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Three-dimensional seasonal deformations induced by underground gas storage. Monitoring by PSI and modeling by FE

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Land subsidence and uplift due to the production/injection of fluids from/into the subsurface have been widely observed worldwide over the last decades and occur for a variety of purposes such as groundwater pumping, aquifer system recharge, gas/oil field development, enhanced oil recovery, geologic CO_2 sequestration, underground gas storage and waste disposal. The need for a reliable prediction of these processes has led to a continuous improvement of the numerical tools employed in poromechanics. However, although sophisticated poro-visco-plastic 3D codes have been developed, the lack of accurate measurements of the ground surface displacements has rarely allowed an accurate calibration of the geomechanical models.

Recently, advanced Persistent Scatterer Interferometry data, obtained by combining ascending and descending RADARSAT-1 images acquired from 2003 to 2008 above gas storage fields located in the sedimentary basin of the Po river plain, Italy, provide reliable measurement of seasonal vertical ups and downs as well as horizontal displacements to and from the injection/withdrawal wells. Combination of the land surface movements together with an accurate reconstruction of the subsurface geology made available by three-dimensional seismic surveys and long-time records of fluid pore pressure within the 1000-1500 m deep reservoirs has allowed for the development of an accurate 3D transversally isotropic poromechanical finite-element model which satisfactorily reproduces the seasonal deformation due to gas injection/removal.

An accurate calibration of the finite element model to the interferometry data is performed by combining metamodeling techniques such as Kriging and global optimization strategies specifically designed for handling uncertain measurements. Furthermore, it is also possible to estimate the functional dependence of physically relevant quantities, e.g., the maximum vertical seasonal displacement, with respect to operational parameters (e.g., working pressure) and to uncertain model parameters (e.g., elastic moduli), leading to uncertainty quantification of the predictions of the reservoir behavior under untested configurations.