Department of Geography and Earth Sciences

WRM 625

Hydrological Modeling

Course Lecturer: Cosmo Ngongondo

Lecture 1

Class Hours

- Class Hours 21 Sept to 2 Oct 2020
  - Monday:8.00-10.00 am & 3.00 to 5.00 pm (Practical)
  - Tuesday: 10.00 am to 12.00 pm & 1.00-3.00 pm (Practical)
  - Wednesday: 8.00-10.00 am & 3.00 to 5.00 pm (Practical)
  - Thursday: 10.00 am to 12.00 pm & 1.00-3.00 pm (Practical)
  - Friday: 8.00-10.00 am & 10.00 am to 12.00 pm (Practical)

Main Text

- Xu, C-Y. (2005). Hydrological Models (Lärobok i Avrinningsmodeller). **Uppsala University Department of Earth Sciences Hydrology**

Assessment

- 50% Continuous assessment
  - Test 1, 30 Multiple Choice Questions
  - Assignment: Modeling with WASMOD-M or , due end of module
- 50% End of Module Exam (3 Hours)

Introduction
Consider the Scenarios:

1. A major expansion of urbanization is planned in forested land – malls, apts, parks, industry

What kind of Water Resources Management Strategy/Measures would be needed to ensure long-term water needs?

2. How will the planned urbanization change the response of the land to rainfall? Increase chances of floods? Flashier? Bring down GWT?

Watershed Models are used to answer such questions

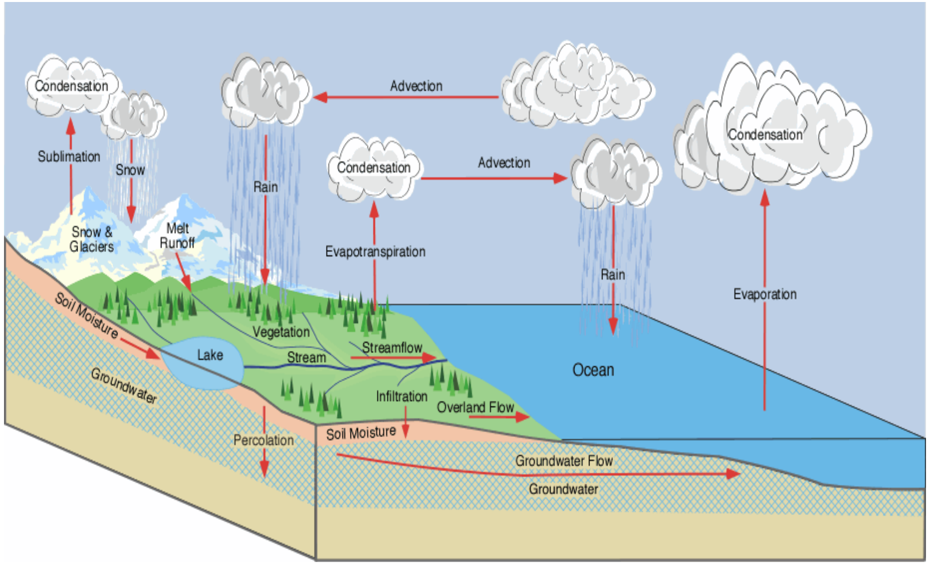
Introduction

GOALS OF THIS COURSE

- Be aware of the Major Models out there and their basic workings
- Understand Data needs and requirements
- Merits/Demerits of Models (situational)
- Ponder over: *What is the Best Model?* (open question)
  - Be able to make an informed decision on the choice of a Model (for Consulting, Industry, Public Works)

Introduction

- **What is a model?**
- A simplified version of reality;
  - A catchment model is a mathematical description and numerical simulation of processes that take place in a catchment.
  - Simplified reality



•All watershed Models (or Rainfall-Runoff) attempt to model the Hydrologic Cycle at the watershed scale.

Introduction

- **Why there is a need for modeling in hydrology science?**
  - Some hydrological parameters are very difficult or impossible to measure directly, so they can be obtained using models, and existing data as input; i.e.,
    - Filling the gaps in the records, extending the records
    - Generating data at ungauged sites
  - One of the most important tasks in hydrology is forecasting flood peaks and runoff volumes; model simulations can do it. i.e.,
    - Forecasting the future

Basic Components of a Hydrologic Model

Water Balance

- Inputs - Outputs = Change in the Storage

$= I - O = \Delta S$

Be careful of units!

