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Full-waveform modelling of coupling and site effects for DAS cables

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The use of optical fibre cables to sense ground motion is one of the most researched topics in seismology at present day. By using the technique of Distributed Acoustic Sensing (DAS), a single fibre can be turned into thousands of seismic sensors, providing unprecedented spatial resolution. The instrument response of optical fibre cables, however, is largely unknown and difficult to separate from source, path, and directivity effects on seismic records, preventing us from using the information from the full seismic waveform.

Here we present a full-waveform simulation scheme developed to model the DAS instrument response using a particle-based Elastic Lattice Model (ELM-DAS). The scheme allows us to simulate a virtual cable embedded in the medium and made of a string of connected particles. By measuring the strain along these particles, we are able to replicate the axial strain natively measured by DAS as well as the effects of irregular cable geometries. The scheme allows us to easily simulate complex properties of the material around the cable (e.g., unconsolidated sediments, nonlinear materials) as well as different degrees of cable-ground coupling, both of which are believed to be the key factors controlling the DAS instrument response.

By simulating DAS cables in 2D, we observe that at the meter scale, realistic DAS materials, cable-ground coupling, and the presence of unconsolidated trench materials around it dramatically affect wave propagation, each change affecting the synthetic DAS record, with differences exceeding at times the magnitude of the recorded signal. By expanding the scheme to 3D, we can accurately include the effects of realistic, complex–and at times sub-wavelength—cable geometries and how they influence DAS records. Our observations show that cable coupling and local site effects have to be considered both when designing a DAS deployment and analysing its data when either true or along-cable relative amplitudes are considered.