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Subsidence and Seismicity in the Groningen Region, North-East Netherlands

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The Groningen gas reservoir, situated in the North-East of the Netherlands, is Europe's largest producing reservoir. A total estimated volume of 2,700 billion cubic meters of gas has been extracted since 1963. Measurable subsidence, attributed to reservoir compaction, has been observed using several geodetic techniques. The region was considered aseismic until 1986, when the first seismic event was detected. Since then there has been an increase in frequency and magnitude of the events across the region, with a magnitude 3.6 earthquake in 2012 causing significant structural damage and public concern.

Induced earthquakes are located for the period 2015-2016 using a high-density shallow-surface network consisting of 60 borehole strings. Events are detected and located using Coalescence Microseismic Mapping (CMM, Drew et al., 2013) and non-linear location methods (NonLinLoc, Lomax et al., 2000), implementing a travel-time inversion technique with a high density 3D velocity model. Most of the located earthquakes lie within the reservoir levels close to fault-planes that have been imaged by seismic reflection surveys.

Surface subsidence data from Optical Levelling, PS-InSAR and GPS are combined to invert for reservoir compaction from the start of gas extraction to present, using an adapted Principle-Component Analysis Inversion Method (PCAIM, Kositsky and Avouac, 2010). The compaction model then allows for a direct comparison of the spatial and temporal representation of strain due to extraction with the located seismicity.

Kositsky, A. P. and Avouac, J.-P., 2010, Inverting Geodetic Time-Series with a Principal Component Analysis-Based Inversion Method (PCAIM), J. Geophys. Res.

Drew, J. and White, R. S. and Tilmann, F. J. and Tarasewicz, J. P. T. (2013) Coalescence Microseismic Mapping. Geophysical Journal International, 195 (3). pp. 1773-1785

Lomax, A., Virieux, J., Volant, P. & Nerge-Thierry, 2000, Probabilistic earthquake location in 3D and layered models, in Advance in Seismic Event Location, Chap. 5, pp. 101-134