D6.7 / D20
Workshop 4 – Lausanne, February, 12th to 15th 2018 - Report

Enigma ITN

Workshop 4: Advanced inverse modeling and stochastic representations of heterogeneous porous and fractured media

The Enigma ITN workshop 4 took place in Lausanne, Switzerland from Monday 12th to Thursday 15th in February 2018.

Main organisers of the workshop: UNIL (University of Lausanne) & UNINE (University of Neuchâtel)

Participants to the workshop:

All 15 ESRs participated in workshop 4 in Lausanne:

1	ESR1	Kevin de Vriendt
2	ESR2	Guilherme Nogueira
3	ESR3	Alvaro Pardo Alvarez
4	ESR4	Justine Molron
5	ESR5	Lara Blazevic
6	ESR6	Behzad Pouladi
7	ESR7	Joel Tirado Conde
8	ESR8	Anne Karin Cooke
9	ESR9	Alejandro Fernandez Visentini
10	ESR10	Peleg Haruzi
11	ESR11	Richard Hoffmann
12	ESR12	Satoshi Izumoto
13	ESR13	Veronika Rieckh
14	ESR14	Andrea Palacios
15	ESR15	Jorge Lopez Alvis

In addition, the workshop was followed by five PhD students external to ENIGMA: Przemyslaw Juda (University of Neuchâtel), Kawtar Sabor (Université Pierre et Marie Curie), Mayumi Claire Hamada (University of Lausanne), Charlotte Le Traon (University of Rennes 1), Luca Guillaumot (University of Rennes 1). Unfortunately, some participants (Kevin de Vriendt, Alejandro Fernandez Visentini, Justine Molron) were caught by a stomach flue or possibly food poisoning. This explains their absence during some of the days of the workshop. However, all lectures and exercises were also made available online on the organizer's webpage: http://wp.unil.ch/linde-hydrogeophysics/about/#WS4 to enable the catch up of missed lectures.

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ENIGMA ITN - This project has received funding from European Union's Horizon 2020 research and innovation programme under the Marie Sklodowska-Curie Grant Agreement N°722028.

Objectives

Provide advanced knowledge and practice in hydrogeophysical inverse modelling and modern geostatistical representations and modelling of subsurface heterogeneity.

Support

Links to various online courses were provided to learn the basics of Matlab programming for those that were unfamiliar with Matlab.

The logistics and communication were done through the website of the organizer: https://wp.unil.ch/linde-hydrogeophysics/about/

Program & Locations

Advanced inverse modeling and stochastic representations of heterogeneous porous and fractured media

February 12-15, 2138 Géopolis, University of Lausanne

Instructors: Philippe Renard (University of Neuchâtel) & Niklas Linde (University of Lausanne)

February 12 (Philippe Renard):

Lecture 1, 9h00-11h00. What is geostatistics? Why using it and when? Illustration with a few examples. Overview of the general approach: exploratory data analysis, model identification, forecasts. Reminders of statistics and probability. Quantification of spatial correlation: experimental variogram, covariance and variogram models. Anisotropy. Variable transforms.

Exercise 1, 11h00-13h00. Exploration of several data sets: basic statistics. Computation of experimental variograms. Variogram modeling.

Lecture 2, 14h00-16h00. The principles of kriging. The equations in the case of Simple and Ordinary Kriging. Cross validation principle and interpretation. How to infer the variogram, test and select a model.

Exercise 2. 16h00-18h00. Mapping soil contamination using kriging. Testing the model using cross validation. Comparing and testing different models.

