Predictive uncertainty analysis of a saltwater intrusion model using null-space Monte Carlo

Because of the extensive computational burden and perhaps a lack of awareness of existing methods, rigorous uncertainty analyses are rarely conducted for variable-density flow and transport models. For this reason, a recently developed null-space Monte Carlo (NSMC) method for quantifying prediction uncertainty was tested for a synthetic saltwater intrusion model patterned after the Henry problem. Saltwater intrusion caused by a reduction in fresh groundwater discharge was simulated for 1000 randomly generated hydraulic conductivity distributions, representing a mildly heterogeneous aquifer. From these 1000 simulations, the hydraulic conductivity distribution giving rise to the most extreme case of saltwater intrusion was selected and was assumed to represent the "true" system. Head and salinity values from this true model were then extracted and used as observations for subsequent model calibration. Random noise was added to the observations to approximate realistic field conditions. The NSMC method was used to calculate 1000 calibration-constrained parameter fields. If the dimensionality of the solution space was set appropriately, the estimated uncertainty range from the NSMC analysis encompassed the truth. Several variants of the method were implemented to investigate their effect on the efficiency of the NSMC method. Reducing the dimensionality of the null-space for the processing of the random parameter sets did not result in any significant gains in efficiency and compromised the ability of the NSMC method to encompass the true prediction value. The addition of intrapilot point heterogeneity to the NSMC process was also tested. According to a variogram comparison, this provided the same scale of heterogeneity that was used to generate the truth. However, incorporation of intrapilot point variability did not make a noticeable difference to the uncertainty of the prediction. With this higher level of heterogeneity, however, the computational burden of generating calibration-constrained parameter fields approximately doubled. Predictive uncertainty variance computed through the NSMC method was compared with that computed through linear analysis. The results were in good agreement, with the NSMC method estimate showing a slightly smaller range of prediction uncertainty than was calculated by the linear method.

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