Course: Watershed Modelling
LV 102-0468-10L (6KP, 4 SWS)

Curriculum: Master in Environmental Engineering
Instructors: Peter Molnar (HIF D 20.1), Scott Sinclair (HIF D 18.2), Anna Costa (HIF D 18.1)
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Monday: 15:45-17:30 (lectures), Wednesday: 11:45-13:30 (exercises)
Room: HIL E 8 (ETH Hönggerberg Campus)

Watershed Modelling is a practical course on numerical water balance models for a range of catchment-scale water resource applications. The course covers GIS use in watershed analysis, model types from conceptual to physically-based, parameter calibration and model validation, and analysis of uncertainty. The course combines theory (lectures) with a series of practical tasks (exercises).

Objective:

The main aim of the course is to provide practical training with watershed models for environmental engineers. The course is built on thematic lectures (2 hrs a week) and practical exercises (2 hrs a week). Theory and concepts in the lectures are underpinned by many examples from scientific studies and practice. A comprehensive exercise block builds on the lectures with a series of 4 practical tasks to be conducted during the semester in group work. Exercise hours during the week focus on explanation of the tasks. The course is evaluated 50% by performance in the graded exercises and 50% by a semester-end oral examination (30 mins) on watershed modelling concepts.

Content:

The first part (A) of the course is on watershed properties analysed from DEMs, and on global sources of hydrological data for modelling applications. Here students learn about GIS applications (ArcGIS, Q-GIS) in hydrology - flow direction routines, catchment morphometry, extracting river networks, and defining hydrological response units. In the second part (B) of the course on conceptual watershed models students build their own simple bucket model (Matlab, Python), they learn about performance measures in modelling, how to calibrate the parameters and how to validate models, about methods to simulate stochastic climate to drive models, uncertainty analysis. The third part (C) of the course is focussed on physically-based model components. Here students learn about components for soil water fluxes and evapotranspiration, they practice with a fully-distributed physically-based model Topkapi-ETH, and learn about other similar models. They apply Topkapi-ETH to an alpine catchment and study simulated discharge, snow, soil moisture and evapotranspiration spatial patterns. The final part (D) of the course provides open classroom discussion about topics learnt in the class.

Digital materials:

LECTURES: PDF files and video recording (Monday block)
EXERCISES: PDF files, Matlab code, data, video recording (Wednesday block)

VIDEO RECORDING (NETHZ Access):
https://www.video.ethz.ch/lectures/d-baug/2023/autumn/102-0468-10L.html
MOODLE LINK:
https://moodle-app2.let.ethz.ch/course/view.php?id=21081

CONTENT (Version 2023)

Week	LECTURES HIL E 8 2x45 min with 15 min break	EXERCISES HIL E 8 45 min exercise explanation + 45 min Q&A and free work time
18. & 20.9. **MOLNAR**	NO LECTURE	**INTRODUCTION** **Le 1: Watersheds in GIS.** Watershed as a landscape unit. GIS basics. Data types & operations. Elevation data (DEM). Topographic operations on DEMs. Hypsometric curve. Slope. Aspect. Curvature. Flow directions (D8). Flow accumulation. Topographic Index.
25. & 27.9. **MOLNAR**	**Le 2: River networks and HRUs.** Extracting river networks from DEMs. The a>at model. Other models and field evidence. Multiple flow direction algorithms (Dinf+). Spatial data sampling effects. Typical spatial datasets for modelling (landcover, soil). Hydrological Response Units.	**Ex 1: Watershed analysis using GIS** - choose Berner Oberland basin - compute hypsometric curve - apply D-8 flow directions (ArcGIS, Q-GIS)
2. & 4.10. **MOLNAR**	**Le 3: Climate data input into models.** Measurement of climatic data in time and space. Summary climate statistics. Weather radar. Satellite data. Climate reanalysis data. Spatial interpolation (IDW) and filling in missing data for rainfall (regression)	- extract the river network (calibrate) - apply D-inf flow directions - define HRUs in your basin
9. & 11.10. **MOLNAR**	**Le 4: Introduction into watershed modelling.** Modelling concepts – perceptual model. Modelling requirements. Model classification. Model complexity versus data availability. Budyko curve.	- describe climatology of your basin - summary statistics (PDFs, extremes)
16. & 18.10. **MOLNAR**	**Le 5: Conceptual watershed modelling.** Build your own lumped bucket model. Linear reservoirs. Examples of model structures – HBV, PRMS. Typical parameters. Case study: Berner Oberland.	**Ex 2: Conceptual hydrological modelling** - apply daily bucket model to your site - manual changing of parameters - analyse outputs of the model (Q,ET,R,…)
23. & 25.10. **MOLNAR**	**Le 6: Calibration and validation.** Systematic and random error sources. Goodness-of-fit measures. Objective functions. Calibration-Validation tests. Multicriteria optimisation.	- automatically calibrate parameters - validate model
31.10+2.11. **MOLNAR**	**Le 7: Sensitivity and uncertainty.** Parameter sensitivity. Sensitivity of model oututs: local and global (Sobol indexes). Uncertainty analysis: sources of errors. Monte Carlo simulation (ensembles), bootstrapping. Parameter and input uncertainty.	- parameter sensitivity - example of Sobol indexes
7.+9.11. **COSTA**	**Le 8: Stochastic processes for rainfall.** 1D Temporal and spatial disaggregation approaches. Point process models. Markov chains. NSRP Model. Nested appraoch. 2D rainfall disaggregation.	**Ex 3: Stochastic input of rain into the model** - fit the WeaGETS rainfall generator to data - prepare stochastic climate for modelling
13. & 15.11. **COSTA**	**Le 9: Climate impacts on hydrology.** Climate models (GCMs, RCMs). Downscaling approaches. Weather generators. Climate impact studies. Uncertainty partitioning in climate change studies.	- run model of Ex 2 with stochastic rainfall - conduct a climate change CC study

20. & 22.11. **SINCLAIR**	**Le 10: Physically-based gridded watershed models: Topkapi.** The concept of a physically-based model. Detailed component description in Topkapi-ETH: surface runoff and subsurface runoff. 2D routing simplifications. Case studies: rainfall variability, climate change, regulation.	- estimate uncertainties in model outputs - partition CC uncertainties to their sources
27. & 29.11. **SINCLAIR**	**Le 11: Physical components – soil hydrology.** Soil properties. Water retention curves. Pedotransfer functions. Darcy and Richard's equation. Concepts for infiltration. Philips and Green-Ampt models. Infiltration and saturation excess overland flow.	**Ex 4: Application of Topkapi-ETH** - apply Topkapi to prepared site (Kl Emme) - analysis of hourly streamflow output
4. & 6.12. **MOLNAR**	**Le 12: Physical components – ET.** Energy balance. Methods to calculate potential evaporation – simlified EB, mass transfer. Process of transpiration. Penman-Monteith equation. Simplifications.	- analysis of grid resolution effect - analysis of rainfall variability
11. & 13.12. **MOLNAR**	**Le 13: Examples of other physically-based watershed models.** Scales and modes of applications: catchment (WaSim), regional (PARFLOW, T&C), global (PRC-GLOBWB, VIC). Combination of watershed models with floodplain inundation models.	- study of spatial model output (snow, ET)
18. & 20.12. **ALL**	**OPEN DISCUSSION CLASS** Open discussion of selected topics in class. Details to be announced later.	- summary of exercises

Evaluation:

- Semester performance (exercises) 50% of grade
- Semester-end oral exam (30 mins, 2-3 week of January 2024) 50% of grade, sign-up on MOODLE