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Sensitivity Analysis and Application of Time-lapse Full Waveform Inversion: Synthetic Testing, and Field Data Example for Monitoring An Underground Gas Blowout, The North Sea, Norway

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ABSTRACT

The recent emergence of the full waveform inversion (FWI) technique is paving the way for robustly incorporating head waves as well as diving waves into reservoir monitoring studies. Time-lapse refraction can provide complementary seismic solutions for monitoring the subtle subsurface changes, which challenge conventional P-wave reflection methods. However, the utilization of refracted energy for time-lapse studies has lagged behind typical methods due, in part, to the lack of robust techniques that allow for extracting easy-to-interpret reservoir information. Here, we investigate the sensitivity of 2D acoustic, time-domain, FWI for monitoring a shallow, weak velocity change (-30 m/s, or -1.6 %). The investigation provides us with practical tips for a better application of the full waveform technique. The sensitivity tests are designed to address issues related to the feasibility and accuracy of FWI results for monitoring the field case of an underground gas blowout that occurred in the North Sea. The blowout caused the gas to migrate both vertically and horizontally into several shallow sand layers. Some of the shallow gas anomalies were not clearly detected by conventional 4D reflection methods (i.e., time shift and amplitude differences) due to low 4D signal-to-noise ratio as well as weak velocity change. On the other hand, FWI sensitivity analysis showed it is possible to detect the weak velocity change with this non-optimal seismic input. The detectability was qualitative with variable degrees of accuracy depending on the different inversion parameters used. With this in mind, the real 2D seismic data from the North Sea were inverted with a greater attention to refracted and diving wave energy (i.e., most of the reflected energy was removed for the shallow zone of interest by removing traces with offset less than 300 meters). The FWI results provided better detectability compared to the conventional 4D stacked reflection difference method for a weak shallow gas anomaly (320 meters deep).