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Inverting near-surface models from virtual-source gathers (SM Division Outstanding ECS Award Lecture)

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The Groningen gas field is a massive natural gas accumulation in the north-east of the Netherlands. Decades of production have led to significant compaction of the reservoir rock. The (differential) compaction is thought to have reactivated existing faults and to be the main driver of induced seismicity.
The potential damage at the surface is largely affected by the state of the near surface. Thin and soft sedimentary layers can lead to large amplifications. By measuring the wavefield at different depth levels, near-surface properties can directly be estimated from the recordings.
Seismicity in the Groningen area is monitored primarily with an array of vertical arrays. In the nineties a network of 8 boreholes was deployed. Since 2015, this network has been expanded with 70 new boreholes. Each new borehole consists of an accelerometer at the surface and four downhole geophones with a vertical spacing of 50 m. We apply seismic interferometry to local seismicity, for each borehole individually. Doing so, we obtain the responses as if there were virtual sources at the lowest geophones and receivers at the other depth levels. From the retrieved direct waves and reflections, we invert for P- & S- velocity and Q models. We discuss different implementations of seismic interferometry and the subsequent inversion. The inverted near-surface properties are used to improve both the source location and the hazard assessment.