ED 398 Géosciences, Ressources Naturelles et Environnement
Proposition de sujet de thèse pour la rentrée universitaire 2021-2022
Funded PhD project (3 years) to start autumn 2021

1. Location and team

Centre de Géosciences MINES ParisTech, 35 rue saint-Honoré, 77300 Fontainebleau (France) and

1. *Title*

Hydrogéophysique probabiliste pour une meilleure articulation des données géophysiques et modèles hydrogéologiques / Probabilistic approach in hydrogeophysics to better articulate geophysical data with hydrogeological models

3. *Research project outline*

Keywords: hydrogeophysics; uncertainty propagation; geophysical data; hydrodynamic models; unsaturated flow; critical zone; seismic methods.

Abstract:

This project focuses on understanding the hydrogeology of the Critical Zone (CZ). This most heterogeneous and complex region of the Earth ranges from the vegetation top to the aquifer bottom, with a highly variable thickness (e.g.. www.ozcar-ri.org). The strategic importance of the CZ for global water, food and energy security resources are increasingly recognized in a context of climate change and human development. Obtaining the components of the water cycle remains a challenge, both in terms of accuracy and budget closure in the exchange fluxes through the CZ. The knowledge of the CZ, its physical properties (hydraulic conductivity, porosity and associated parameter) and its water content dynamics (permanent and transient states) are essential to describe and simulate the bio-geochemical-physical processes involved. The resolution of flow and transport problems in the CZ suffers from (1) limited knowledge of the heterogeneities of its porous media; and (2) sparse and local direct observations to calibrate models. The water flow, matter and energy transport are therefore estimated with high uncertainties (which are quantified by stochastic methods). As a countermeasure, hydrogeophysics provides a suite of tools that limit these uncertainties and the equifinality (non-unicity of the parameters setup) affecting hydrogeological modeling. The development of innovative geophysical methods combined with hydrogeological and geotechnical measurements, have improved the spatial and temporal characterization of the physical parameters of the porous media and, consequently, the evolution of infiltration processes and preferential flow paths within the CZ. This articulation between data and methods is encouraging, but efforts should be made to improve the quantification and estimation of the spatial and temporal resolutions of the physical parameters and their associated uncertainties. This PhD project takes advantage of available databases (geophysical and hydrogeological, e.g. http://hplus.ore.fr/en/) and associated simulations to: (1) characterize how uncertainties propagate from geophysical data (field observation) to the models (according to the methods used and the contexts involved); (2) question the articulation between estimations derived from these geophysical models and the hydrogeological models parametrization; adapt or revise forward geophysical problems to better satisfy modeling objectives; (3) Estimate the relevance of the information transferred from geophysical models to hydrogeological models and the associated propagation of uncertainties in order to obtain more reliable calibrations.

Context and scientific environnement :

This PhD project corresponds to the continuation of an active cooperation for 10 years between the SHR team at **Mines ParisTech** and the applied geophysics team of the UMR METIS at **Sorbonne Université**, in particular through the PhD of S. Pasquet (EDGRNE 2011-2014, SU funding) and M. Dangeard (EDGRNE 2015-2018, SU funding) and within the framework of the PIREN-Seine and CRITEX programs, for applications to observatory networks (e.g. H+) and research infrastructures (e.g. OZCAR). The results and approaches have an international influence (on the critical zone observatories in the USA for instance, or in the framework of the european project ITN ENIGMA, with L. Blazevic PhD thesis defended in 2020). Developments are also currently in progress in the context of industrial collaborations. The PhD project will benefit from the support of the UMR METIS, the associated geophysics team of H+ and CRITEX/OZCAR for experimental activities. Collaborations are planned with specialists in petrophysics (METIS, U. Lausanne), stochastic

methods (Géostat Mines ParisTech), numerical modeling and parallel computing (GET) and hydrogeophysical experiments (Géosciences Rennes).

Scientific skills and role of each supervisor :

- A. Rivière: hydrodynamic modeling: theory, physical processes within the critical zone, conceptualisation and parameterization of codes and implementation with adapted constraints and from dedicated field measurements;

- L. Bodet: geophysical methods/imaging, methodologies, field measurements, combined interpretation of geophysical and geotechnical data, information theory and signal processing, wave propagation and mechanical properties;

- A. Gesret, inverse problems, probabilistic approaches, estimation and propagation of uncertainties.

5. *Candidate: prerequisite skills and knowledge*

We are looking for highly motivated doctoral candidates to join our project dealing with hydrogeology and geophysics on a quantitative point of view. Candidates must have obtained or be in the process of obtaining a master's degree in a field related to geophysics and/or quantitative hydrogeology and/or engineering or even applied mathematics. A good background in statistics, probability, mechanics and wave propagation, or even petrophysics is/are desirable. Experience in data analysis, information processing (signal processing, inverse problems), numerical modeling, and programming (Fortran/C; Python/Matlab) will be advantageous. Teamwork and good communication skills are essential. Written and verbal communication skills in English are required. The duration of a PhD is very short: ability of quick familiarization with new topics and strong motivation to produce results are necessary (mobility, autonomy).

6. How to apply?

Outstanding candidates should apply by email to agnes.riviere@mines-paristech.fr; alexandrine.gesret@mines-paristech.fr; ludovic.bodet@sorbonne-universite.fr with a letter of motivation, a curriculum vitae, full transcripts of Bachelor and Master studies and, at least, two references (with up to date contacts). Short-listed candidates will be interviewed.

NB, the candidate will be fully funded for 3 years (100% position). He/She will benefit from a dynamic working environment, with stimulating scientific support, state-of-the-art facilities and advanced computational modeling tools. The appointment will be given in accordance with the French labour laws. The applicant will benefit from additional resources to cover the purchase of equipment and consumables; possible data acquisition and analyses; travels for meetings and stays with cooperators; participation in conferences, workshops; summer schools; payment of publication/appraisal costs, etc.