Curriculum Vitæ

Moussa Mory Diédhiou

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Table of contents

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1 Curriculum vitæ

DIEDHIOU Moussa Mory

Born June 19, 1985 and Senegalese nationality.
Temporary Teaching and Research Assistant (PhD contract).

Professional address
Laboratoire MIA, EA 3165, Université de La Rochelle
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Previous position

Assistant Engineer 09/11/2015 to 27/12/2015 at MIA Laboratory, Mathematics, Images and Applications of the University of La Rochelle led by Pr. Catherine Choquet, on a project entitled " `Coupling Analysis flood / aquifer in a dedicated model`" in collaboration with the University Gaston Berger of Saint-Louis (Sénégal).

EDUCATION

2015 **Phd.** in Applied Mathematics, *University of La Rochelle, France.*
Supervisor : Pr. Catherine Choquet and Dr. Laurence Cherfils
Subject : Mixed sharp/diffuse interface approach for free aquifer modeling.

2012 **Master** in Applied Analysis and Modeling, *University of Picardie Jules Verne, France.*

2010 **Master 1** in Applied Mathematics and Computing (Option Probability-Statistics), *University of Gaston Berger of Saint-Louis, Sénégal.*

2009 **Licence** in Applied Mathematics and Computing, *University Gaston Berger of Saint-Louis, Sénégal.*

2006 **Bachelor degree** in Mathematics and Physics (Option S1), *High School of Ahoune Sané of Bignona, Sénégal.*

TEACHING EXPERIENCE

2012-2015 Teaching "Statistics 1 and 2" for undergraduate students (L1 and L2) at *University of La Rochelle, France.*

2011-2012 Tutorial teaching in mathematics for undergraduate students L1 at *University of Picardie Jules Verne, France.*

RESEARCH EXPERIENCE

2012-2015 **Phd.** in Applied Mathematics, *University of La Rochelle, France.*
Supervisor: Pr. Catherine Choquet and Dr. Laurence Cherfils
Subject: Mixed sharp/diffuse interface approach for free aquifer modeling.
Abstract: The context of the subject is the management of aquifers, in especially the control of their operations and their possible pollution. A critical case is the saltwater intrusion problem in costal aquifers. The goal is to obtain efficient and accurate models to simulate the displacement of fresh and salt water fronts in coastal aquifer for the optimal exploitation of groundwater. We propose an original model mixing abrupt interfaces/diffuse interfaces approaches. The advantage is to adopt the (numerical) simplicity of a sharp interface approach, and to take into account of the existence of dispersive transition zones.
Key words: Modeling. Mathematical analysis of systems of coupled nonlinear PDE. Numerical analysis. Simulations.

2011-2012 Six-month internship in LAMFA laboratory of *University of Picardie Jules Verne, France.* **Supervisor:** Pr. Alberto Farina.
Subject: Some methods for solving nonlinear partial differential equations.

RESEARCH INTERESTS

— Partial Differentials Equations.
— Nonlinear Parabolic Systems.
— Strongly coupled systems.
— Free boundary problems.
— Theoritical and numerical analysis.
— Numericals simulations.
— Finite Elements Method.

Applications

Pollution in porous media.
Monophasics flows.
Multiphasics flows.
Mechanical effects.
Interactions fluid/fluid.
Interactions fluid/structure.

COMPUTER SKILLS

Programming Languages: FreeFem++, C++, Matlab.

Operating Systems : Windows, Unix, Mac.

Others: LATEX, Office package (Word, Excel, Access, PowerPoint).

LANGUAGE SKILLS

French: fluent.

English : writing and oral skills.

Wolof : oral skills.

Diola : oral skills.

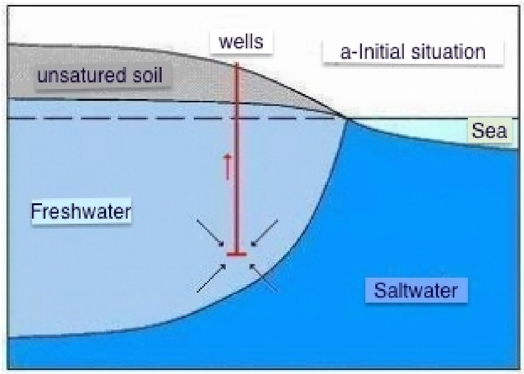
2 Scientific research current

Research activities (Abstract) [1]

