Hydrological Modelling (3 ECTS)

Lecturer: Dr. Tran Van Ty
Dr. Huynh Vuong Thu Minh

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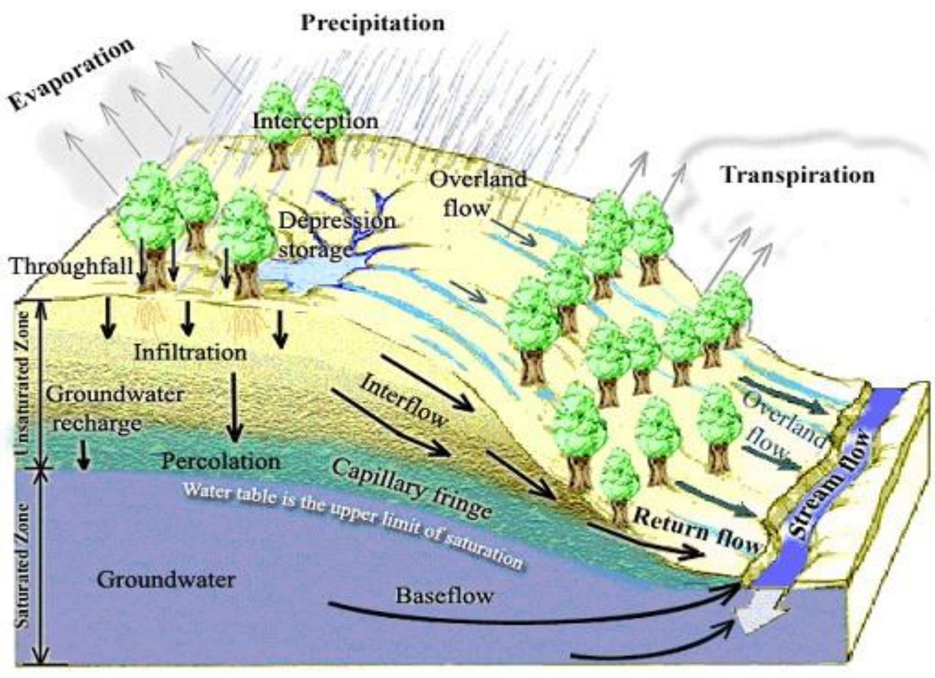

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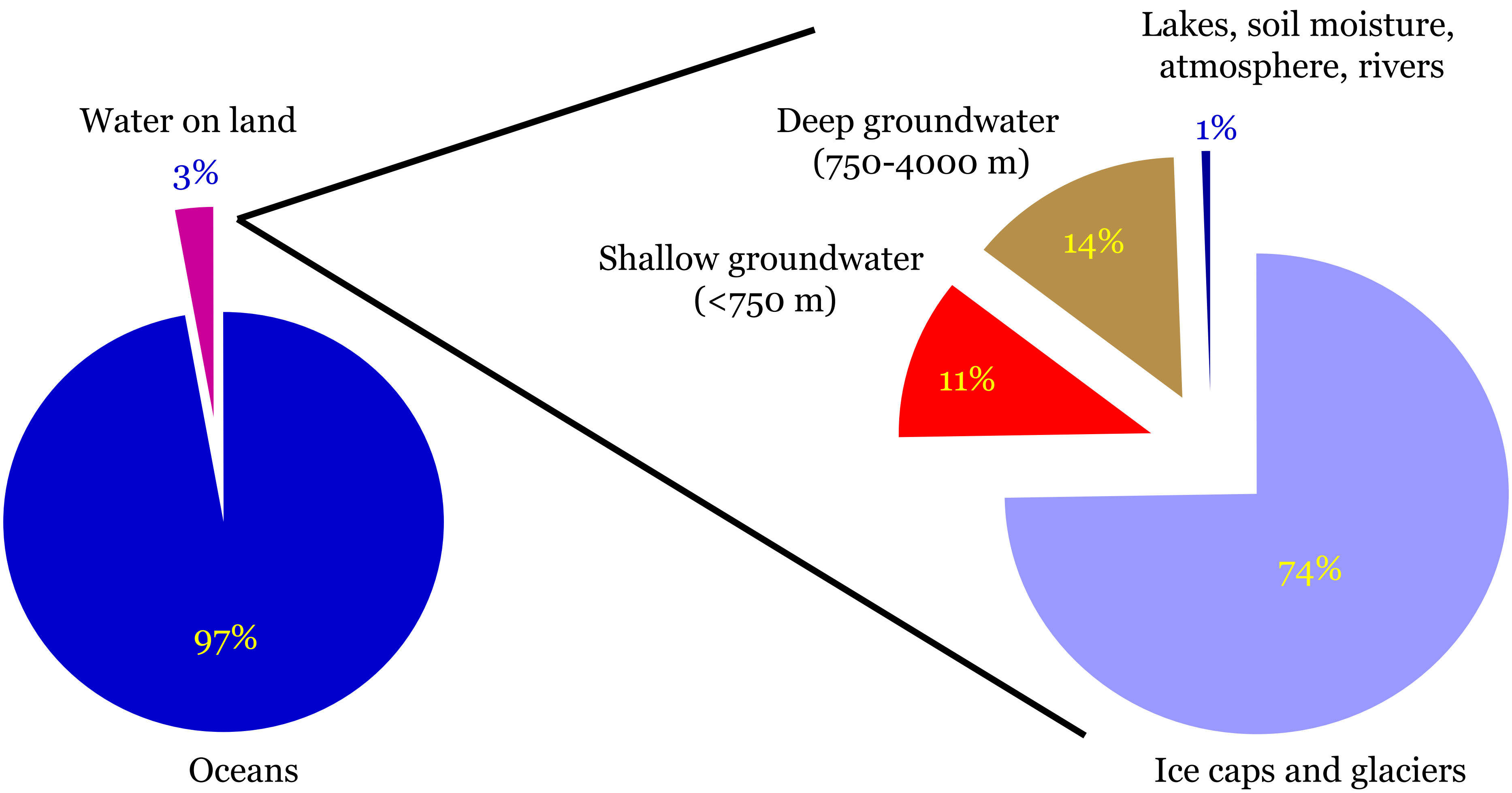
Course’s Description

The course is designed to provide learners with knowledge and skills in conceptual modeling, physical principles of the water cycle, hydrological systems, and the steps involved in developing hydrological modeling. The course also covers deterministic and stochastic hydrological models, as well as statistics model application.

Cooordinator	**College of Technology**
Credits	3 ECTS
Lecturers	Tran Van Ty, Huynh Vuong Thu Minh
Level	Master
Host institution	Can Tho University
Course duration	30 hours

1. Inventory of water on Earth



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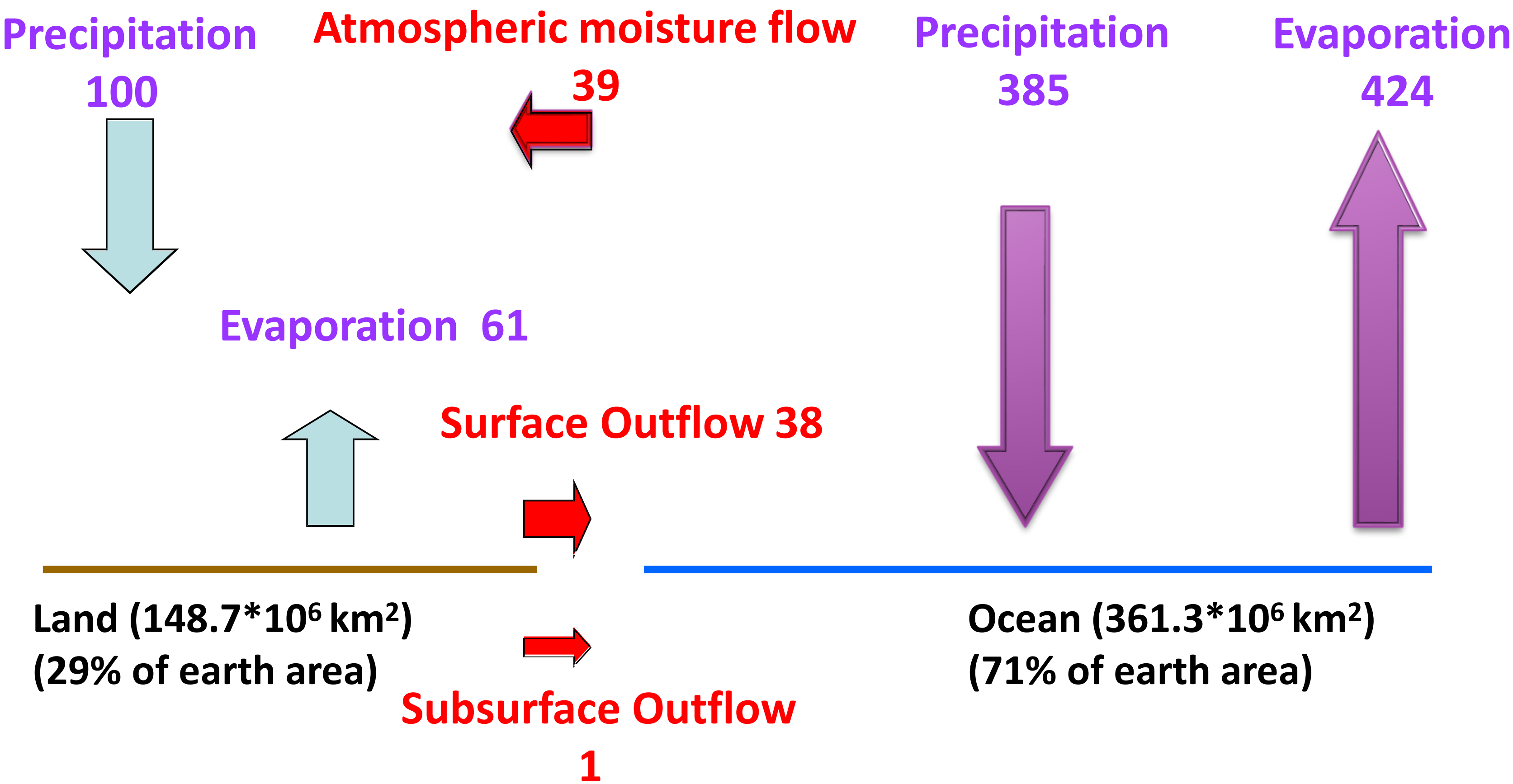
2. Global Water Balance (Volumetric)



