Space-Time Monitoring of Groundwater Fluctuations via Passive Seismic Interferometry

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Historic levels of drought, globally, raise vital calls for sustainable freshwater management. Urgently needed is a refined understanding of the structures and dynamics of groundwater systems. Here we present a novel, cost-effective approach to *in-situ* monitoring of groundwater fluctuations using data from seismograph arrays. By advancing seismic interferometry techniques, we manage to measure the *space-time* evolution of relative changes in seismic velocity (Δv/v), which can be used as a proxy for hydrological parameters. We demonstrate that Δv/v in the Coastal Los Angeles Basins during 2000-2020 match both the groundwater tables measured in isolated wells and the surface deformations inferred from InSAR. This illustrates the potential of seismological approach to augment the temporal and, in particular, depth resolution for aquifer monitoring. Maps of Δv/v reveal distinct long-term patterns (decline or recovery) of groundwater storage in basins that are adjacent but adjudicated to water districts conducting different pumping practices. Bridging the gap between seismology and hydrology, this pilot application shows the promise of leveraging seismometers worldwide to monitor, image, and evaluate underground hydrologic processes. We anticipate Δv/v to be a powerful 4-D geodataset that will bring unique perspectives for monitoring environmental systems and assessing the impact of human activities on Earth's shallow subsurface.

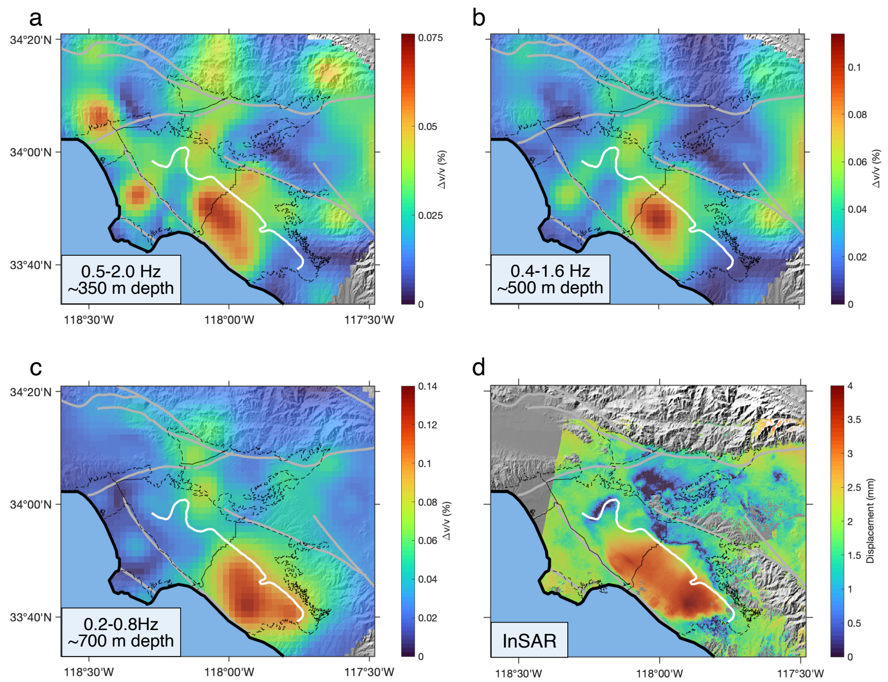

Figure 1. Seasonal variabilities of Δv/v and surface deformation. a-c: Maps of the seasonal amplitude of Δv/v measured in three decreasing frequency bands, sensitive to changes at increasing depths. **d** The map showing the seasonal amplitude of vertical displacement at the Earth's surface inferred from InSAR [Riel *et al.*, 2018].

Reference: Riel, B., Simons, M., Ponti, D., Agram, P., & Jolivet, R. Quantifying ground deformation in the Los Angeles and Santa Ana Coastal Basins due to groundwater withdrawal. *Water Resources Research*, 54(5), 3557-3582 (2018).