Multidimensional forward modelling of EM induction data within a salinization context – is it worth the extra cost?

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In (time-domain) Electromagnetic Induction (EMI) surveys, an image of the electrical conductivity of the subsurface is obtained non-invasively. The electrical conductivity serves as a proxy for salinity via petrophysical laws. The advantage of geophysical EMI surveys is their cost-effectiveness because it is a non-contacting method, one can easily walk with the device or mount it on a vehicle or a helicopter (AEM).

An accurate interpretation of the data is computationally expensive as it requires a full 3D simulation of the induced electric currents embedded within an iterative and ill-posed inverse problem. Therefore, this forward model is usually approximated with an 1D forward model which only considers horizontal layers, for which fast analytical forward models exist. Quasi-2/3D inversion allows for lateral variation in the subsurface models, but uses those 1D forward models to generate the data. The final inversion model usually fits the (potentially intrinsic 2/3D) data well up to noise level. But what with the discrepancy between the 1D and 2D data? The biased modelling error, introduced by using a 1D forward model in a 3D problem, is difficult to estimate. Does the inversion model that fits the data via 1D model also fit the data via a 3D model? This question has already been addressed in the literature about fault detection, but in a saltwater intrusion context, the lateral variation is expected to be much smoother. And the question remains to what extent multidimensional modelling is crucial.

The time-domain AEM field data from the salinization map of the region of Flanders, Belgium is used as the case study (Flanders environment agency published the map in 2019). A specific flight line is selected for which validation data is available that shows a 2D (lateral) variation. Both results from the quasi-2D and stitched inversion with a traditional smoothing regularization is presented. An accurate 3D forward modelling is performed on both inversion models via the SimPEG package. The results of the simulations are compared with the actual field data and help us to answer the question of whether multidimensional modelling is crucial in geophysical inversion at the AEM scales and a saltwater intrusion context.