Units are in volume per year relative to precipitation on land (119,000 km^3/yr) which is 100 units

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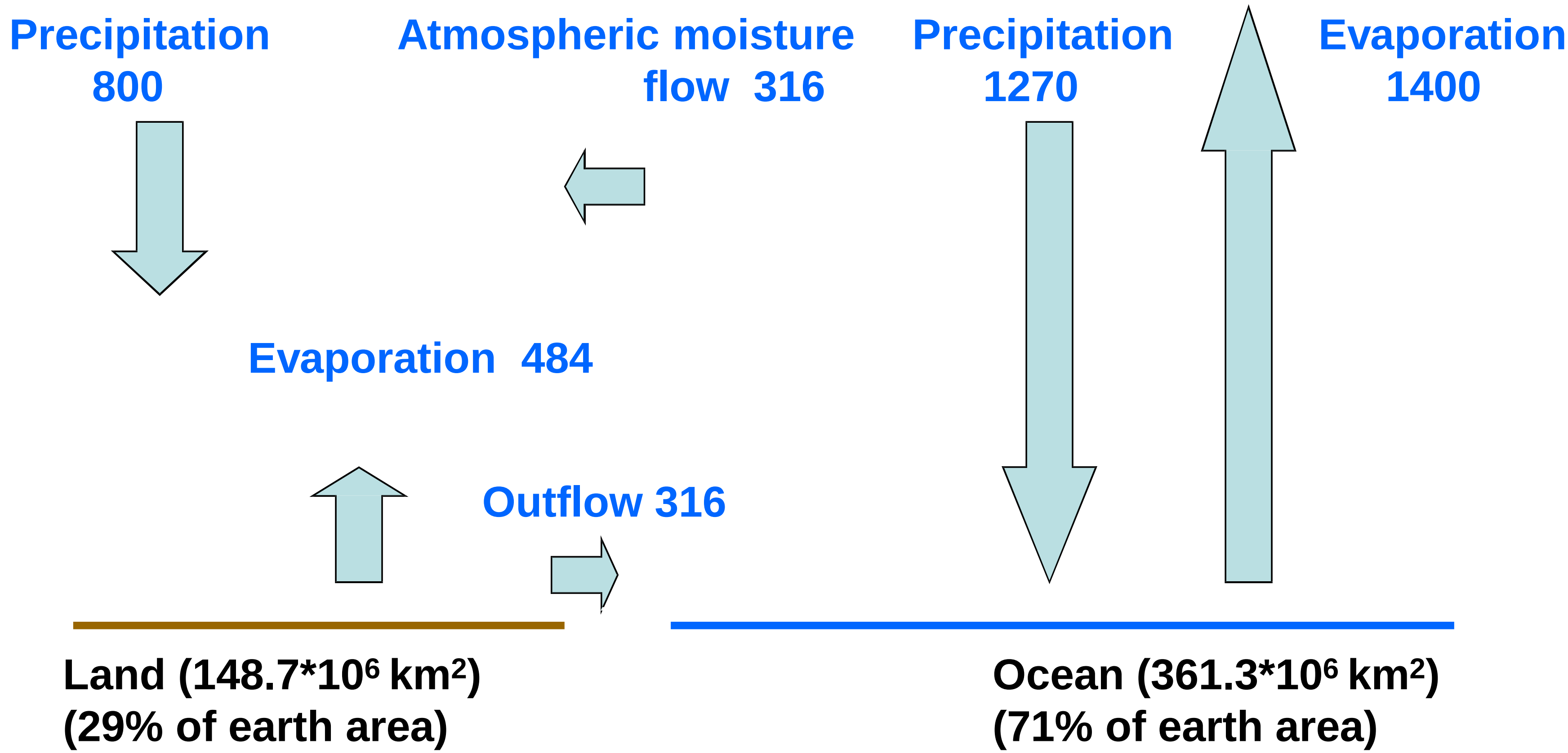
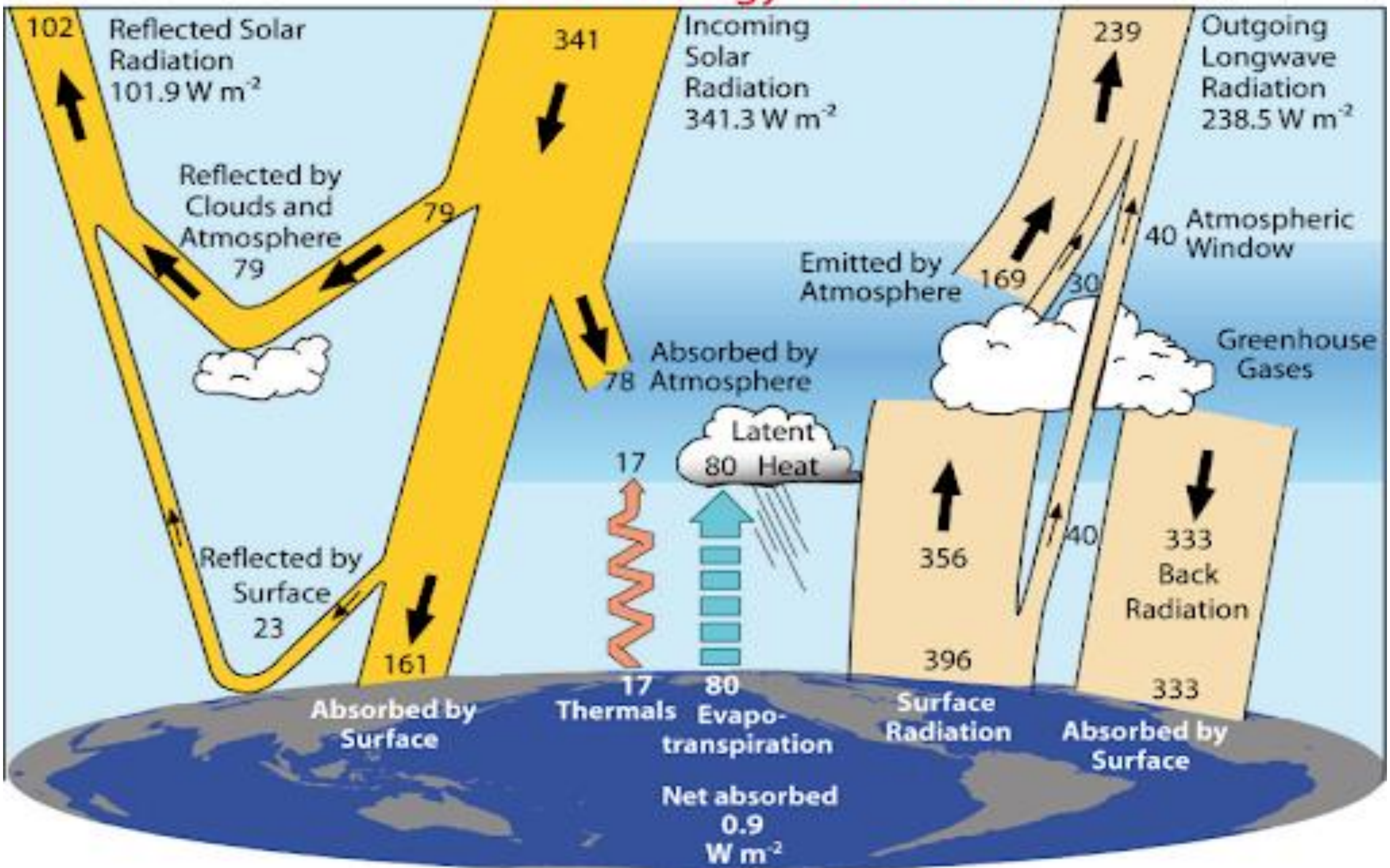
2. Global Water Balance (mm/yr)



