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3D-Finite-Volume groundwater and heat-transport modeling with non-orthogonal grids, using a coordinate transformation method

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Many popular groundwater modeling codes are based on the finite-differences or finite-volume method for orthogonal grids. In cases of complex subsurface geometries this type of grid either leads to coarse geometric representations or to extremely fine meshes. We use a coordinate transformation method to circumvent this shortcoming. In computational fluid dynamics, this method has been applied successfully to the general Navier-Stokes equation. The method is based on tensor analysis and performs a transformation of a curvilinear into a rectangular unit grid, on which a modified formulation of the differential equations is applied. Therefore it is not necessary to reformulate the code in total. We applied the coordinate transformation method to an existing three-dimensional code (SHEMAT), a simulator for heat conduction and advection in porous media. The finite-volume discretization scheme for the non-orthogonal, hexahedral grid yields to a 19-point stencil and a correspondingly banded system matrix. The implementation is straightforward and it is possible to use some existing routines without modification. The accuracy of the modified code was demonstrated on a two-dimensional analytical solution for flow and heat transport and further on with a thermal free-convection benchmark.