data obtained over the past decades, as reconciled with the nearby GPS station. To interpret these signals and potentially reveal the reservoir's temporal activity, we employ state-of-art finite element models (FEMs) to simulate a more realistic crustal domain near the energy-production zone with irregular reservoir geometry, distributed rock materials, and surface topography. Linear Bayesian geodetic inversion and Green's function library area were adopted to quantify the cause of surface subsidence, as compared to the documented production history. Our study demonstrates an unprecedented approach to precisely simulate the elastic deformation caused by geothermal energy extraction and pumping, providing an important platform to further explore the in-depth evolving stress state and its relation to surrounding induced and natural seismicity.