Global Energy Flows W m^{-2}



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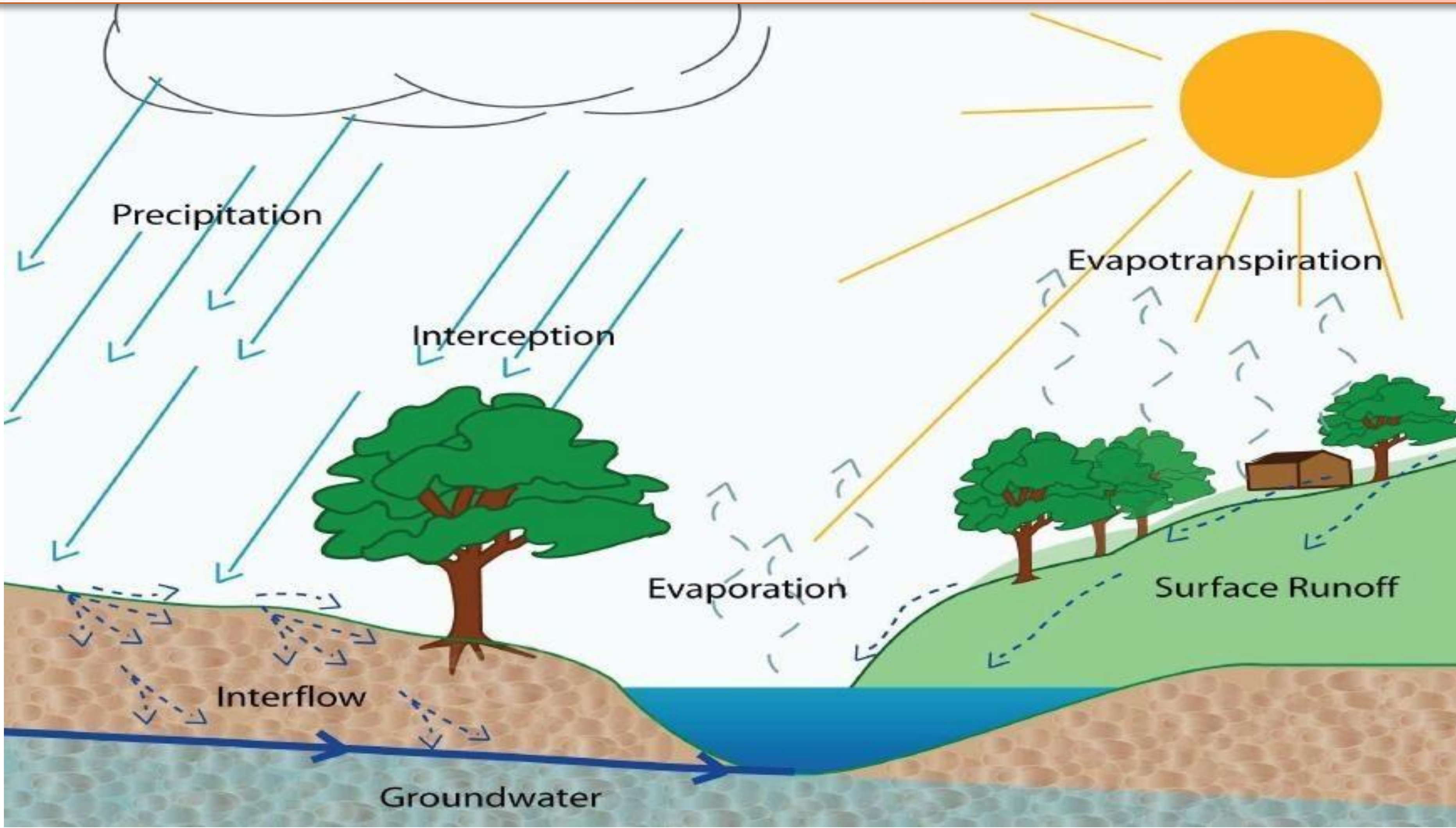
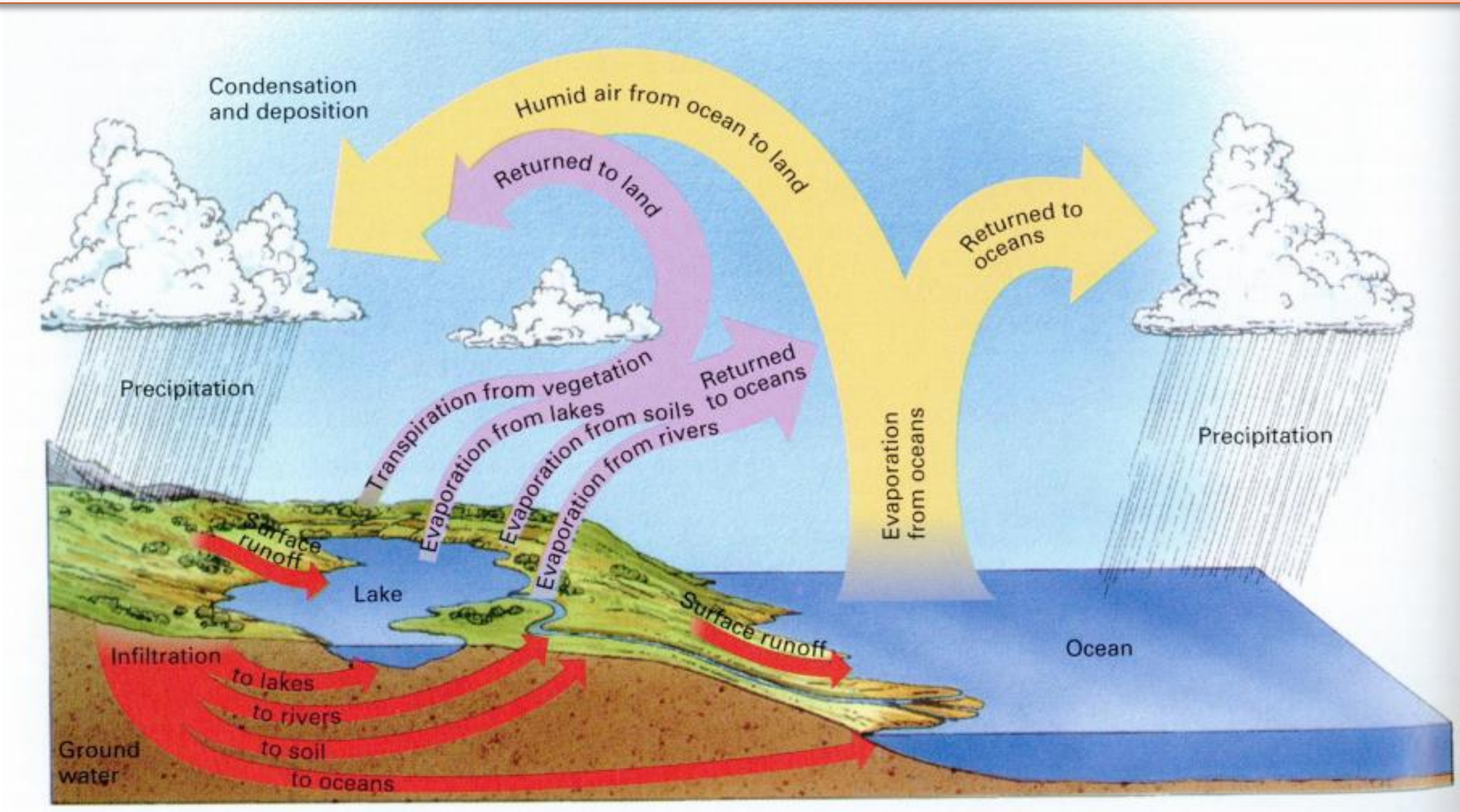
What is the Hydrologic Cycle?

The hydrologic cycle is the system which describes the *distribution* and *movement* of water between the earth and its atmosphere. The model involves the continual circulation of water between the oceans, the atmosphere, vegetation and land.

