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A natural pump-probe experiment reveals nonlinear elastic properties along the Irpinia Fault, Southern Apennines

Nicola D'Agostino[1], Stefania Tarantino[2], Piero Poli[3], Maurizio Vassallo[2], Gerardo Ventafridda[4], Gaetano Festa[5], and Aldo Zollo[5]

[1]Istituto Nazionale Geofisica Vulcanologia, Osservatorio Nazionale Terremoti, Roma, Italy
[2]Istituto Nazionale Geofisica Vulcanologia, Sismologia e Tettonofisica, Roma, Italy
[3]Dipartimento di Geoscienze, Università di Padova, Italy
[4]Acquedotto Pugliese SpA, Italy
[5]Dipartimento di Fisica, Università di Napoli Federico II, Italy

The conventional picture of the earthquake cycle implies that rupture is reached by progressive stress buildup until reaching fault's failure strength. Alternatively, the failure strength may be altered by changes in pore pressure and/or properties of fault rocks. This last scenario may be associated with significant modifications of the elastic properties of the crust potentially detectable with seismological tools. Natural oscillatory stress sources (tides, seasonal and multiannual) can thus be exploited to probe the time-dependent response of active fault zones to stress variations at various temporal and spatial scales and investigate time-dependent variations of its elastic properties (Delorey et al., 2021). A multidisciplinary (seismology, geodesy, geochemistry) study is carried out along the Irpinia Fault System (IFS, Southern Apennines) to investigate the response of the crust to hydrological forcing associated with phases of recharge/discharge of karst aquifers in terms of time-dependent variations of its elastic and hydraulic properties. Charge/discharge phases of the karst aquifers in the Apennines cause significant seasonal and multi-annual strain transients (Silverii et al, 2019), that modulate the secular, tectonic deformation (~3 mm/yr extension across the Apennines). It has been previously observed that these seasonal and multi-annual transients correlate with the seismicity rate (D'Agostino et al, 2018) and seismic velocity variations (Poli et al., 2020). Recent studies (Silverii et al., 2016; D'Agostino et al., 2018) have shown the high sensitivity of the IFS to hydrological stresses reflected in a complex, time-dependent response of deformation and seismicity. We performed a natural pump-probe experiment to assess the non-linear behavior of the seismogenic volumes in response to non-tectonic deformations. Seasonal horizontal strains associated with the discharge and recharge of karst aquifers are used as the "pump". Coda wave interferometry demonstrates to be a powerful tool to probe time-dependent crustal elastic properties. We computed seismic velocity variations using empirical Green's functions reconstructed by autocorrelation on continuous 14-year-long time series of ambient noise. We analyzed two different sites (co-located GPS and seismic stations), near and afar the IFS. We found that velocity variations are significant (□0.2%) near IFS and not significant farther away from IFS. We compared the velocity variations near IFS with the time series of Caposele spring discharge,

temperature, horizontal deformation and seismicity rate. Our observations are coherent at seasonal and multi-annual scales and can be explained by the same mechanism. At the time of the maximum peak of the discharge spring, representing a proxy of the hydraulic head, the seismic wave velocity is minimum, the dilation of crust is maximum and related to the opening of pre-existing cracks' system. The background microseismicity occurrence is favored by the hydrologically-related dilatation, superimposed on the ongoing tectonic extension. From the comparison between hydrological strain variations and velocity changes, we estimate a strain sensitivity of velocity change of ~-10^3 typical of worn crustal material and in good agreement with laboratory experiments. This nonlinear elasticity regime suggests the presence of a multi-fractured and damaged crust subject to periodic seasonal phases of weakening/healing, potentially affecting earthquake nucleation processes.