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Time-lapse changes within the Groningen gas field caused reservoir by compaction and distant borehole drilling

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Between 2013 and 2017, the Groningen gas field was monitored by several deployments of an array of geophones in a deep borehole at reservoir level (3 km). Zhou & Paulssen (2017) showed that the P- and S-velocity structure of the reservoir could be retrieved from noise interferometry by cross-correlation. Here we show that deconvolution interferometry of high-frequency train signals from a nearby railroad not only allows determination of the velocity structure with higher accuracy, but also enables time-lapse measurements. We found that the travel times within the reservoir decrease by a few tens of microseconds for two 5-month periods. The observed travel time decreases are associated to velocity increases caused by compaction of the reservoir. However, the uncertainties are relatively large.
Striking is the large P-wave travel time anomaly (-0.8 ms) during a distinct period of time (17 Jul - 2 Sep 2015). It is only observed for inter-geophone paths that cross the gas-water contact (GWC) of the reservoir. The anomaly started 4 days after drilling into the reservoir of a new well at 4.5 km distance and ended 4 days after the drilling operations stopped. We did not find an associated S-wave travel time anomaly. This suggests that the anomaly is caused by a temporary elevation of the GWC (water replacing gas) of approximately 20 m. We suggest that the GWC is elevated due to pore-pressure variations during drilling. The 4-day delay corresponds to a pore-pressure diffusivity of ~5m^2/s, which is in good agreement with the value found from material parameters and the diffusivity of (induced) seismicity for various regions in the world.