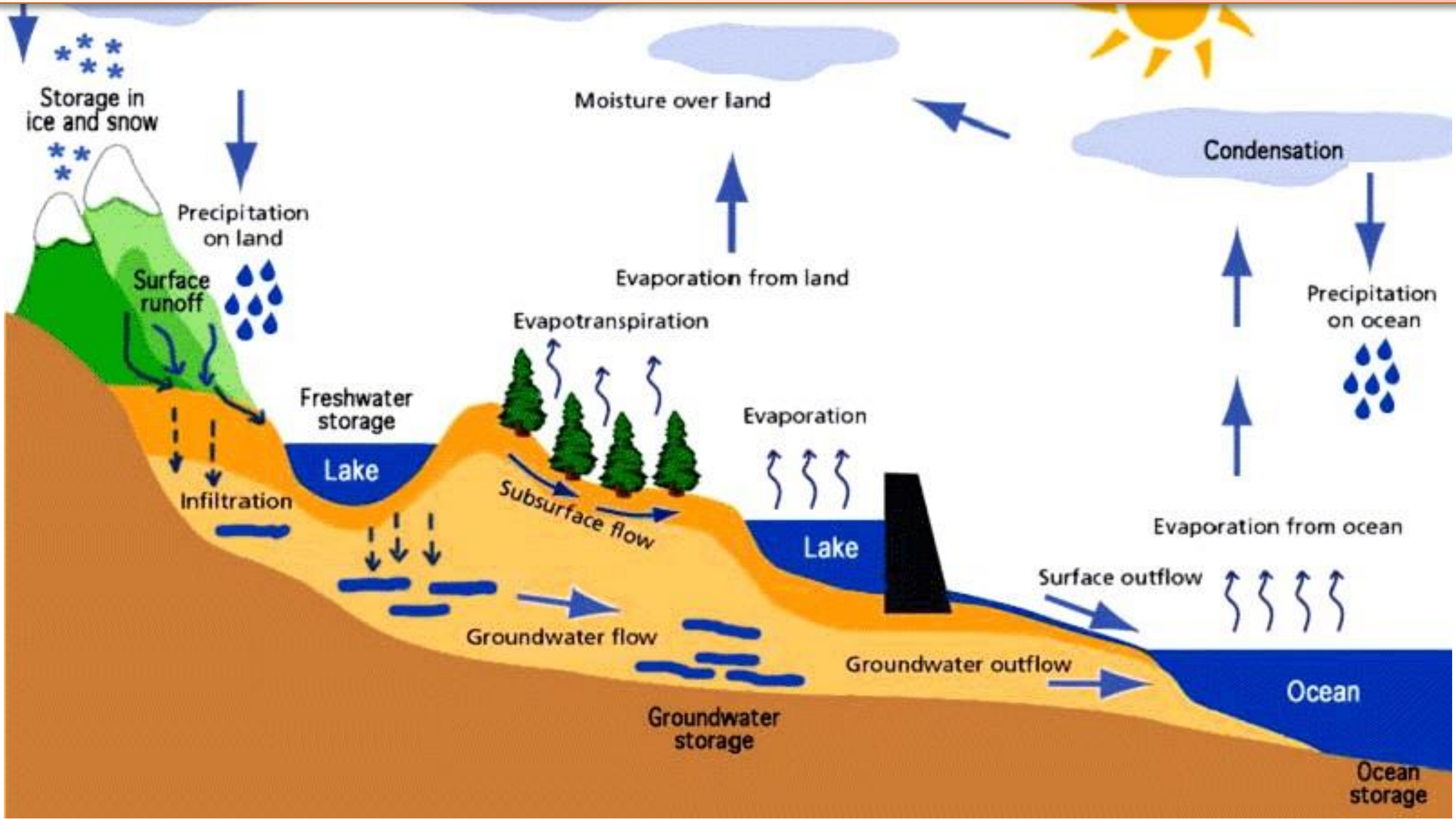
3. The hydrologic cycle concept



3. The hydrologic cycle concept



3. The hydrologic cycle concept



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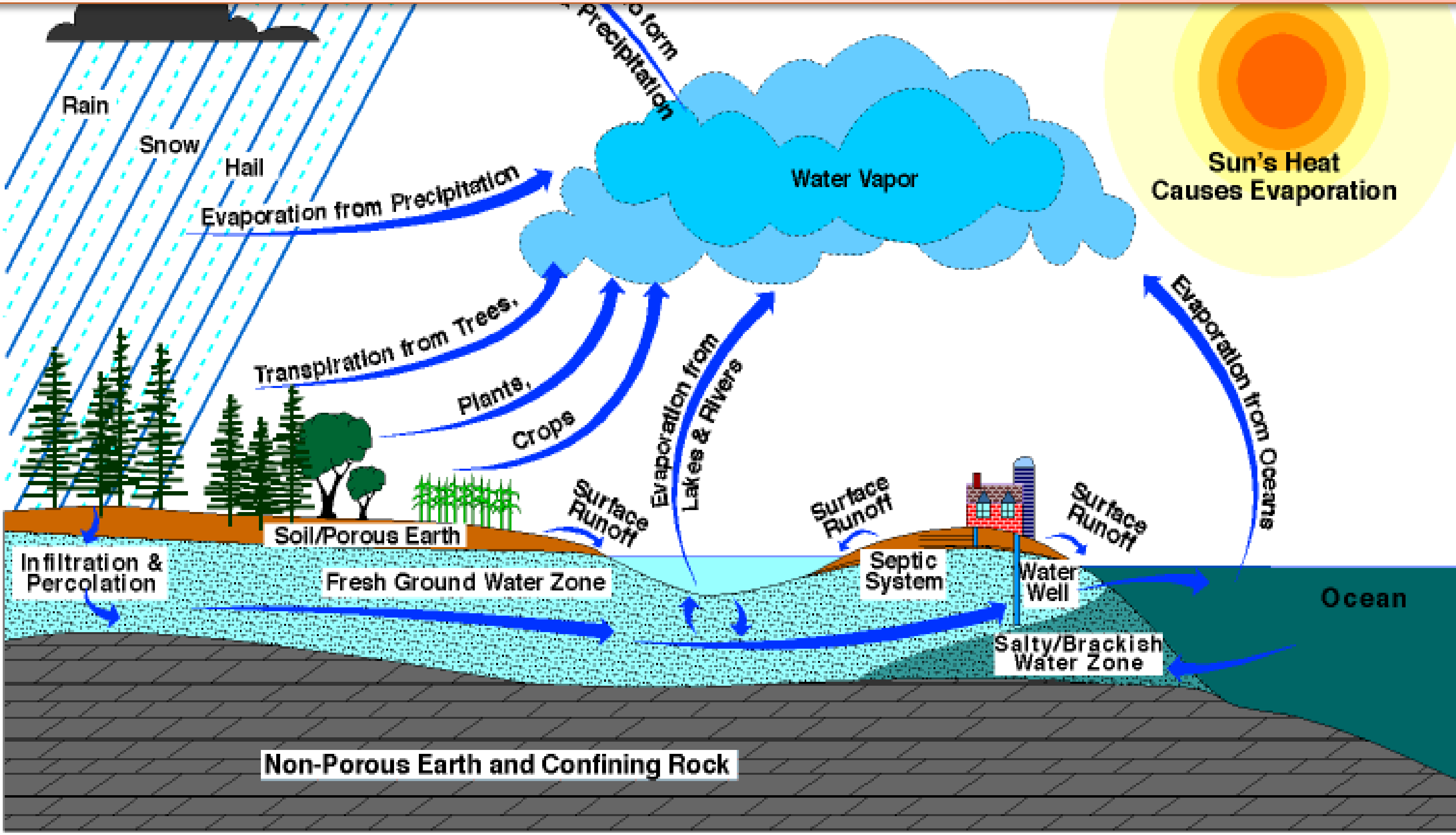
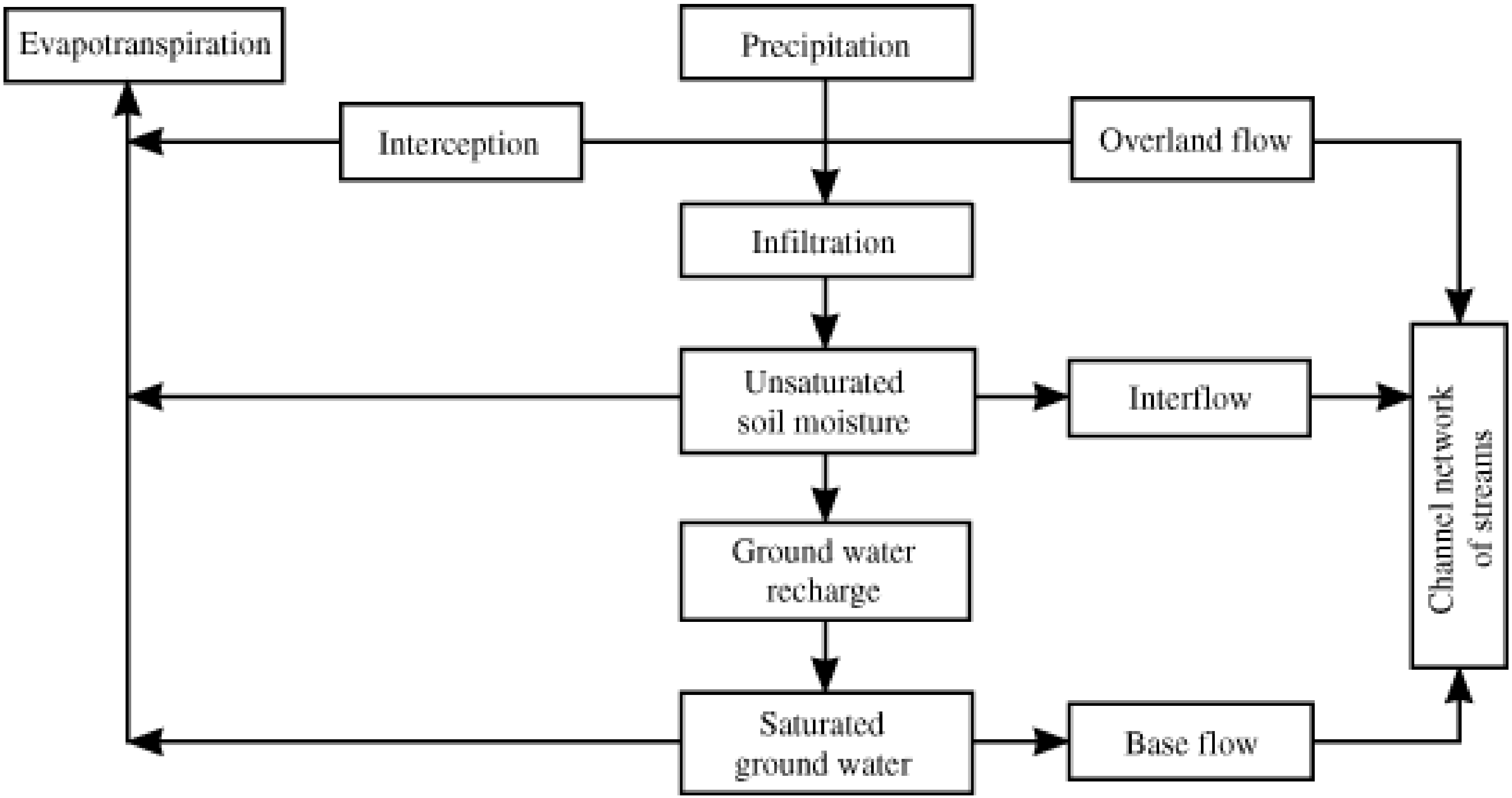
3. The hydrologic cycle concept

