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Adaptive multiresolution modeling of groundwater flow in heterogeneous porous media

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Proposed methodology was originally developed by our scientific team in Split who designed multiresolution approach for analyzing flow and transport processes in highly heterogeneous porous media. The main properties of the adaptive Fup multi-resolution approach are: 1) computational capabilities of Fup basis functions with compact support capable to resolve all spatial and temporal scales, 2) multi-resolution presentation of heterogeneity as well as all other input and output variables, 3) accurate, adaptive and efficient strategy and 4) semi-analytical properties which increase our understanding of usually complex flow and transport processes in porous media.
The main computational idea behind this approach is to separately find the minimum number of basis functions and resolution levels necessary to describe each flow and transport variable with the desired accuracy on a particular adaptive grid. Therefore, each variable is separately analyzed, and the adaptive and multi-scale nature of the methodology enables not only computational efficiency and accuracy, but it also describes subsurface processes closely related to their understood physical interpretation. The methodology inherently supports a mesh-free procedure, avoiding the classical numerical integration, and yields continuous velocity and flux fields, which is vitally important for flow and transport simulations.
In this paper, we will show recent improvements within the proposed methodology. Since "state of the art" multiresolution approach usually uses method of lines and only spatial adaptive procedure, temporal approximation was rarely considered as a multiscale. Therefore, novel adaptive implicit Fup integration scheme is developed, resolving all time scales within each global time step. It means that algorithm uses smaller time steps only in lines where solution changes are intensive. Application of Fup basis functions enables continuous time approximation, simple interpolation calculations across different temporal lines and local time stepping control. Critical aspect of time integration accuracy is construction of spatial stencil due to accurate calculation of spatial derivatives. Since common approach applied for wavelets and splines uses a finite difference operator, we developed here collocation one including solution values and differential operator. In this way, new improved algorithm is adaptive in space and time enabling accurate solution for groundwater flow problems, especially in highly heterogeneous porous media with large lnK variances and different correlation length scales. In addition, differences between collocation and finite volume approaches are discussed. Finally, results show application of methodology to the groundwater flow problems in highly heterogeneous confined and unconfined aquifers.