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Reevaluating seismic hazard and ground motions for North Sea CO2 storage projects

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The North Sea plays a strategic role in the transition towards the green economy, as it hosts many offshore wind farms and carbon capture and storage (CCS) sites. The North Sea is characterized by moderate seismicity. For example, the 2023 Mw 5.1 North Sea earthquake was the largest earthquake in the region in 33 years, and led to a temporary shutdown of production of Equinor's oil platform Snorre B.

The last comprehensive seismic hazard assessment of the North Sea was performed about twenty years ago (Bungum et al. 2000). Since then, there have been many new ground motions recorded from both onshore and offshore seismic stations in the North Sea region, as well as major advancements in probabilistic seismic hazard assessment (PSHA) methodology. As a result, this study aims to develop the first region-specific ground-motion model for the North Sea, which will be used in an updated PSHA to ensure the safe design of new offshore wind farms and CCS sites.

This research forms a part of the SHARP-Storage project, an interdisciplinary Accelerating CCS Technologies project developing improved methods for quantitative assessment of subsurface CO_2 storage containment risks. The SHARP project compiled a dataset of North Sea ground-motion records, which comprises data on natural seismicity from broadband seismometers, both onshore and offshore. Moreover, synthetic ground motions are generated to address the paucity of recordings (especially strong motions) in the North Sea region. The associated flat-file, including the metadata and intensity measures (e.g., spectral acceleration and Fourier amplitude) of manually processed waveforms is constructed for the analysis of the ground motion characteristics in the North Sea. An empirical ground-motion model is developed based on the recorded and synthetic data, which is validated and compared with the available observations and models for the North Sea.

The ground-motion model is defined for a reference rock condition. Amplification factors to

estimate shaking at the soil surface are derived based on a database of one-dimensional site response analyses. The sediments encountered in the North Sea have been deposited in dynamically changing environments ranging from arctic to temperate and reworked by the movement of ice sheets. As a result, a wide range of soil types and properties are found. To capture this variability, representative profiles are developed based on site investigations from locations with different soil conditions encountered in the North Sea. One dimensional non-linear site response analyses are then performed using the recorded and synthetic ground motion database to generate a database of response spectra amplification values.

This study presents the preliminary results of the North Sea ground-motion model and highlights the challenges in conducting PSHA for the North Sea region. These results improve the assessment of seismic hazard and risks to CO_2 storage security in the North Sea.