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Assessing earthquake focal mechanisms in the North Sea for risk mitigation of large-scale CO2 injections

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Decarbonisation of the European economy represents one of the current challenges to both society and the energy sector. The advancement and further application of carbon capture and sequestration (CCS) technologies are crucial components of the EU's effort to become climate-neutral by 2050. The success of CCS depends heavily on understanding the present-day stress field to anticipate reservoir and cap rock response to fluid injection. Despite its importance, many proposed carbon storage sites in the North Sea are located in areas with little to no borehole stress data available, presenting a significant challenge.

Within the ACT project SHARP Storage framework, we have addressed this gap by generating a comprehensive earthquake bulletin for the North Sea, revealing spatial clusters of seismic events with the majority of earthquakes with ML < 4. Focal mechanisms of earthquakes are excellent indicators of crustal dynamics, which are essential for assessing the present-day stress field. Therefore, to improve the understanding of the in-situ stress conditions, we created a comprehensive workflow to evaluate focal mechanisms based on data from the North Sea (Kettlety et al., 2023). First, we developed a routine for the seismological bulletin to aggregate the recorded earthquakes from international seismological centres. The following step included retrieval of the waveforms from data centres and quality control routines, which included dead channels check, exclusion of files with significant recording gaps and low signal-to-noise ratio, and corrections of errors in the station XML files. Then, a subset of data traces with sufficient quality was selected for moment tensor computations using a Bayesian bootstrap-based probabilistic inversion scheme (see Heimann et al., 2018). Using existing focal mechanism solutions for the North Sea region, we calibrated our processing routine and then applied it to selected earthquakes (after 1990, M > 3.5) to expand the existing focal mechanisms database.

The newly computed focal mechanism solutions provide valuable insight into the present-day stress field in areas outside the main hydrocarbon provinces and improve the risk assessment of ongoing and future CCS projects. Furthermore, we will release our processing workflow as an open-source package and a new focal mechanisms database of the North Sea to establish a standard processing routine that can be readily utilised for similar seismological studies.

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