Advanced Modeling of Water Flow and Contaminant Transport in Porous Media Using HYDRUS Software Packages (2 credit points)

The short course is organized by the Albert Katz International School of Desert Studies at the Sede Boqer Campus of the Ben-Gurion University in Israel. September 11-14, 2017.

INSTRUCTORS:

Prof. Jirka Šimůnek, Dept. of Environmental Sciences University of California, Riverside, California, USA
Prof. Naftali Lazarovitch, French Associates Institute for Agriculture and Biotechnology of Drylands, The Ben-Gurion University of the Negev, Sede Boqer Campus, Israel
Prof. Günter Langergraber, Institute for Sanitary Engineering and Water Pollution Control, BOKU University, Vienna, Austria

Jirka Šimůnek is a professor of Hydrology with the Department of Environmental Sciences of the University of California. He received an M.S. in Civil Engineering from the Czech Technical University, Prague, Czech Republic, and a Ph.D. in Water Management from the Czech Academy of Sciences, Prague. His expertise is in numerical modeling of subsurface water flow and solute transport processes, equilibrium and nonequilibrium chemical transport, multicomponent major ion chemistry, field-scale spatial variability, and inverse procedures for estimating the hydraulic properties of unsaturated porous media. He has authored and coauthored over 250 peer-reviewed publications and over 20 book chapters. His numeric models are used by virtually all scientists, students, and practitioners modeling water flow, chemical movement, and heat transport through variably saturated soils.

Naftali Lazarovitch is an associate professor at the French Associates Institute for Agriculture and Biotechnology of Drylands, Jacob Blaustein Institutes for Desert Research, Ben-Gurion University of the Negev. He received his PhD in 2006 from the Hebrew University in Jerusalem. His main research interests are creating a better understanding of water flow and solute transport in the soil-plant-atmosphere system, increasing agricultural water use efficiency using optimal irrigation and fertigation scheduling and modeling (numerical and analytical), measurements and interpretation of water, heat and solute movement in the root zone.

Günter Langergraber is senior scientist at the Institute for Sanitary Engineering and Water Pollution Control at the University of Natural Resources and Life Sciences, Vienna, Austria (BOKU University). He is the main developer of the WETLAND module of the HYDRUS (2D/3D) software. His main research interests are wastewater treatment with constructed wetlands, modeling of treatment wetlands and activated sludge systems, and resources oriented sanitation systems. He is currently a co-chair of the IWA (International Water Association) Task Group on "Mainstreaming the Use of Treatment Wetlands" and was awarded IWA Fellow in 2014.
OVERVIEW
Soil and groundwater pollution is an ever-increasing, worldwide problem. Tens of billions of dollars are spent each year in the United States and elsewhere to remediate groundwater pollution, and to limit or prevent future contamination of the subsurface. Most subsurface pollution problems stem from activities involving the unsaturated (vadose) zone between the soil surface and the groundwater table. The unsaturated zone hence provides the best opportunities to limit or prevent groundwater pollution. Once contaminants enter groundwater, pollution is essentially irreversible, or can be remediated only with extreme costs. Numerical modeling is becoming an increasingly important tool for analyzing complex problems involving water flow and contaminant transport in the unsaturated zone. This course is designed to familiarize participants with the principles and mathematical analysis of variably-saturated flow and transport processes, and the application of state-of-the-art numerical codes to site-specific subsurface flow and transport problems. Additionally, the HYDRUS Wetland Module for simulation subsurface flow treatment wetlands will be introduced.

COURSE DESCRIPTION
The course begins with a detailed conceptual and mathematical description of water flow and solute transport processes in the vadose zone, followed by an brief overview of the use of finite element techniques for solving the governing flow and transport equations. Special attention is given to the highly nonlinear nature of the governing flow equation. Alternative methods for describing and modeling the hydraulic functions of unsaturated porous media are also described. "Hands-on" computer sessions will provide participants an opportunity to become familiar with the Windows-based HYDRUS-1D and HYDRUS (2D/3D) software packages. Emphasis will be on the preparation of input data for a variety of applications, including flow and transport in a vadose zone, variably saturated flow through a dam, flow and transport to a tile drain, and two-dimensional leachate migration from a landfill through the unsaturated zone into groundwater. Calibration will be discussed and demonstrated by means of both one-dimensional inverse problem. In the final part of the course, the HYDRUS Wetland Module will be introduced and its application to subsurface flow treatment wetlands will be demonstrated.

