Un modèle pour un problème d'intrusion saline combinant les approches interfaces nettes et interfaces diffuses.

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Résumé

Le but de ce travail est de fournir des modèles efficaces pour simuler le déplacement du front d'eau salée dans les aquifères côtiers (libres ou confinés) et de permettre ainsi une exploitation optimale des eaux souterraines.

Nous proposons un modèle nouveau qui combine l'approche de l'interface nette à celui, plus réaliste, de l'interface diffuse. La moyennisation verticale du problème initial $3D$ permet de réduire l'étude à celle d'un problème $2D$. Ce problème $2D$ implique un système fortement couplé d'edps de type parabolique qui décrivent l'évolution des hauteurs des surfaces libres (eau douce/eau salée et zone saturée/zone insaturée).

Concernant les études théorique et numérique, l'introduction des interfaces diffuses permet de neutraliser la dégénérescence du système apparaissant dans l'approche 'interface nette' et de prouver un principe du maximum plus naturel d'un point de vue de la physique.

Sharp-diffuse interfaces model for a seawater intrusion problem in free and confined aquifers.

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Abstract

Groundwater is a major source of water supply. In coastal zones there exist hydraulic exchanges between fresh groundwater and seawater. They are slow in "natural conditions" and thus are often forgotten and replaced by a quasi-equilibrium between two fluid layers. The picture fails in case of more drastic conditions due to meteorological events or to human interventions : Intensive extraction of freshwater leads for instance to local water table depression causing problems of saltwater intrusion in the aquifer. We thus need efficient and accurate models to simulate the displacement of saltwater front in coastal aquifer for the optimal exploitation of fresh groundwater.

We derive a new model for seawater intrusion phenomenons in free and confined aquifers. It combine the efficiency of the sharp interface approach with the physical realism of the diffuse interface one. The three-dimensional problem is reduced to a two-dimensional model involving a strongly coupled system of pdes of elliptic-parabolic type describing the evolution of the depths of the two free surfaces.

In the present work we essentially have chosen to adopt the simplicity of a sharp interface approach. We compensate the mathematical difficulty of the analysis of the free interfaces by an upscaling procedure which allows to model the three-dimensional problem by a pdes system set in a two-dimensional domain. The originality and novelty is to mix this abrupt interface approach with a phase field approach, thus reinjecting in a new way the realism of diffuse interfaces models. We exploit here the specificity of the dynamics of the fluids in an aquifer for using such a model which was originally developed for phase transition phenomenons in binary fluids. We thus combine the advantage of respecting the physics of the problem and that of the computational efficiency.

From a theoretical point of view, the addition of the two diffusive areas has the following advantages : If they are both present, the system has a elliptic-parabolic structure, it is thus no longer necessary to introduce viscous terms in a preliminary fixed point step for avoiding degeneracy. But the main point is we can demonstrate a more efficient and logical maximum principle from the point of view of physics, which is not possible in the case of sharp interface approximation.