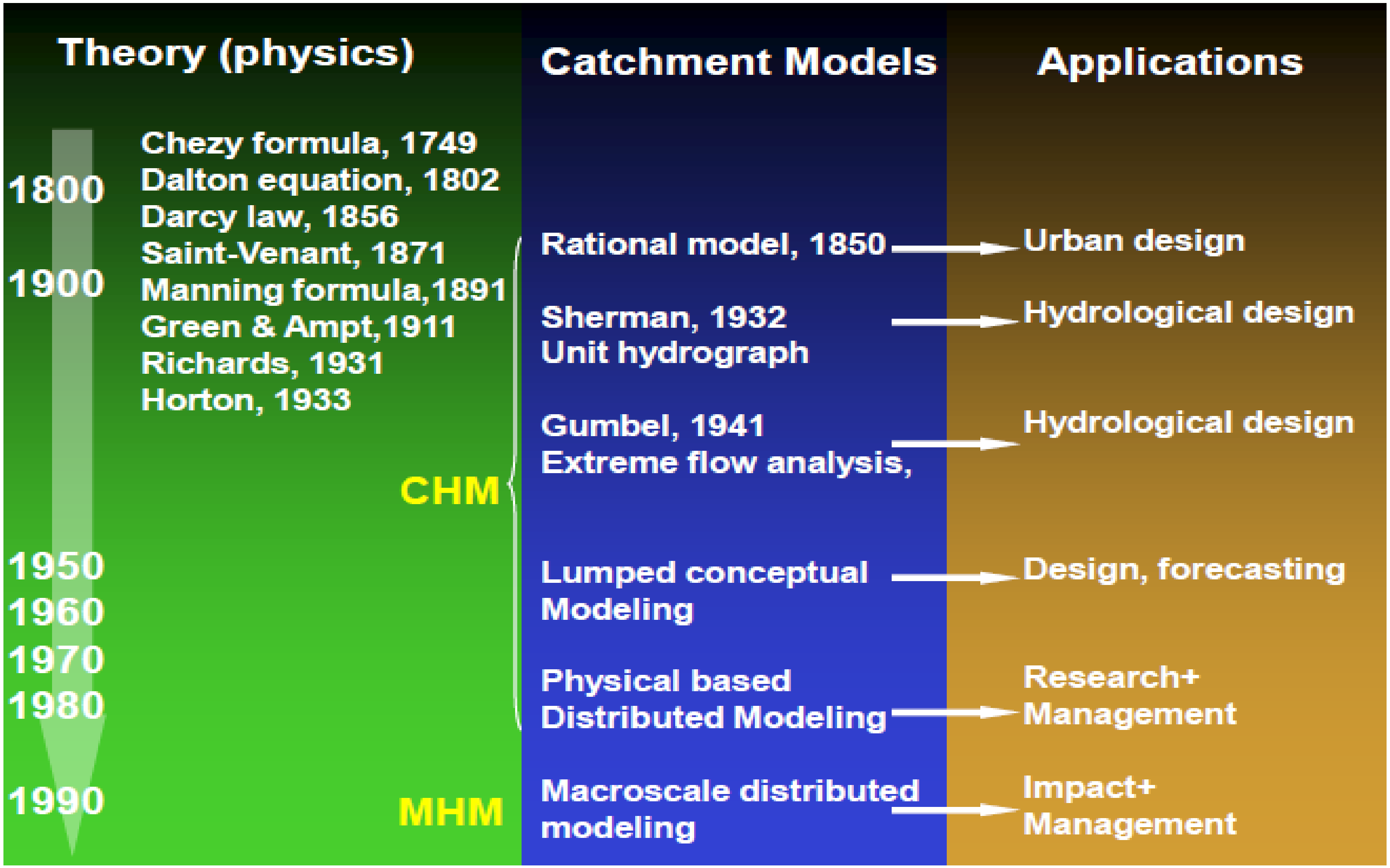
Mass continuity Equation

$P - R - E - T - G = \Delta S$

Work with uniform units!
(Golden rule!)