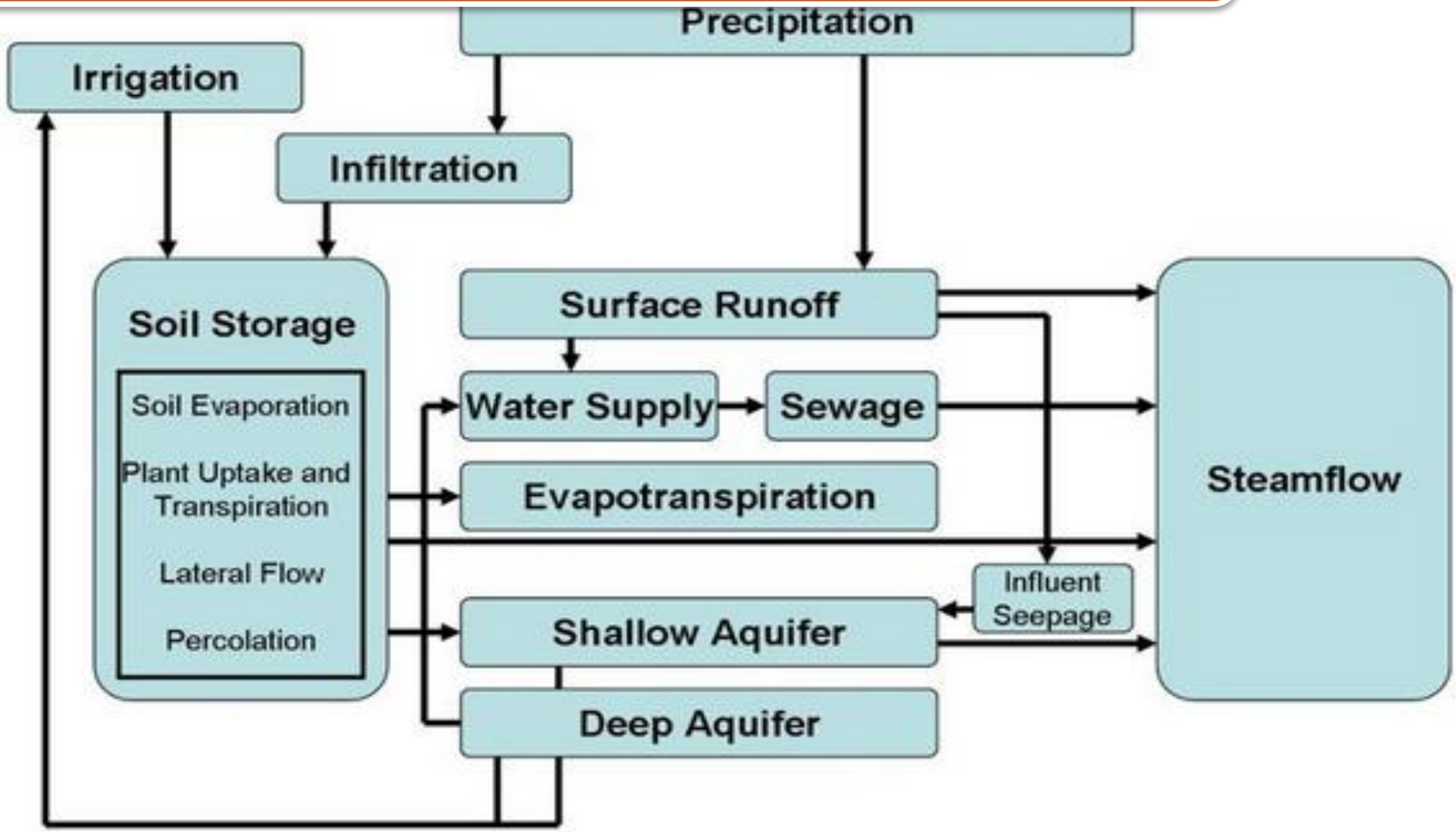


4. Components of hydrologic cycle

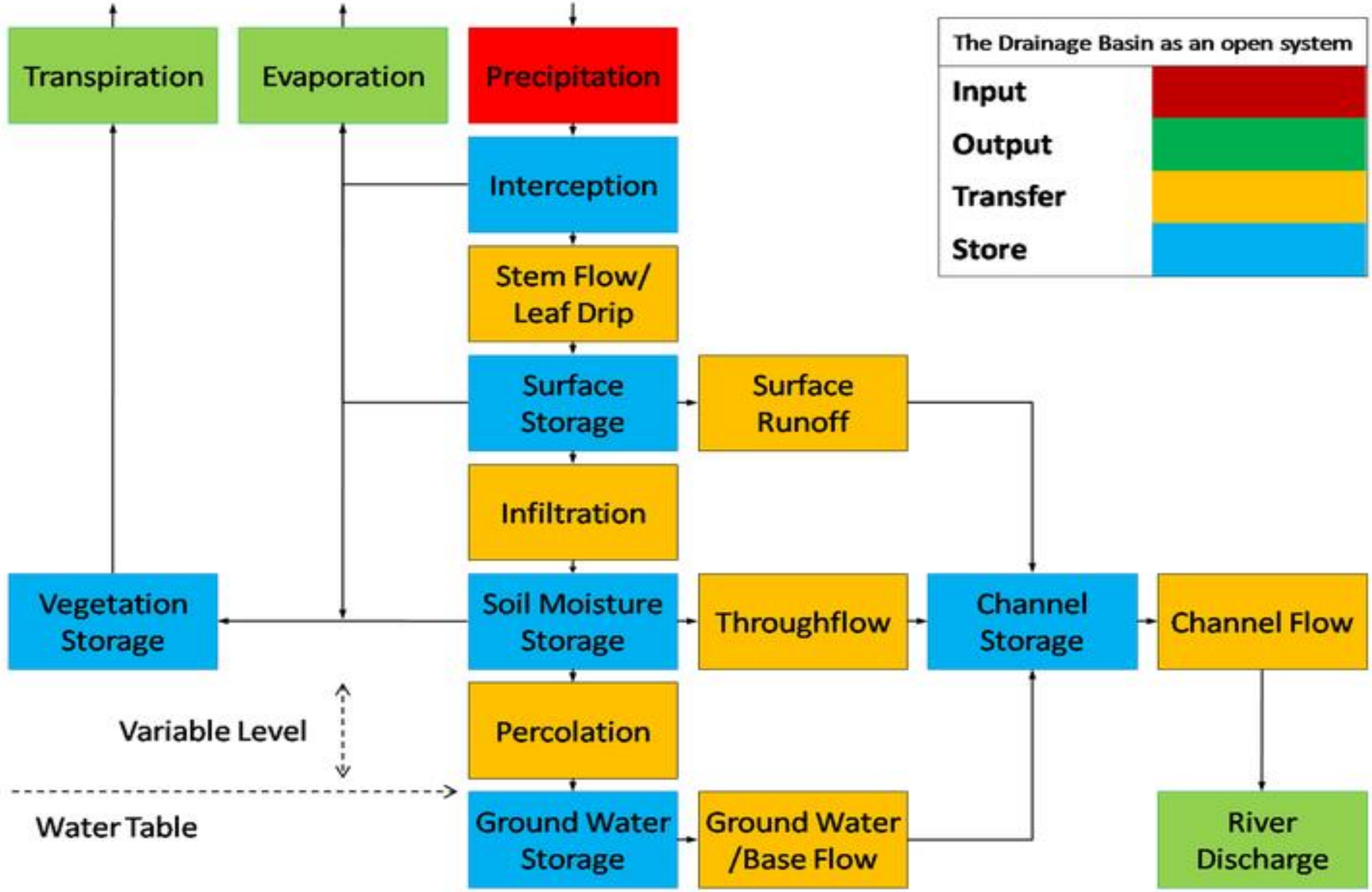


Schematic diagram of the Hydrologic Cycle (after Domenico & Schwartz, 1990)

4. Components of hydrologic cycle



4. Components of hydrologic cycle



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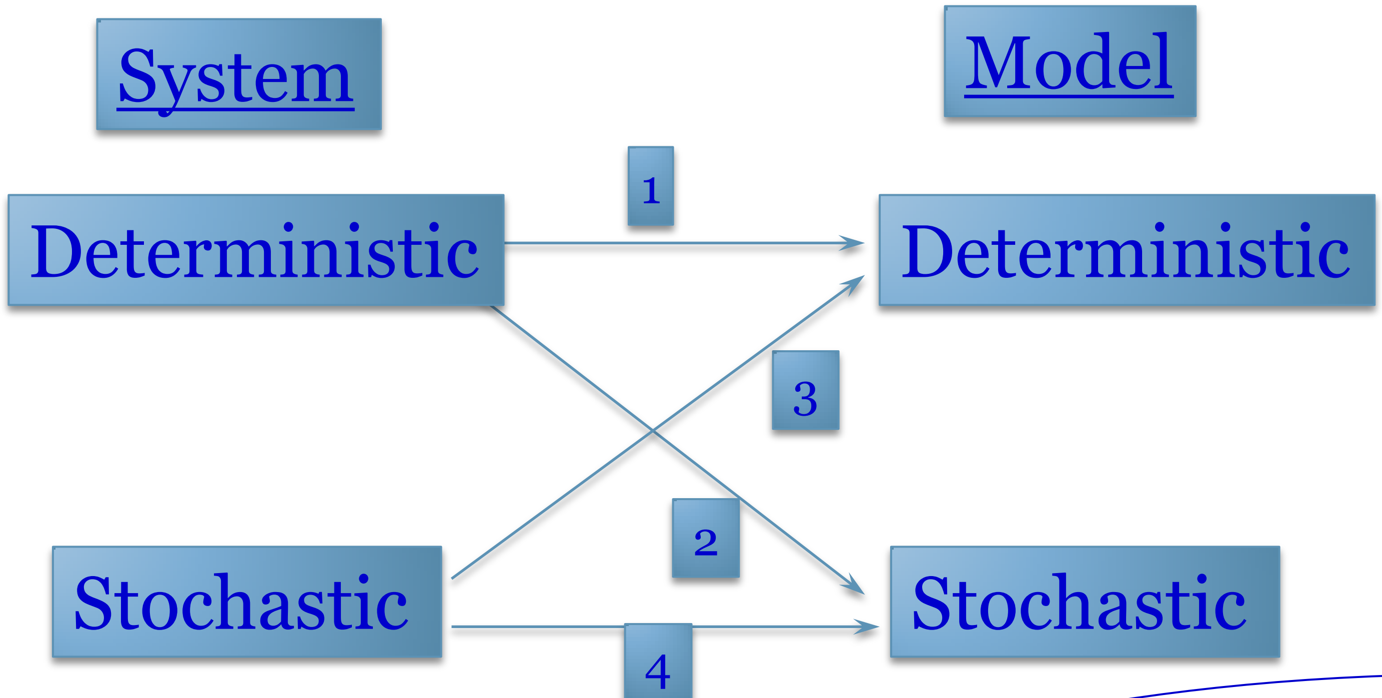
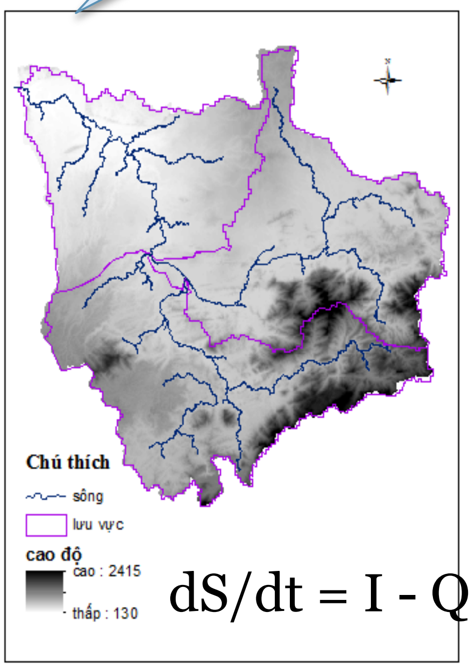
Stochastic vs. Deterministic ?