COURSE SOFTWARE
The course introduces a new generation of Windows-based numerical models for simulating water, heat and/or contaminant transport in variably-saturated porous media. These include the HYDRUS-1D and HYDRUS (2D/3D) codes for one- and two dimensional simulations, respectively, and the Rosetta code for estimating the soil hydraulic properties (and their uncertainty) from soil texture and related data. HYDRUS-1D and HYDRUS (2D/3D) are supported by interactive graphics-based interfaces for data-preprocessing, generation of unstructured as well as structured finite element grid systems, and graphic presentation of the simulation results. Except for HYDRUS (2D/3D), all software packages are in the public domain.
COURSE HANDOUTS
Course handouts include lecture notes prepared by the instructors. Documentation of the RETC, STANMOD, HYDRUS-1D, and HYDRUS (2D/3D) models, as well as of the HYDRUS Wetland module, is in a DROPBOX folder with access given to each course participant.

GENERAL
Basic knowledge of the theory of water movement, solute transport and heat transport is recommended. The participant will bring his/her personal laptop computer (Minimum system requirements: operating system Windows XP / 10 CPU with 1 GHz, 512 MB RAM, 10 GB total hard disk capacity with about 500 MB reserved for installation, graphic card with a resolution of 1024 x 768 pixels). The course grading will be based on home exam that will include preparation of short research paper that includes the use of HYDRUS.

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COURSE OUTLINE

Monday (11.9.17)

8:00-9:00 Setup

9:00-10:30 Session 1
Conceptual and mathematical description of variably-saturated water flow and solute transport processes, root-water uptake, nonequilibrium transport, decay chains, initial conditions, boundary conditions.

11:00-12:30 Session 2
The HYDRUS-1D software for simulating one-dimensional variably-saturated water flow and solute transport.

Computer session: HYDRUS-1D: Infiltration of water into a one-dimensional soil profile.

Lunch

14:00 -15:00 Session 3
Review of the hydraulic properties of unsaturated porous media; measurement, description, parameter estimation. RETC and Rosetta codes.

15:30 - 16:30 Session 4
Review of numerical methods for solving the variably-saturated water flow and solute transport equations; Application of finite element method to 1D flow and transport.

17:00 - 18:30 Session 5
Computer session: Application of HYDRUS-1D to a transient water flow and solute transport in a layered soil profile.

Tuesday (12.9.15)

8:30-10:00 Session 6
Inverse modeling; application of HYDRUS to laboratory and field experiments.

Computer session: Advanced one-dimensional forward and inverse problems with HYDRUS-1D.

10:30-12:00 Session 7
Application of finite element method to 2D variably-saturated water flow and solute transport; The HYDRUS (2D/3D) software package – model structure, examples; Pre- and post-processing with HYDRUS (2D/3D) using the finite element mesh generator.

Lunch

14:00 -15:30 Session 8
Computer session: Application of HYDRUS (2D/3D) to a simple two-dimensional problem.

16:00 - 17:30 Session 9
Computer session: Application of HYDRUS (2D/3D) to a complex two-dimensional problem (water flow and solute migrating to a stream).

18:00 - 19:00 Session 10
Computer session: Application of HYDRUS (2D/3D) to a simple three-dimensional problem.

Wednesday (13.9.15)

8:30-10:00 Session 11
Computer session: Advances in modeling drip irrigation (Triggered irrigation, Back pressure, dynamic wetting

10:30-12:00 Session 12
Computer session: Application of UNSATCHEM to a simple solute transport problem involving cation exchange.

Lunch
14:00 -15:30 Session 13
Computer session: Application of HP1 to a simple solute transport problem involving cation exchange.

16:00 - 17:30 Session 14
Introduction to modelling of constructed wetlands

Thursday (14.9.15)

8:30-10:00 Session 15
Computer session: HYDRUS Wetland Module tutorial parts 1 (VF wetlands)

10:30-12:00 Session 16
Gujer matrix presentation of biokinetic models
Computer session: HYDRUS Wetland Module tutorial part 2 (VF wetlands)

Lunch

14:00 -15:30 Session 17
Computer session: HYDRUS Wetland Module tutorial parts 3 (HF wetlands)

16:00 - 17:30 Session 18
General session: Student presentations (15 min each) regarding their research projects; discussion.