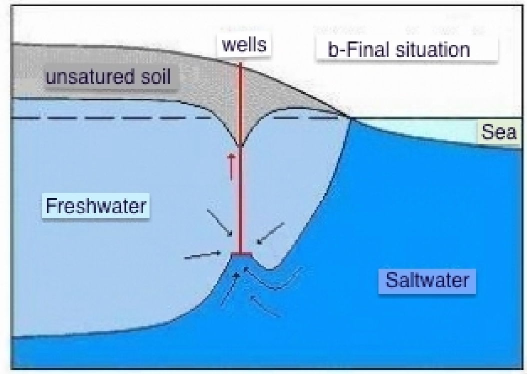
Flows fluids in porous media.

Groundwater is a major source of water supply. In coastal zones there exist hydraulic exchanges between fresh groundwater and seawater. And intensive extraction of freshwater may lead 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 fresh and salt water fronts in coastal aquifer for the optimal exploitation of groundwater.

[1]Bibliographique references at the end of the document



Aquifer without depression



Aquifer with depression

In the literature there are three categories of models for seawater intrusion:

Hidden diffuse interfaces : This is the physically correct approach. Fresh and salt water are two miscible fluids. Due to density contrast they tend to separate into two layers with a transition zone characterized by the variations of the salt concentration. Moreover the aquifer has to be considered as a partially saturated porous medium. There is another transition zone between the completely saturated part and the dry part of the reservoir, the definition of the area of desaturation being difficult. Two "diffusive interfaces" are thus hidden in this kind of model. The approach is very heavy from theoretical and numerical points of view (see [2]).

Hidden sharp interfaces : A first simplification consists in assuming that fresh and salt water are two immiscible fluids. Points where the salty phase disappears may be viewed as a sharp interface. Nevertheless the explicit tracking of the interfaces remains unworkable to implement without further assumptions. (see [4]).

Abrupt interfaces : This approach is also based on the hypothesis that the two fluids are immiscible. Moreover the domains occupied by each fluid are assumed to be separated by a smooth interface, no mass transfert occurs between the fresh and the salt area and capillary pressure's type effects are neglected.
Of course, this type of model does not describe the behavior of the real transition zone but give informations concerning the movement of the saltwater front. The other price to pay for this simplified approach is the mathematical handling of free interfaces. (see [1], [3]).

We have adopted several **approaches** :

– Modelling :

In this work we propose a mixed approach combining the (numerical) simplicity of sharp interfaces with the realism of diffuse interfaces. The derivation of the model is based on the coupling of Darcy's law and mass conservation principle written for freshwater and saltwater. The difficulty induced by the mathematical handling of free interfaces is compensated by an upscaling procedure reducing the problem to a two-dimensional setting. Mass transfers around the fronts are included through a phase-field model in fluid-fluid context.

We obtain two new systems that model both the evolution of saltwater fronts (h) and the upper free surface of the aquifer (h_1) by taking into account the thickness of the transition zone (δ). **incompressible media** (without S_f):

$$(\mathcal{P}_1)\left\{\begin{array}{rcl} \phi\mathcal{X}_0(h)\partial_t h - \nabla\cdot\big(KT_s(h)\mathcal{X}_0(h_1)\nabla h\big) - \nabla\cdot\big(\delta\phi\mathcal{X}_0(h)\nabla h\big) & & \\ -\nabla\cdot\big(KT_s(h)\mathcal{X}_0(h_1)\nabla h_1\big) & = & -\mathcal{Q}_s T_s(h), \\ \phi\mathcal{X}_0(h_1)\partial_t h_1 - \nabla\cdot\big(K\big(T_f(h-h_1)+T_s(h)\big)\mathcal{X}_0(h_1)\nabla h_1\big) & & \\ -\nabla\cdot\big(\delta\phi K\mathcal{X}_0(h_1)\nabla h_1\big) - \nabla\cdot\big(KT_s(h)\mathcal{X}_0(h_1)\mathcal{X}_0(h)\nabla h\big) & = & -\mathcal{Q}_f T_f(h-h_1) - \mathcal{Q}_s T_s(h), \end{array}\right.$$

compressible media (with S_f) :