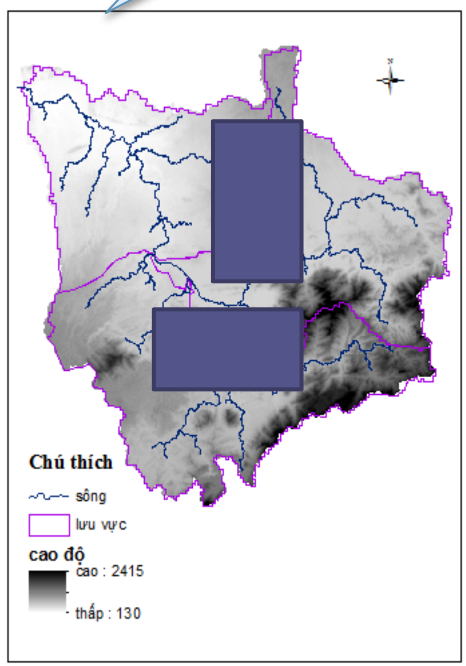
5. Deterministic Hydrologic Model

Lumped model

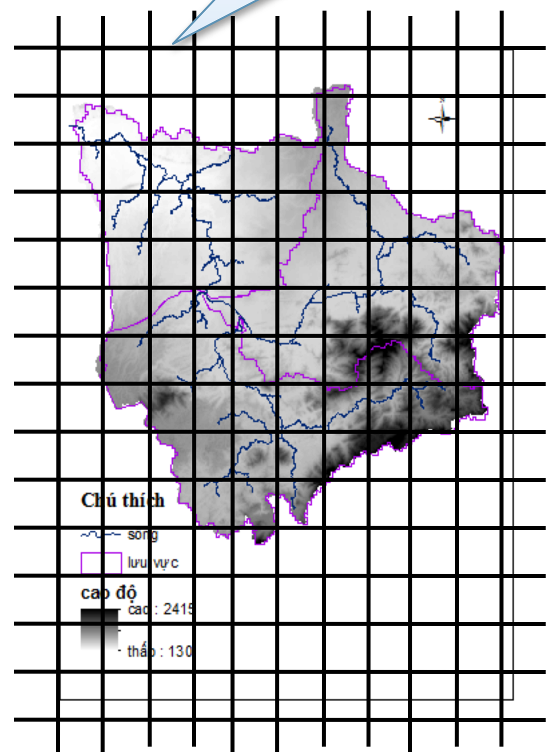


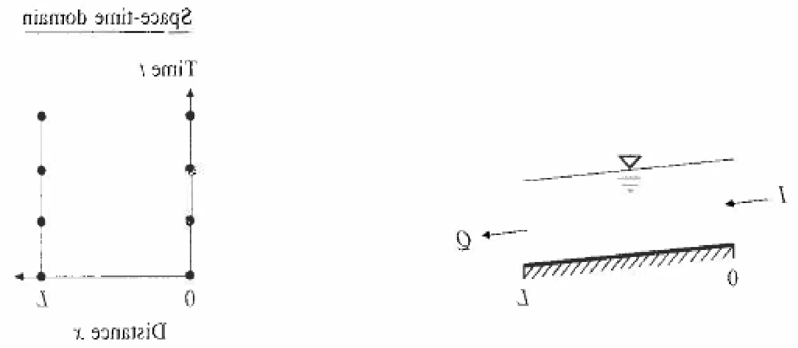
$$dS/dt = I - Q$$

Semi-Distributed



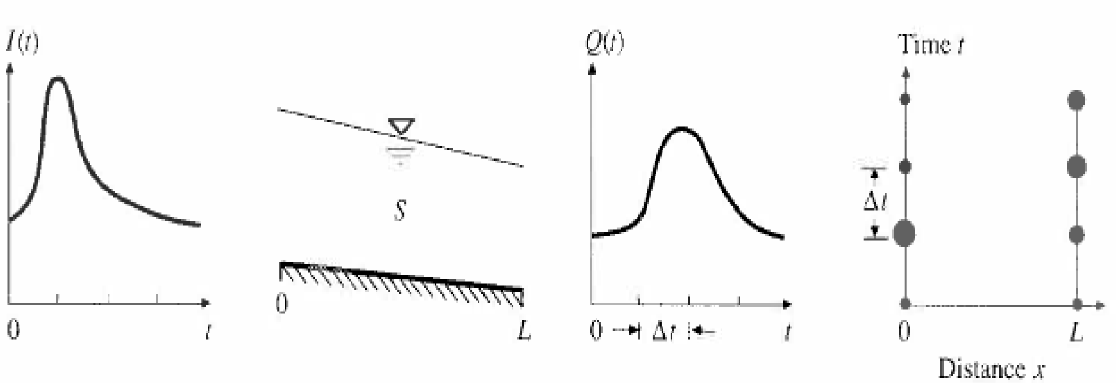
Fully-Distributed





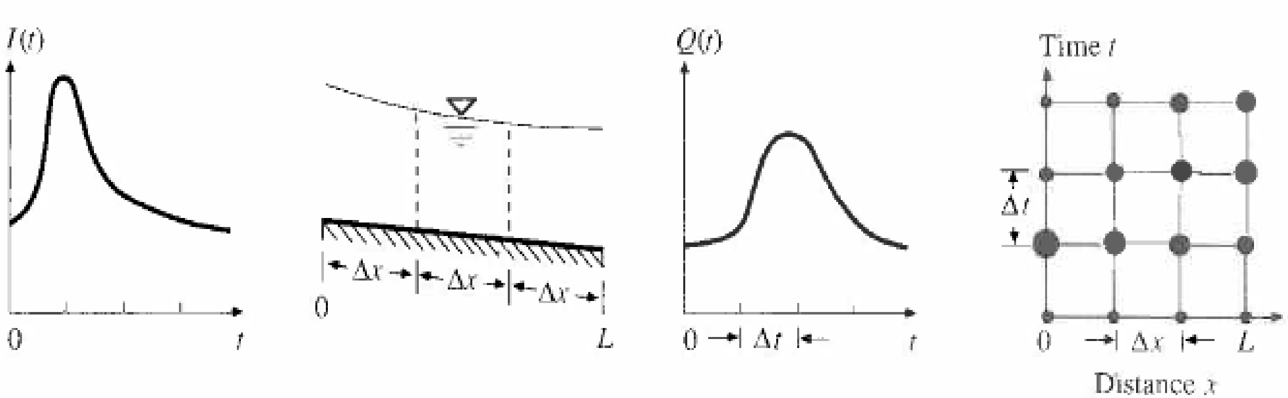
Lumped Steady Flow Model

$I = Q$



Lumped Unsteady Flow Model

$dS/dt = I - Q$



Distributed, Unsteady Flow Model

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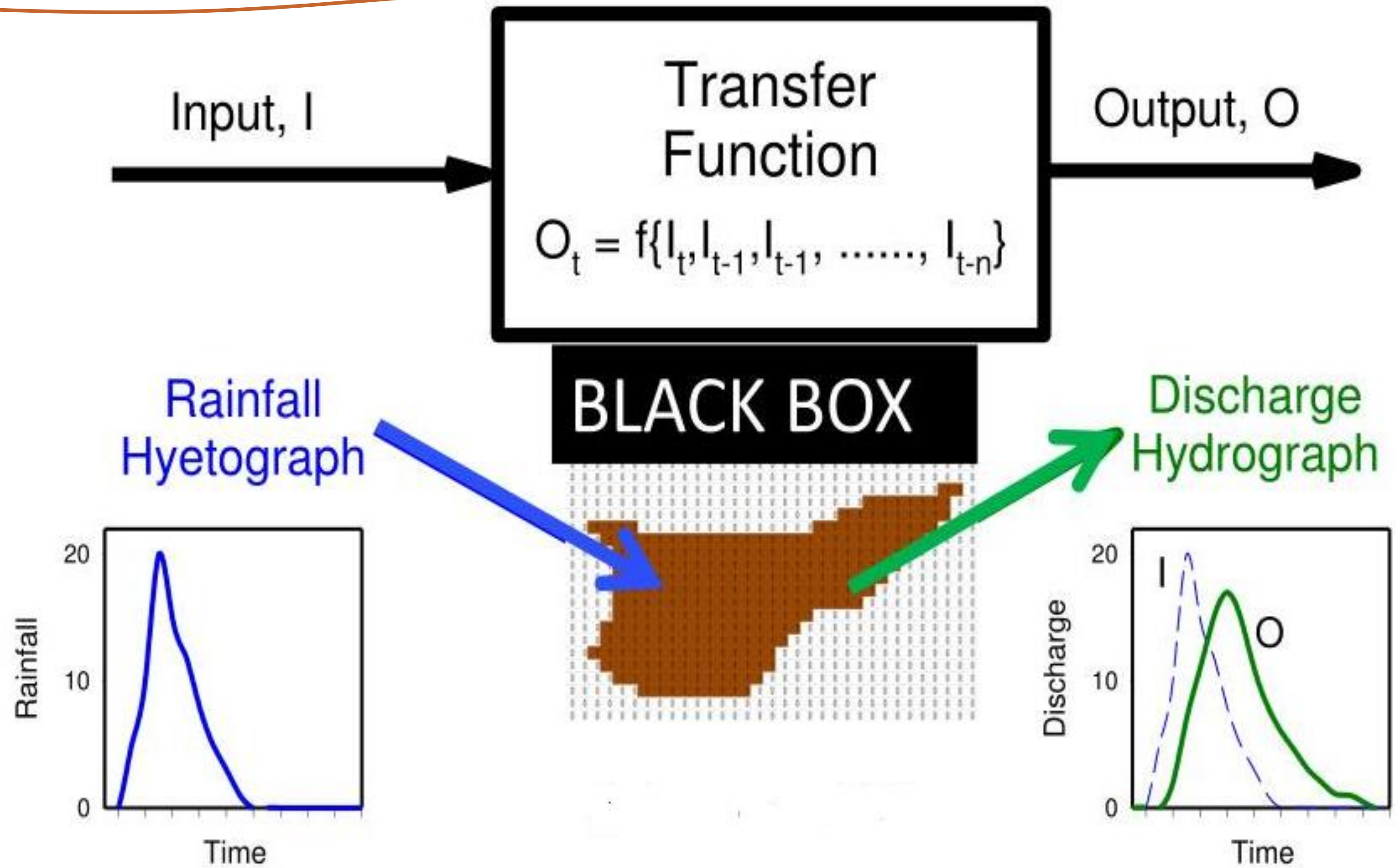
5. Deterministic Hydrologic Model

