Geophysical Research Abstracts
Vol. 16, EGU2014-4991, 2014
EGU General Assembly 2014

Sequential hydrogeophysical inversion using airborne EM for 3D hydrostratigraphical zonation

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Regional hydrological models are important tools in water resources management. Model prediction uncertainty is primarily due to structural (geological) non-uniqueness which makes sampling of the structural model space necessary to estimate prediction uncertainties. Today geological input to hydrological models is made by geologists, who use cognitive approaches based on geophysical surveys and borehole observations to construct one-truth geological models. Good spatial coverage along with high resolution make airborne time-domain electromagnetic (AEM) data valuable for the hydrostratigraphical input to hydrological models. Geological structures and heterogeneity, which spatially scarce borehole lithology data may overlook, are well resolved in AEM surveys. Due to the discrepancy between hydrological and geophysical parameter spaces the challenge is to translate the electrical resistivity distribution into hydrogeological properties. The translation between hydrological and geophysical parameter space varies spatially and between sites, making a fixed translation insufficient.

This study presents a semi-automatic sequential hydrogeophysical inversion method for the integration of AEM and borehole data into regional groundwater models in sedimentary areas, where sand/clay distribution govern groundwater flow. The coupling between hydrological and geophysical parameters is managed using a translator function with spatially variable parameters followed by a 3D zonation. Observed borehole lithologies are represented as clay fractions. The translator function translates the electrical resistivities obtained in a preceding geophysical inversion into clay fractions and is calibrated with observed clay fraction data from boreholes. Principal components are computed for the translated clay fractions and geophysical resistivities. Zonation is carried out by k-means clustering on the principal components. The hydraulic parameters of the zones are determined in a hydrological model calibration using head and discharge observations. The method was applied to field data collected at a Danish field site. The dataset includes interpreted borehole observations and AEM flight path coverage. A classical geological model is available for comparison.

Our results show that a competitive hydrological model can be constructed from the AEM dataset using the automatic procedure outlined above. Alternative zonations using various clustering settings, comprising the number of clusters and clustering variables, were evaluated with respect to the performance and prediction uncertainty of the associated hydrological model, and by comparison with the classical geological model.