

# Surface deformation induced by extraction from the Groningen gas field: Implications for reservoir rheology and induced seismicity modeling

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The Groningen gas field is located in the Netherlands and is the largest onshore natural gas field in Europe. Over the years, gas extraction has caused consequential land subsidence and seismicity making it an archetype case example to test models of induced seismicity. In this study, we integrate geodetic datasets including InSAR (TerraSAR-X, Sentinel-1) and GNSS displacement timeseries during 2013-2022 to measure surface deformation. While the data show prominent multiannual subsidence, we focus our analysis on the extraction of the seasonal signal. The seasonal fluctuation of the gas production is indeed observed to modulate the seismicity and must induce seasonal stress and strain. To extract the seasonal geodetic signal, we apply the variational Bayesian independent component analysis (vbiCA). With this technique, we are able to successfully isolate the component that corresponds to the seasonal gas extraction. The seasonal geodetic signal will be used to constrain the reservoir rheology, test in particular if reservoir compaction is elastic or inelastic, estimate seasonal stress variations and constrain better the relationship between earthquake rate and stress changes.