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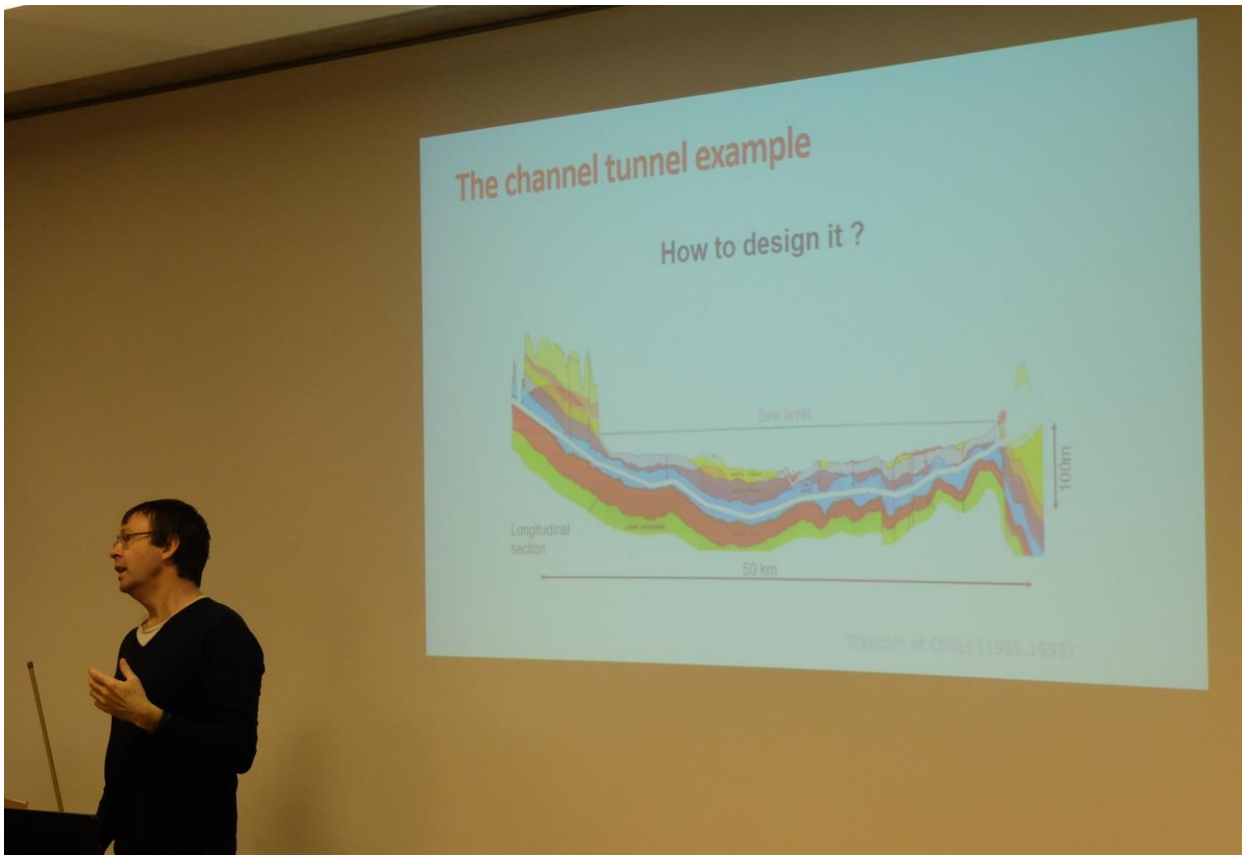

Photo: First lecture by Philippe Renard.

February 13 (Philippe Renard):

Lecture 3. 9h00-11h00. Simulations versus estimation. Why do we need simulations? Revisiting the kriging results. Marginal and conditional probabilities, conditional estimation. The multi-Gaussian framework. Normal score transform. Simulating pseudo-random numbers. The Sequential Gaussian Simulation (SGS) algorithm. Overview of different simulation algorithms.

Exercise 3. 11h00-13h00. Using SGS to estimate a volume of contaminant and its related uncertainty.

Lecture 4. 14h00-16h00. Other simulation techniques, in particular for categorical variables: overview of Sequential Indicator Simulation (SIS), object based techniques, truncated gaussian methods, and introduction to Multiple-Point Statistics (MPS).

Exercise 4. 16h00-18h00. Simulation of a categorical variable. Example to model geological heterogeneity: Illustration of the truncated gaussian and MPS approaches.

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Photo: Computer exercises.

