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Upscaling of Hydraulic Conductivity using the Double Constraint Method

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The mathematics and modeling of flow through porous media is playing an increasingly important role for the groundwater supply, subsurface contaminant remediation and petroleum reservoir engineering. In hydrogeology hydraulic conductivity data are often collected at a scale that is smaller than the grid block dimensions of a groundwater model (e.g. MODFLOW). For instance, hydraulic conductivities determined from the field using slug and packer tests are measured in the order of centimeters to meters, whereas numerical groundwater models require conductivities representative of tens to hundreds of meters of grid cell length. Therefore, there is a need for upscaling to decrease the number of grid blocks in a groundwater flow model. Moreover, models with relatively few grid blocks are simpler to apply, especially when the model has to run many times, as is the case when it is used to assimilate time-dependent data. Since the 1960s different methods have been used to transform a detailed description of the spatial variability of hydraulic conductivity to a coarser description. In this work we will investigate a relatively simple, but instructive approach: the Double Constraint Method (DCM) to identify the coarse-scale conductivities to decrease the number of grid blocks. Its main advantages are robustness and easy implementation, enabling to base computations on any standard flow code with some post processing added. The inversion step of the double constraint method is based on a first forward run with all known fluxes on the boundary and in the wells, followed by a second forward run based on the heads measured on the phreatic surface (i.e. measured in shallow observation wells) and in deeper observation wells. Upscaling, in turn is inverse modeling (DCM) to determine conductivities in coarse-scale grid blocks from conductivities in fine-scale grid blocks. In such a way that the head and flux boundary conditions applied to the fine-scale model are also honored at the coarse-scale. Exemplification will be presented for the Kleine Nete catchment, Belgium. As a result we identified coarse-scale conductivities while decreasing the number of grid blocks with the advantage that a model run costs less computation time and requires less memory space. In addition, ranking of models was investigated.