Three-dimensional finite element modelling of geophysical electric response on complex saltwater intrusion scenarios

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ABSTRACT

2D resistivity profiles are very efficient and increasingly applied to delineate the freshwater/saltwater interface in coastal aquifers and freshwater lenses in islands. Inversion of field resistivity data acquired along linear transects is usually performed over 2D vertical cross-sections. In many field conditions, the resultant 2D inverted models can include inaccuracies or distortions as consequence of lateral 3D effects, such as the presence of out-of-plane geological heterogeneities. Inverted resistivity data obtained on coastal zones to monitor saltwater intrusion can also be influenced by the position of geophysical lines in relation with the seafront. Drawing conclusions after interpretation of distorted profiles may lead to misconceptions of the real settings, including under or overestimation of the depth to saltwater leading to inaccurate predictions of the risk of saltwater intrusion. In this work we aim to improve the understanding of lateral effects on measured resistivity in coastal settings by means of a three-dimensional modelling approach. Salt concentration distributions obtained from numerical saltwater intrusion models are translated to a geophysical forward model to obtain the simulated electrical response. The geophysical synthetic data is then inverted and compared with original resistivity distributions to explore the influence of lateral three dimensional effects. The methodology is explained with synthetic models that include complex three-dimensional scenarios with geological heterogeneities affecting saltwater distribution and localized upconing caused by well over-extraction. Two-dimensional and three-dimensional model responses are compared and assessed against the original 'true' groundwater model. The procedure is finally applied to field data from Northern Ireland, where saltwater intrusion patterns are controlled by the presence of volcanic dykes. The results of this work provide some insights in studies where lateral effects would affect the electric signal, and recommendations for designing 2D surveys which minimize 3D effects. The approach can be used to increase confidence when using resistivity profiles to verify three dimensional numerical groundwater simulations.

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