Generating hydraulic models by upscaling geophysical joint inversion through airborne electromagnetics

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ABSTRACT

Realistic hydraulic models in the area of saltwater intrusion problems require the spatial distribution of the parameters hydraulic conductivity, storativity/porosity and salinity. Although boreholes provide point information, retrieving target parameters is not straightforward and restricted to few drilling locations. Geophysical measurements are able to provide parameters and their distribution non-invasively. Particularly, airborne electromagnetics (AEM) can produce 3D subsurface images of bulk conductivity of large areas. The separation between saltwater and clay/till by electrical or electromagnetic methods alone is difficult, as both exhibit high electrical conductivities. Surface nuclear magnetic resonance (SNMR) is a technique that enable to distinguish those by the target parameters water content and relaxation time, which are also linked to hydraulic conductivity. However, these are mainly available as 1D information through soundings and require an electrical conductivity distribution. We present an approach that combines different 1D information with 2D/3D models of electrical conductivity to reduce ambiguities in predicted hydraulic models. Geophysical inversion is prone to ambiguity, i.e. many models can fit the data within error bounds. Joint inversion helps to decrease model uncertainties by combining different methods. A classic option for a joint inversion is the combination of airborne EM (HEM) and ground transient (TEM) data. Another approach is a structural joint inversion of TEM/HEM with SNMR data. The three parameters, electrical conductivity, water content and relaxation time are first independently inverted using classical smoothness constraints. Subsequently, a parameter coupling is initiated by constraint weights that eventually lead to more structured models. To couple 1D inversion to the laterally or spatially constrained inversion of 2D lines or 3D volumes, two strategies can are followed: 1) use hard constraints at the 1D positions and subsequent interpolation, or 2) include the 1D problem directly into the 2D/3D problem using geostatistic regularization.

We apply the technique to measurements on the North Sea island of Langeoog. The target is a 50 m deep reaching freshwater lens in a sandy substratum with an imbedded shallow clay layer and trapped saltwater from past inundation events. The method is demonstrated on two flight lines on which coincident SNMR and TEM sounding have been acquired. Along with petrophysical parameter relations, which are calibrated on borehole data, the presented inversion is able to provide 2D images of hydraulic conductivity, porosity and salinity that can be used for hydraulic modelling of saltwater intrusion phenomena.

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