NERC Centre for Doctoral Training in Oil & Gas (2016 start)

Project Title: Exploiting sparse structures in seismic modelling and inversion

Host institution: Dept of Earth Sciences, University of Oxford
Supervisor 1: Tarje Nissen-Meyer
Supervisor 2: Karin Sigloch

Project description: Seismic imaging is at the core of hydrocarbon upstream and numerous other exploration activities. With modern acquisition campaigns exceeding hundreds of thousands of shots, the corresponding modelling and inversion of waves in complex 3D media poses a formidable computational challenge. In the past, 2D acquisition and modelling represented a compromise to decrease the computational cost by orders of magnitude compared to 3D. Nowadays, most campaigns and the complexity of underlying structures (e.g. subsalt) are inherently 3D. However, large fractions of the structure are less complex or not of interest.

This project examines a new modelling approach that exploits such sparsity to connect the extent of complex structures with overall computational cost. This is achieved upon the backbone of our own well-established wave propagation solver AxiSEM, which accurately simulates waves in a 3D domain but at the cost of a 2D method. The project will connect and analyse three on-going separate activities in the context of realistic crustal structures: a local-scale version (developed at ETH Zurich), a hybrid 2D-3D approach (PhD project, Oxford), and a 3D model extension ideally suited for high frequency waves in sparse 3D structures (PhD project, Oxford). The modelling framework will be embedded within the context of imaging and inversion, and focus on optimally balancing computational shortcuts with appropriate complexity. To achieve this, we will compute and analyse sensitivity kernels from the new methodology as the basis for both imaging and inversion which will give us constraints on the nonlinearity of the inverse problem depending on structural complexity. Finally, the computational speedup allows for a closer inspection of uncertainties along the imaging workflow than previously possible. This uncertainty quantification within a Bayesian framework will assume a central role for the later part of the project and deliver crucial insight into the applicability of such full-waveform inversion in the presence of localised complex structures. We will extensively test this new approach against reference solutions such as the SEG/EAGE salt and overthrust models. Connections to the seismic industry exist, such that we shall apply it to industry datasets. This joint framework of efficient hybrid modelling will be of wide interest to the fields of seismic modelling, imaging and inversion and has the potential for transformative impact in the industry.

CDT Research theme(s): This project relates to theme 3) “exploitation in challenging environments”, in particular onshore, subsalt, complex media. The proposed project develops and examines a new methodology for seismic imaging at a significantly reduced cost and opens doors to significantly refined imaging capabilities.

Research context: Dr. Nissen-Meyer is the main author of the method AxiSEM which utilises the technology for global scale. An experienced and active team is involved in the various extensions to AxiSEM. Dr. Karin Sigloch has extensive experience in data processing, tomography and Bayesian inference. The project will be in cooperation with ETH Zurich.

Research costs: The research is computer-based, and access to national supercomputers (ARCHER) is available. Limited travel funds exist.

Career routes: The student will gain vast and unique experience in seismic modelling and imaging, and will be exposed to the exploration industry through the training (via the supervisors’ connections to industry). She/he will be in demand as specialist researcher in exploration geosciences, signal processing, field engineer for a service or oil company, as well as a wide spectrum of technical positions in science & engineering. Core industry skills such as parallel programming, wave propagation, imaging, inversion will be acquired during the training.