P = precipitation
R = surface runoff
E = evaporation
T = transpiration
G = ground water flow
Δ S = change in storage

Historical Developments



Simplest Models: Rational Formula

- **In the 19th century**: in response to three types of engineering problems: (1) urban sewer design, (2) land reclamation drainage systems design, and (3) reservoir spillway design.
- The rational formula (Mulvaney, 1851):

$$Q_p = CiA$$

- Where C is the coefficient of runoff (dependent on catchment characteristics) *i* is the intensity of rainfall in time T_c and A is the area of catchment.
- C is model parameter with variables A and I
- Simplified conceptual model of travel times on basins with negligible storage.

Historical Developments

- **In the 1920s:** the need for a corresponding formula for large catchments was perceived, many modifications were introduced in the rational method in order to cope with the non-uniform distribution, in space and time, of rainfall and catchment characteristics.

- The modified rational method, based on the concept of isochrones or lines of equal travel time

Historical Developments

- **In the 1930s:** A major step forward in hydrological analysis was the concept of the unit hydrograph introduced by the American engineer Sherman in 1932 on the basis of superposition principle.
- Unit hydrograph made it possible to calculate not only the flood peak discharge (as the rational method does) but also the whole hydrograph (the volume of surface runoff produced by the rainfall event).

Historical Developments

- **In the 1950s:** This was the period when conceptual models originated.
- **From the 1960s:** A large number of conceptual, lumped, rainfall-runoff models appeared thereafter.
- **In the 1970s:** autoregressive moving average (ARMA) model and other forms of time series stochastic models, The real-time forecasting models.

Historical Developments

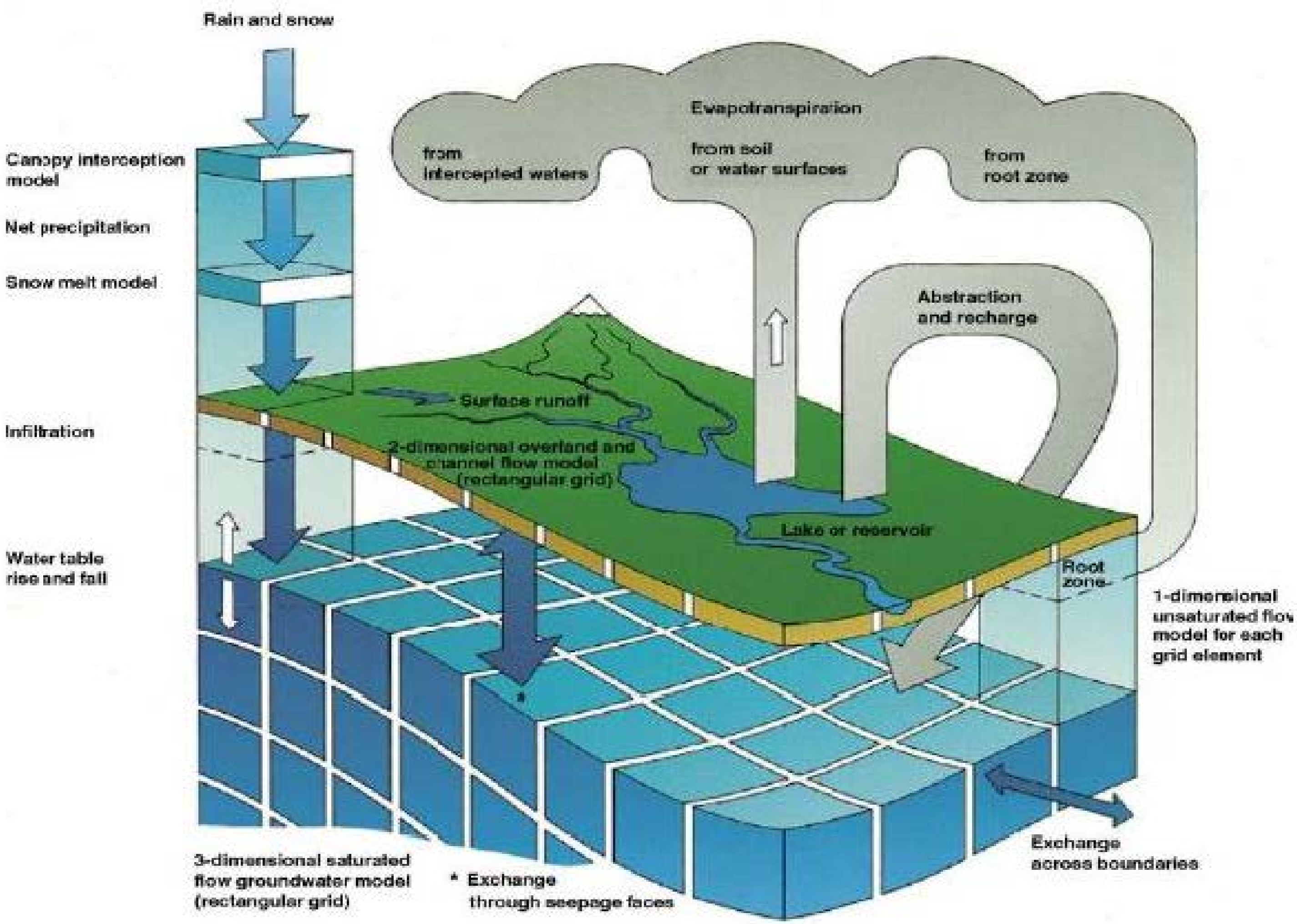
- **In the 1980s:** physically-based distributed parameter models:
  - the effects of land-use changes,
  - the effects of spatially variable inputs and outputs,
  - the movements of pollutants and sediments, and
  - the hydrological response of ungauged catchments where no data are available for calibration of a lumped mode

