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Numerical simulation of groundwater flow in heterogeneous and strongly anisotropic aquifers using multiple-point flux approximation method

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Numerical simulation of groundwater flow in anisotropic aquifers usually suffers from the lack of accuracy of calculating groundwater flux across grid blocks. Conventional two-point flux approximation (TPFA) can only obtain the flux normal to the grid interface but completely neglects the one parallel to it. Furthermore, the hydraulic gradient in a grid block estimated from TPFA can only poorly represent the hydraulic condition near the intersection of grid blocks. These disadvantages are further exacerbated when the principal axes of hydraulic conductivity, global coordinate system, and grid boundary are not parallel to one another. In order to refine the estimation the in-grid hydraulic gradient, several multiple-point flux approximation (MPFA) methods have been developed for two-dimensional groundwater flow simulations. For example, the MPFA-O method uses the hydraulic head at the junction node as an auxiliary variable which is then eliminated using the head and flux continuity conditions.

In this study, a three-dimensional MPFA method will be developed for numerical simulation of groundwater flow in three-dimensional heterogeneous and strongly anisotropic aquifers. This new MPFA method first discretizes the simulation domain into tetrahedrons. The 2D MPFA-O method is then extended to these tetrahedrons, using the unknown head at the intersection of hexahedrons as an auxiliary variable along with the head and flux continuity conditions to solve for the head at the center of each hexahedron. Currently, this new MPFA method has been verified with analytical solutions in 2D aquifers. Further verifications in 3D aquifers and applications to real-world cases are still on-going.

Keywords: Multiple-point flux approximation, anisotropic aquifer, groundwater flow simulation