February 14 (Niklas Linde):

Lecture 5, 9h00-11h. Joint and marginal probability density functions. The data and model space. Conditional probabilities and Bayes theorem. Linear vs. non-linear problems. Prior probability density functions. Likelihood functions. Rejection sampling.

Lecture 6, 11h-13h. Markov chain Monte Carlo (MCMC). The Metropolis, Metropolis-Hastings and the extended Metropolis algorithm. Assessing convergence of Markov chain Monte Carlo methods. Acceptance rate and auto-correlation. Reaching the posterior vs. exploring the posterior. Brief introduction to modern Markov chain Monte Carlo methods (parallel tempering, differential evolution, Hamiltonian) and global optimization (simulated annealing; genetic algorithms).

Exercise 5, 14h00-18h00. Consider a linear crosshole tomographic GPR example and a multi-Gaussian prior. Implement rejection sampling and MCMC using gradual deformation as model proposal. Assess convergence and compare results with analytical solutions for the mean and the posterior covariance. The code is to be written in Matlab; the forward solver and error-contaminated data will be supplied. If times permit, implement hierarchical Bayes to invert for the standard deviation of the data errors and consider correlated data errors. It will also be possible to work with truncated multi-gaussian fields.

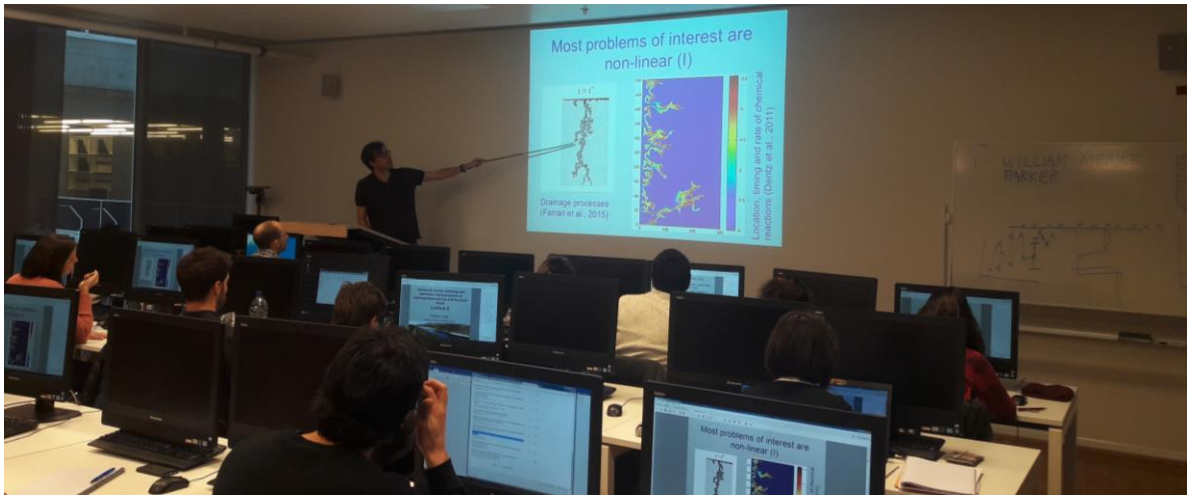

Photo: Lecture by Niklas Linde

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February 15 (Niklas Linde):

Lecture 7, 9h00-11h00. Over-determined linear inverse problems. Least-squares solutions to linear problems. Optimization and uncertainty quantification for linear over-determined problems. Regularization and its effects on model solutions. How to determine the appropriate regularization weight?

Lecture 8, 11h-13h. Non-linearity and its implications for parameter estimation. Iterative gradient-based methods. Occam's inversion. Linearized uncertainty and model resolution estimates. Robust and compact inversion. Time-lapse inversion.

Exercise 6, 14h00-18h00. Consider a linear crosshole tomographic GPR example. Implement a deterministic inversion solution together with model appraisal in terms of point-spread functions and posterior covariances. If time permits, implement robust inversion and compact inversion for a test model that is sharp (e.g, an MPS realization).

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4th Workshop Report

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