Syllabus

Advanced Hydrology
(Revised August 2024)
CE 20644, Credits: 3

Prerequisite: Engineering Hydrology, Environmental Engineering, Advanced Mathematics, Computer Programming

Course Description

This course provides a comprehensive overview of the concepts behind river basin hydrology and land-surface modeling. It covers key topics such as river basin terminology and classification, principles of channel network formation, river basin hydro-geomorphologic characteristics, conceptual frameworks for hydrologic modeling, and the physical basis of water cycle processes in land-surface models. The course also explores stochastic transport of water and solute in hydrological systems, including time-variant travel time distributions.

Course Outline

- River Basin Terminology and Classification (2 sessions)
  - What Is a River Basin?
  - River Basin Features (Divide, Source, Confluence, Tributary, Mouth)
  - River Basin Classification

- Principles of Channel Network Formation (2 sessions)
  - How a Channel Network Forms
  - Channel Initiation Area
  - The Practical Implication of Channel Initiation Area
  - How to Determine the Channel Initiation Area

- River Basin Hydro-Geomorphologic Characteristics (5 sessions)
  - River Network Terminology
  - Ordering of River Network
  - Horton Laws
  - Self-Similarity in River Basins
  - Tokunaga Trees
  - Hack's Law
  - Hydraulic-Geometry Relationships
  - Tests of Hortonian and Tokunaga Self-Similarity
  - Physiographic Attributes of a River Basin
  - The Width Function

- Conceptual Frameworks for Hydrologic Modeling (2 sessions)
  - Model Classification based on Conceptual Framework
  - Model Classification based on Spatial Structure (Lumped vs. Distributed)

- Introduction to Land-Surface Models (1 session)

- Physical Basis of Water Cycle Processes in Land-Surface Models (11 sessions)
  - Water Balance Components at Surface (Precipitation, Interception, Dripping, Evaporation from Vegetation, Throughfall, Transpiration, Evaporation from Soil, Snowmelt, Surface Runoff, Infiltration)
  - Runoff Generation Mechanisms
  - Partitioning of Soil Water between Surface Storage, Surface Runoff, and infiltration
  - Subsurface Flow (Subsurface Flow Structure, Confined and Unconfined Aquifers, Darcy's Equation, Soil Hydraulic Properties, Flow in Unsaturated Soils, Soil-Water Characteristic Curves, Richards' Equation, Coupling of Surface and Subsurface Flow, General Flow Equation and its Applications in Confined and Unconfined Aquifers)

- Energy Balance and Evapotranspiration at Earth's Surface (4 sessions)
  - Classification of Approaches to Estimate Evapotranspiration
  - Energy Balance-based Method to Estimate Evapotranspiration
  - Radiative Fluxes at the Vegetated and Non-Vegetated Surfaces
  - Turbulent Diffusion Approach to Estimate Evapotranspiration
  - Eddy Covariance Method to Estimate Evapotranspiration
  - Monin-Obukhov Similarity Theory

- Stochastic Transport of Water and Solute in Hydrological Systems (5 sessions)
  - Overview of Unit Hydrograph Theory: Concept, Assumptions, and Limitations
  - Theory of Time-Variant Travel Time Distribution: Motivation
  - Residence Time, Travel Time, and Life Expectancy of Water
  - The Fokker-Plank Equation and Age-Mass Density Function
  - Analytical Expressions for the Residence and Travel Time Distributions
  - The Concept StorAge Selection (SAS) Function
  - SAS Function Estimation Methods

References:

- "Runoff Prediction in Ungauged Basins" by Blöschl et al., Cambridge University Press, 2013.
- "Land Surface Hydrology, Meteorology, and Climate: Observations and Modeling", Lakshmi V., J. Albertson, and J. Schaake, American Geophysical Union, 2013.
- "Fractal river basins: chance and self-organization", I. Rodríguez-Iturbe & A. Rinaldo, Cambridge University Press, 2001.
- "Water-Resources Engineering" by David A. Chin, Pearson; 3rd edition, 2012.
- "Rainfall-runoff modelling: the primer" by K. J. Beven, John Wiley & Sons, 2012.