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Tectonic and hydrological controls on multiscale deformations in the Levant: numerical modeling and theoretical analysis

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Understanding the role of the dynamics of water bodies in triggering deformations in the upper crust and subsequently leading to earthquakes has been attracting considerable attention. We suggest that dynamic changes in the levels of the water bodies occupying tectonic depressions along the Dead Sea Transform (DST) cause significant variations in the shallow crustal stress field and affect local fault systems in a way that eventually leads to earthquakes. This mechanism and its spatial and temporal scales differ from those in tectonically-driven deformations. In this study we present a new thermo-mechanical model, constructed using the finite element method, and extended by including a fluid flow component in the upper crust. The latter is modeled on a basis of two-way poroelastic coupling with the momentum equation. This coupling is essential for capturing fluid flow evolution induced by dynamic water loading in the DST depressions and to resolve porosity changes. All the components of the model, namely elasticity, creep, plasticity, heat transfer, and fluid flow, have been extensively verified and presented in the study. The two-way coupling between localized plastic volumetric deformations and enhanced fluid flow is addressed, as well as the role of variability of the rheological and the hydrological parameters in inducing deformations in specific faulting environments. Correlations with historical and contemporary earthquakes in the region are discussed.