Lumped models

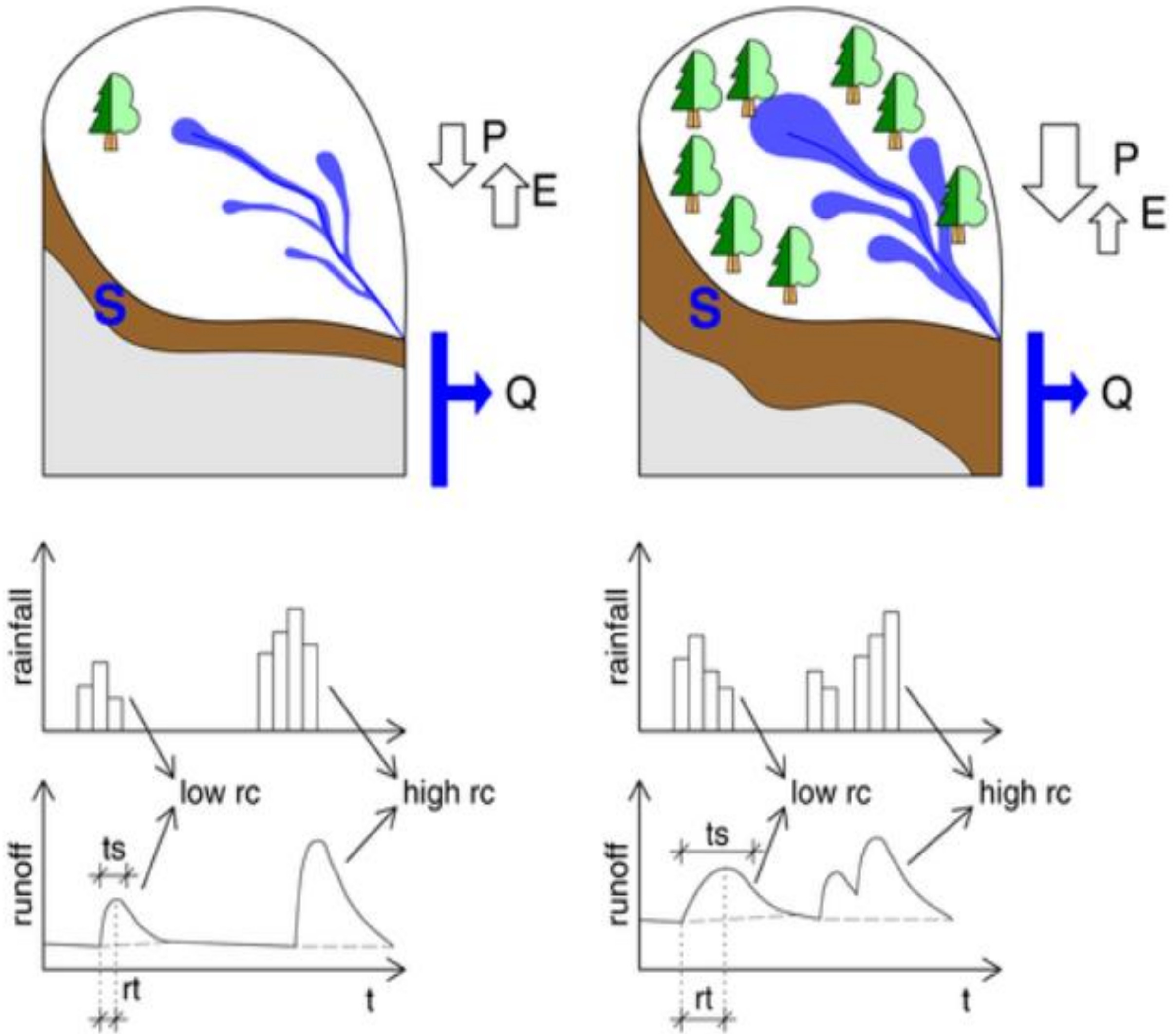
Parameters do not vary spatially within the basin & response is evaluated only at the outlet, without explicitly accounting for the response of individual sub-basins.

- Parameters do not represent physical features of hydrologic processes; model parameters – area weighted average
- Not applicable to event based processes
- Discharge prediction at outlet only
- Simple & minimal data requirements, easy use
- Eg. SCS-CN based models; IHACRES, WATBAL etc.

Lumped model – Black box



Lumped model example



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5. Deterministic Hydrologic Model

Semi – distributed models

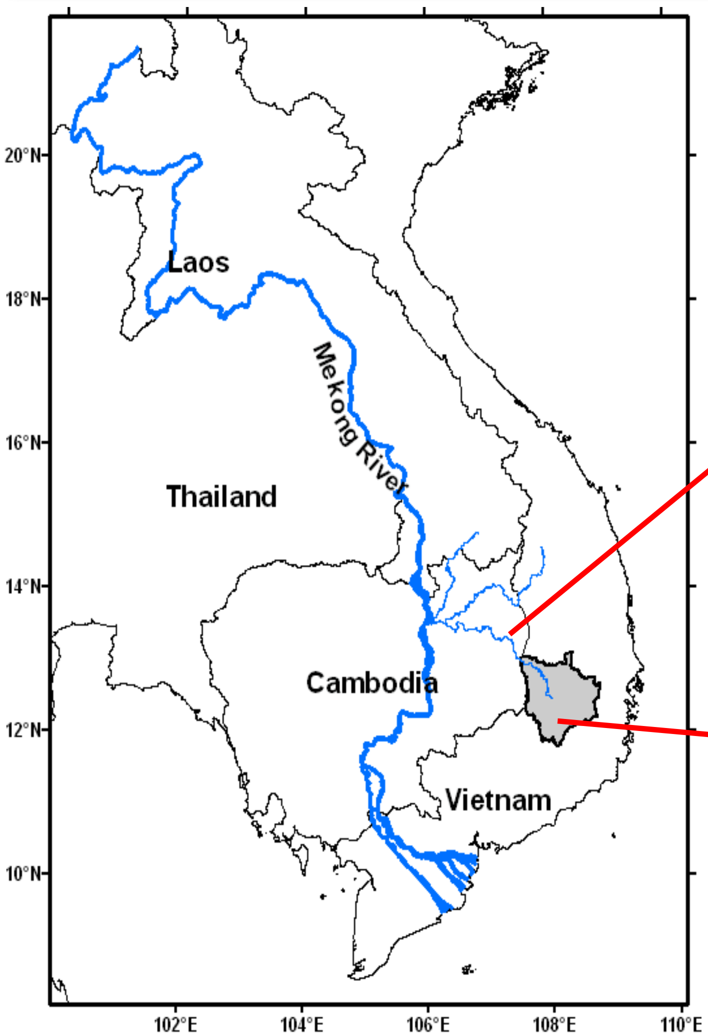
- Parameters are partially allowed to vary in space by dividing the basin into a number of smaller sub-basins
- Mainly two types: Kinematic wave theory models (eg. HEC-HMS model) - simplified version of surface flow equations of physically based model
- Probability distributed models – spatial resolution is accounted for by using probability distributions of input; parameters across the basin.
- Advantage: structure is more physically based than lumped models; Less demanding on input data than distributed models
- Eg: SWMM, HEC-HMS, TOPMODEL, SWAT etc.

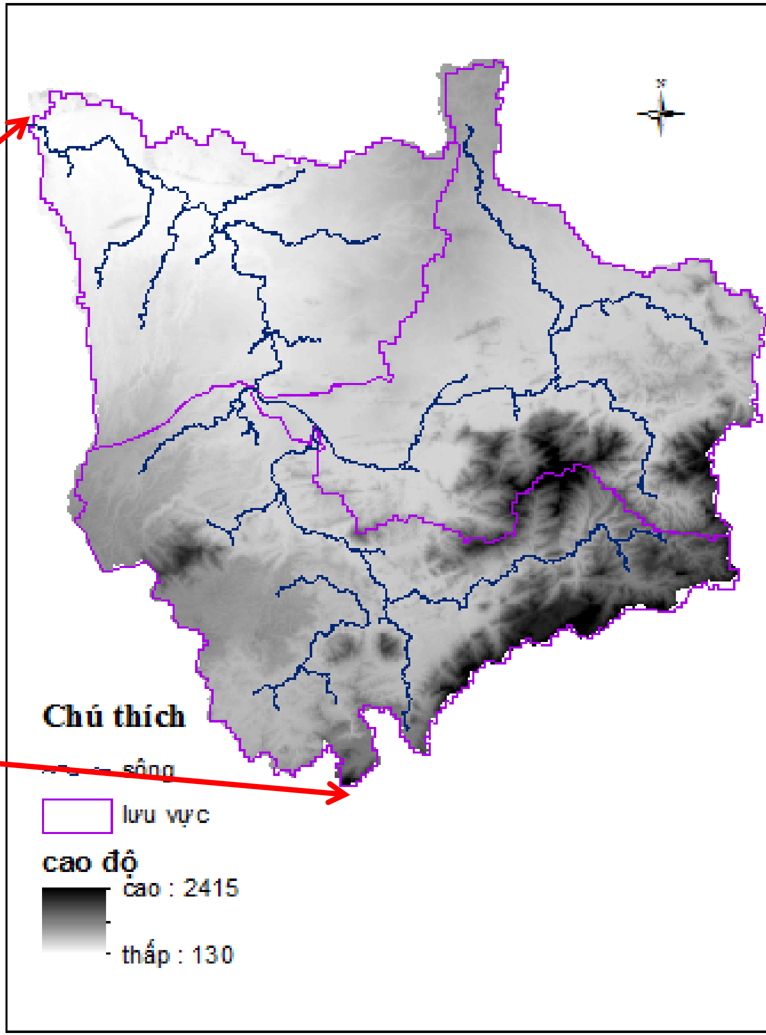
5. Deterministic Hydrologic Model

Distributed models

- Parameters are fully allowed to vary in space at a resolution
- Attempts to incorporate data concerning the spatial distribution of parameters variation
- Requires large amount of data; Governing physical processes are modeled in detail; Results at any location & time
- Highest accuracy in the rainfall-runoff modeling – if accurate data is available
- High computational time, Cumbersome, experts required
- HYDROTEL; MIKE11/SHE, WATFLOOD etc.

