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Constraints on temporal velocity variations associated with an underground gas storage in the Gulf of Valencia using earthquake and seismic ambient noise data

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During September 2013, the injection of the base gas in a depleted oil reservoir used as an underground natural gas storage (CASTOR) caused a sudden seismic activity increase in the eastern coast of Spain. As a result, a compact cluster of more than 550 earthquakes with magnitudes mbLg > 0.7 were located in the shallow offshore area of the Gulf of Valencia during two months. The strongest event, having a magnitude of Mw=4.2, was followed by two Mw=4.1 events the day after and took place once the gas injection activities had finished.
Using the seismic data recorded by permanent stations at more than 25 km from the injection well, we applied coda wave interferometry to monitor changes in seismic velocity structure between similar earthquakes. Then we solved for a continuous function of velocity changes with time by combining observations from all the closely located earthquake sources. The rate of repeating events allowed measurements of relative velocity variations for about 30 days on a daily scale. To extend the analysis in time, we also processed the continuous data using the autocorrelation of band-pass filtered ambient seismic noise. A 10-day average was required to achieve a sufficient signal-to-noise ratio in the 0.2-0.5 Hz and 0.5-1 Hz frequency bands. We quantified the time lags between two traces in the frequency and time domains by means of the Moving Window Cross Spectral Analysis and a Dynamic Time Warping technique, respectively.
Injection of fluids in geologic formations causes variations in seismic velocities associated to changes in fluid saturation, increase in pore pressure or opening or enlargement of cracks due to the injection process. Time delays associated with stress changes caused by moderate to large earthquakes have also been established. In this work, we found no velocity changes during the gas injection period nor on the occasion of the Mw 4.2 earthquake. The sensitivity of the method is dependent on the seismic network geometry and the lateral extent of the velocity anomaly. With the given network configuration we conclude that any temporal changes in seismic velocities in the CASTOR gas storage area must be smaller than 0.05%.