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Uncertainties caused by the geological structure in hydrogeological modeling: Stochastic simulation of a heterogeneous glacial structure with emphasize on stationarity issues and the incorporation of borehole- and geophysical data.

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The heterogeneity of the geological structure causes uncertainties in hydrogeological investigations of groundwater flow and contaminant transport. Traditionally the best comprehensive knowledge is combined in order to create one model of the subsurface structure, often based on subjective interpretations and sparse data availability. Stochastic simulation methods address this problem by generating an ensemble of realizations of the geology, all of them equally plausible, because they honor available data and follow predefined geometrical attributes such as proportions and mean lengths. In this study the geostatistical software T-ProGS is utilized to simulate an ensemble of realizations for a binary (sand/clay) hydrofacies model in the Norsminde catchment, eastern Jutland, Denmark. Categorized borehole data and geophysical data (SkyTEM) indicate a variation of sand proportion within the model area. Therefore the model domain is subdivided into three independent and statistically stationary sub-model domains of different sand proportions and mean lengths. The sand proportion in the SkyTEM data depends on a cut-off value, separating the dataset into sand and clay. This cut-off value is manually calibrated by assuming the smallest deviation between the sand proportions in the borehole- and in the SkyTEM data in areas with a high sample density. The calibration yields an overall sand proportion of 23% with a cut-off value of 46 Ωm. The stochastic simulations are conditioned against the available datasets with hard and soft conditioning. The category probabilities for the SkyTEM dataset are derived from a histogram approach, where resistivity is associated with corresponding lithology from the categorized borehole data. The boreholes are grouped in four quality groups, which are associated with trust scores, allowing soft conditioning. In total, 30 realizations are simulated for each sub-domain and for the entire domain. Ten simulations are selected by favoring minimal deviations between simulated and desired sand proportions. The simulations for the individual sub-domains produce more accurate results with respect to the sand proportion than the case where the entire domain is simulated altogether. However the variation in mean lengths in the sub-domains is not simulated correctly. Moreover, a split sample test indicates a significant gain in simulation accuracy, if SkyTEM data are incorporated. If only borehole data are used for conditioning, it simulates only 25% of the sand cells correctly.