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### Publication date

2021

### Document Version

Accepted author manuscript

### Citation (APA)

Shirmohammadi, F., Draganov, D. S., & Wapenaar, C. P. A. (2021). *Monitoring changes in the Groningen subsurface using non-physical arrivals in seismic interferometry*. Poster session presented at Nederlands Aardwetenschappelijk Congres 2021.

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## **Monitoring changes in the Groningen subsurface using non-physical arrivals in seismic interferometry**

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Seismic interferometry (SI) refers to the principle of generating seismic responses by crosscorrelating seismic observations at different receiver locations. Theory requires that the boundary sources emit the same energy, have regular spacing and are spaced densely enough. When these assumptions are not met, not only the desired physical reflections will be retrieved, but also non-physical (ghost) arrivals, including reflections. This is a result of insufficient destructive interference. The non-physical reflections are caused by internal reflections inside subsurface layers, and they are particularly important for monitoring changes in the specific subsurface layer that causes them to appear in the SI results.

We test this concept on data from numerical modelling using a subsurface model of the Groningen gas field for purposes of the DeepNL programme. The Rotliegend reservoir is located at depths between 2600 m and 3200 m, the total thickness of the Rotliegend in the Groningen field ranges from approximately 100 m to 300 m. The Groningen field is cut by several fault systems, subdividing the field into a large number of fault blocks.

We investigate utilization of non-physical reflections in multi-offset gathers and zero-offset gathers. From the multi-offset gathers, which are retrieved from SI by crosscorrelation, we show that in case of changes in the velocity and thickness of the Groningen reservoir, the non-physical reflections show a clear change. Furthermore, we show that the changes can be quantified. Thus, they can be used for monitoring purposes in the subsurface layers. The non-physical reflections in zero-offset gathers show very good conformity with the geometry of the specific subsurface layer, thus allowing imaging, e.g., of faults.

**Keywords:** Groningen, seismic interferometry, non-physical reflection, monitoring, DeepNL