Historical Developments

- **From the late 1980s:** The macro-scale hydrological models

- operational and planning purposes, climate change and land use change over large geographical domains

Complex Models: The SHE Model



The SHE model –basic info

- SHE = Systéme Hydrologique Européen
- Physically-based, distributed catchment modelling system
- Developed by
  - Danish Hydraulic Institute –unsaturated, saturated zoon components
  - British Institute of Hydrology -snowmelt, interception, evaporation
  - SOGREAH (France) –overland flow, channel flow
- Financial support by EU
- Started from 70’s and completed in 1984

The SHE model –basic info

- **Major physical processes**
  - Interception: Rutter accounting procedure
  - Evapotranspiration: Penman-Monteith method
  - Overland flow and channel flow: St. Venant equation
  - Unsaturated zone flow: Richards equation
  - Saturated zone flow: Boussinesq equation
  - Snowmelt: energy balance method

Note

- Thousands of models lie in between the simple and complex models

- Examples include HBV model, WASMOD, TOPMODEL

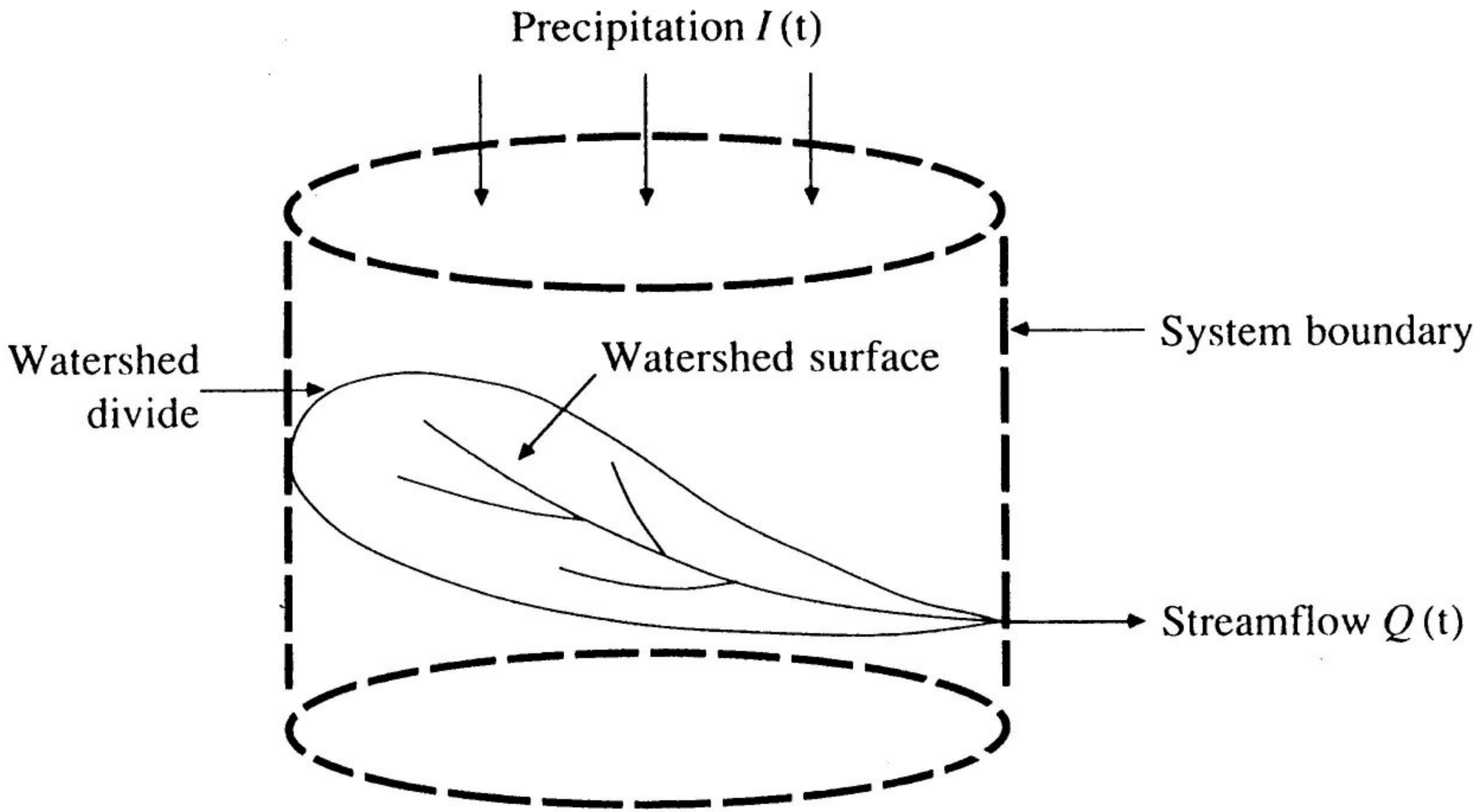
Basic definitions