$$(\mathcal{P}_2)\left\{\begin{array}{rcl} \phi\mathcal{X}_0(h)\partial_t h - \nabla\cdot\big(KT_s(h)\mathcal{X}_0(h_1)\nabla h\big) & & \\ -\nabla\cdot\big(\delta\phi\mathcal{X}_0(h)\nabla h\big) - \nabla\cdot\big(KT_s(h)\mathcal{X}_0(h_1)\nabla h_1\big) & = & -\mathcal{Q}_s T_s(h), \\ \big(S_f(h-h_1)+\phi\big)\mathcal{X}_0(h_1)\partial_t h_1 & & \\ -\nabla\cdot\big(K\big(T_f(h-h_1)+T_s(h)\big)\mathcal{X}_0(h_1)\nabla h_1\big) & & \\ -\nabla\cdot\big(\delta\phi K\mathcal{X}_0(h_1)\nabla h_1\big) - \nabla\cdot\big(KT_s(h)\mathcal{X}_0(h_1)\mathcal{X}_0(h)\nabla h\big) & = & -\mathcal{Q}_f T_f(h-h_1) - \mathcal{Q}_s T_s(h). \end{array}\right.$$

($\mathcal{P}_1$) and ($\mathcal{P}_2$) are completed by initial and boundary conditions, for instance :

$$h = h_D, \quad and \quad h_1 = h_{1,D} \quad on \quad \Gamma = \partial\Omega \tag{1}$$

$$h(0,x) = h_0(x), \quad and \quad h_1(0,x) = h_{1,0}(x) \quad in \quad \Omega. \tag{2}$$

– Mathematical analysis :

The resulting model consists in a system of strongly and nonlinearly coupled pdes of parabolic type. We state an existence result of variational solutions for the models ($\mathcal{P}_1$) and ($\mathcal{P}_2$) completed by initial and boundary conditions using a Schauder fixed point strategy. We introduce a weight based on the velocity of the salt front in the equation of the upper free interface. A subsequent difficulty is that the mapping used for the fixed point approach has to be continuous. We then prove that we have sufficient control on the salt front to ignore the latter weight.

An important point is we can demonstrate a natural maximum principle from the point of view of physics, which is not possible in the case of sharp interface approximation.

– Numerical analysis and simulations :

We compare numerically the results provided by this upscaled model with the ones obtained using the classical three-dimensional model for miscible and compressible displacements in slightly deformable porous media.

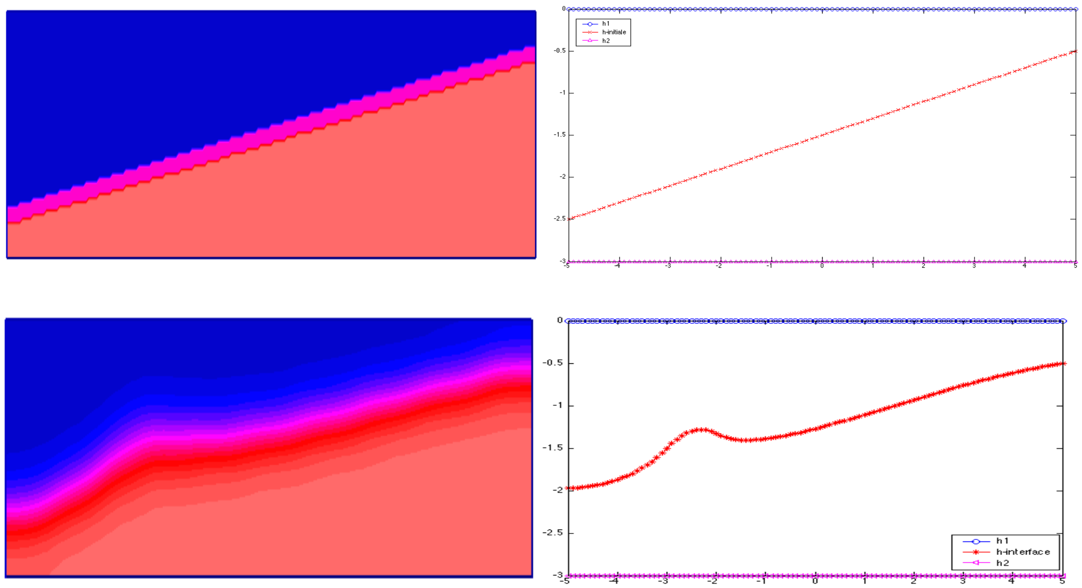


Figure 1 Vertical cross section of the solution of a $3D$ problem (left) and the solution of the new integrated $2D$ model with the mixed approach (right), where a freshwater pumping. One observes the cone above for the production well for fresh water.

