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Project title: Robust inversion of controlled source electromagnetic (CSEM) data

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1.

Marine controlled source electromagnetic (CSEM) method has gained popularity recently as a supplement exploration method alongside the widely used seismic method. The main advantage of the CSEM method is its ability to discriminate between hydrocarbon-filled and brine-filled formations, due to high conductivity contrasts. Although the conductivity contrasts are weaker between different brine-filled formations, it is still possible to distinguish between large-scale geological structures (strata) using CSEM. Since seismic data are sensitive to the interface between different geological strata, it seems natural to incorporate seismic data into an inversion of CSEM data. Hence, this project has aimed to use CSEM data for estimating realistic subsurface geometries, both with and without a hydrocarbon reservoir present, where interpreted results from seismic data are used as prior information. To preserve geological strata, the subsurface conductivity was represented using different model-based approaches where it was possible to change the strata interface and conductivity content separately. For inversion of CSEM data and incorporation of seismic data we developed two different strategies. The first strategy used a gradient-based optimization approach to invert CSEM data, where structures from seismic interpretation were incorporated using a technique called shape prior. Numerical experiments showed that the used of shape priors were necessary to obtain the best results. In the second strategy, CSEM data were inverted using an ensemble-based Bayesian method, where structures from interpreted seismic data are naturally incorporated as prior knowledge. The latter strategy provides a quantification of uncertainty in the conductivity content and in the shapes and positions of the geological strata. Numerical experiments showed that the methodology was able to identify relatively complex geological strata, with and without hydrocarbon reservoirs present.

2.

The main objective of this project was to further develop a previously existing model-based inversion methodology to account for the exploration setting. No major changes to the main objective occurred during the project duration. The new inversion methodology was developed to handle the unknown overburden geoelectric model and potential reservoirs.

3.

S. Tveit, S.A. Bakr, M. Lien, T. Mannseth. *Identification of subsurface structures using electromagnetic data and shape priors*, submitted to Journal of Computational Physics.
S. Tveit, S.A. Bakr, M. Lien, T. Mannseth. *Ensemble-based, Bayesian Inversion of CSEM Data Using Structural Prior Information*, in proceedings of the 76th EAGE Conference and Exhibition 2014, Amsterdam, the Netherlands.

S. Tveit, S.A. Bakr, M. Lien, T. Mannseth. *Ensemble-based Bayesian inversion of CSEM data for subsurface structure identification*, submitted to Geophysical Journal International.

4.

The ensemble-based Bayesian method, in particular, has produced promising results for model based CSEM inversion with structural prior information (assumed to be available from seismic inversion/interpretation). We think that both research direction (a) and (b) below would be interesting to pursue for a good postdoc candidate.

(a) The ensemble based method splits the available CSEM data into groups, and assimilates the data groups sequentially. So far, the splitting into data groups has been performed in a naïve manner, but it is clear that the quality of the results obtained will depend on how this split is performed. There are numerous ways the data can be split, such as; according to frequency, according to receiver positions, etc. This suggests a research direction investigating into optimal, or at least beneficial, ways to split the data into groups.

(b) The inversion experiments have so far been performed on 2.5D models (2D subsurface geometry and 3D source and receiver geometries). Uni CIPR has recently participated in the development of a CSEM simulator based on a domain decomposition Fourier finite element technique (see, S. A. Bakr, D. Pardo, T. Mannseth: *Domain decomposition Fourier finite element method for the simulation of 3D marine CSEM measurements*. J. Comput. Phys. **255**, (2013)). This technique allows CSEM simulation of subsurface models where user-selected parts of the subsurface (e.g., in the vicinity of potential reservoirs) are modelled in 3D while other parts are modelled in 2D. The joint 2D/3D simulations are much less computationally expensive than full 3D simulations, facilitating use of the DDFFE simulator in an inversion setting. This opens up an interesting research direction in addition to and in combination with (a).