- **Hydrological system**: a set of physical, chemical and/or biological processes acting upon an input variable or variables, to convert it (them) into an output variable (or variables).

- **a variable**: is a characteristic of a system which may be measured, which assumes different values when measured at different times. Daily rainfall, runoff, evaporation, temperature, infiltration, soil moisture.

- **parameter**: is a quantity characterising a system. It may or may not remain constant in time (in most cases of modelling we consider it as time constant).

Hydrologic System



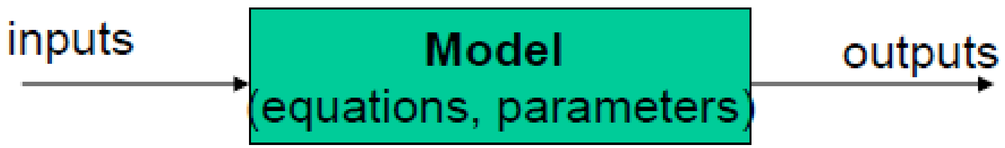
Watershed $\quad Q(t) = \Omega I(t)$

$$Q(t) = C\, I(t)$$

$$S = kQ$$

Basic Model structure

- All mathematical hydrological models have the following general structure



$$y_t = f^*(x_t, x_{t-1}, x_{t-2}, \cdots; y_{t-1}, y_{t-2}, \cdots; a_1, a_2, \cdots) + \varepsilon_t$$

Where

Y_t = observed values of the variable to me modeled

$f^*(.)$ = a function of specified form

X_i = input variable of the present and past times

Y_{t-i} = output variables at the present and past times

a_t = parameters

ε_t = a residual term

Specific models can be obtained by defining different forms of $f^*(.)$ and give different assumptions about variables and parameters

End of Lecture 1