PUBLICATIONS

Internationals Journals

[A1] C. Choquet, M. M. Diédhiou and C. Rosier
Mathematical analysis of a sharp-diffuse interfaces model for seawater intrusion, *in Journal of Differential Equations*, 259(8) :3803–3824, 2015.

[A2] C. Choquet, M. M. Diédhiou and C. Rosier
Derivation of a sharp-diffuse interfaces model for seawater intrusion in a free aquifer. Numerical simulations, *in SIAM Journal on Applied Mathematics*,Vol. 76, No. 1 : pp. 138-158, 2016.

[A3] C. Choquet, M. M. Diédhiou and C. Rosier
Mathematical analysis of seawater intrusion model including storativity, **to appear** *in SIAM, Journal on Mathematical Analysis.*

[A4] L. Cherfils, C. Choquet and M. M.Diédhiou
Numerical validation of an upscaled sharp-diffuse interface model for stratified miscible flows, **to appear** *in Mathematics and Computers in Simulation*.

Preprints

[A5] C. Choquet, M. M. Diédhiou and C. Rosier
Seawater intrusion problem in a free aquifer : derivation a sharp–diffuse interfaces model and existence results, 2014 (https://hal.archives-ouvertes.fr/hal-01057220v1).

[A6] M. M. Diédhiou and al.
Modelling of Potential Depolarization Signals in the Hippocampus.
ESSIM Modelling Week, July 27, 2013.

In preparation

[A7] C. Choquet, M. M. Diédhiou and M. Sy
Model derivation and analysis for contaminant exchanges between surface water and groundwater.

CONFERENCES-WORKSHOPS

- Oral Communication, "Symposium on Trends in Applications of Mathematics to Mechanics-STAMM" (Poitiers), september 2014. *Mixed sharp-diffuse approach for seawater modeling.*

- Oral Communication, "6th International Conference on Approximation Methods and Numerical Modelling in Environment and Natural Resources -MAMERN15" (Pau), Juin 2015. *Three-dimensional model versus upscaled mixed sharp-diffuse models for saltwater intrusion. Numerical results.*

Perspectives

This is the purpose of my present contract : the interactions between subsurface and overland flows those are facts that we can not ignore for understanding the hydrological cycle. Taking account of these facts in the modeling will provide robust and accurate models to simulate the coupling of surface runoff and those in porous media.
This Work has been made in this direction include: the coupling of Richards equations for incompressible fluids, Darcy in the underground and those of Navier-Stokes or Shallow-water surface (see [5], [6]). In the present work in collaboration with Pr. Mamadou Sy, we consider two more things : the media and the fluids are compressible and there is a pollutant both in surface waters and in those of the sub ground. The goal is to get a model that will take into account surface flows from surface water (rivers, tides, floods ...) and be able to follow the movement of polluting surface water towards the middle porous when there is infiltration, or the porous medium to the surface of water when operating.

Bibliographique references

[1] J. Bear. *Dynamics of Fluids in Porous Media*, American Elsevier, 1972.
[2] C. Choquet. *Parabolic and degenerate parabolic models for pressure-driven transport problems*, Math. Models Methodes Appl. 20 (2010), 543-566.
[3] H. L. Essaid. *A multilayered sharp interface model of coupled freshwater and saltwater flow in coastal systems: Model development and application.* Water Resources Research, 26(7): 1431-1454, July 1990.
[4] E.V Radkevich. *On conditions for the existence of classical solution of the modified stefan problem (the Gibbs-Thomson law).* Russian Aca. Sci. Sb Math., 75(1): 221-246, 1993. **[5]** P. Sochala, A. Ern, S. Piperna. *Mass conservative BDF-discontinuous Galerkin / explicit finite volume schemes for coupling subsurface and overland flows*, Preprint.
[6] M. Discacciati, E. Miglio, A. Quarteroni. *Mathematical and numerical models for coupling surface and groundwater flows*, Applied Numerical Mathematics 43(2002) 57-74.