5. Deterministic Hydrologic Model





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Assignment 1

- Natural phenomena ==> Develop a conceptual model (depending on the intended use) ==> Create a water balance equation to demonstrate this relationship.

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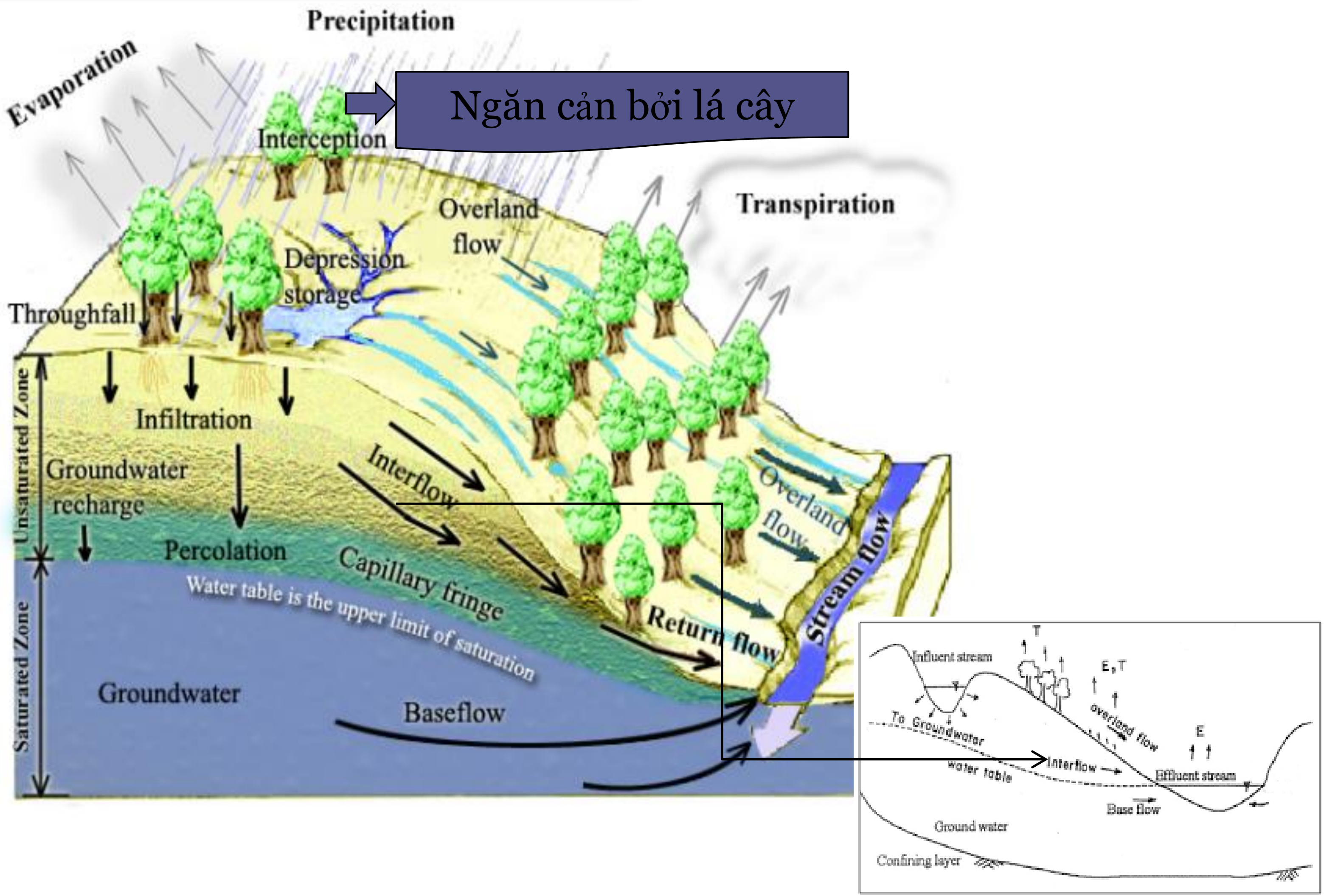
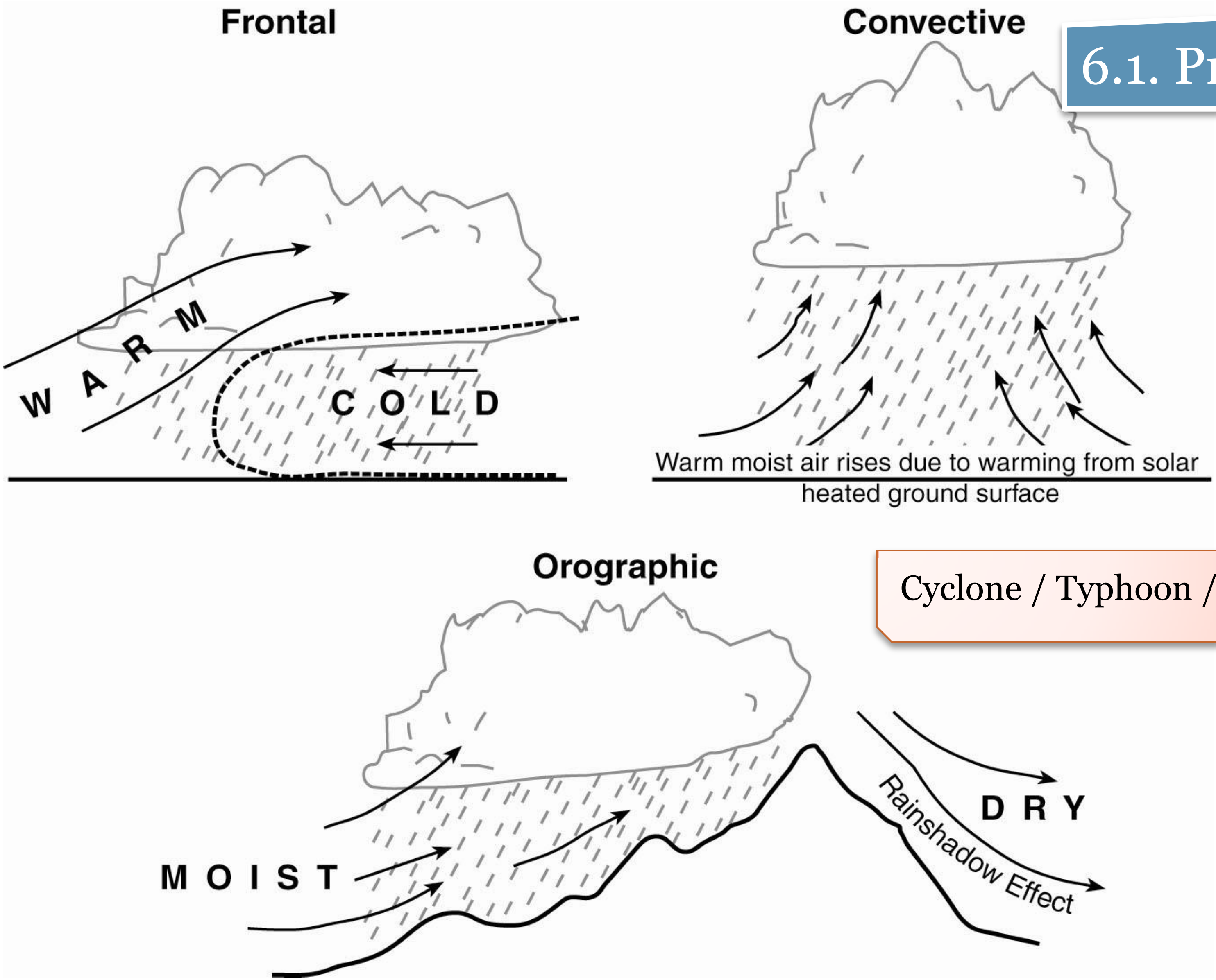
6.Rainfall-runoff processes



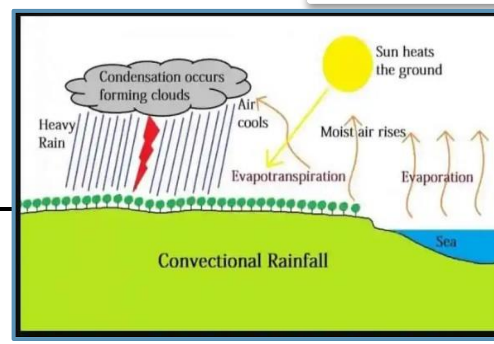
6.1. Precipitation

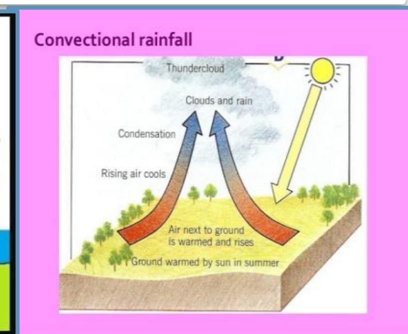


Cyclone / Typhoon / Hurricane

6.1. Precipitation

Convectional rainfall





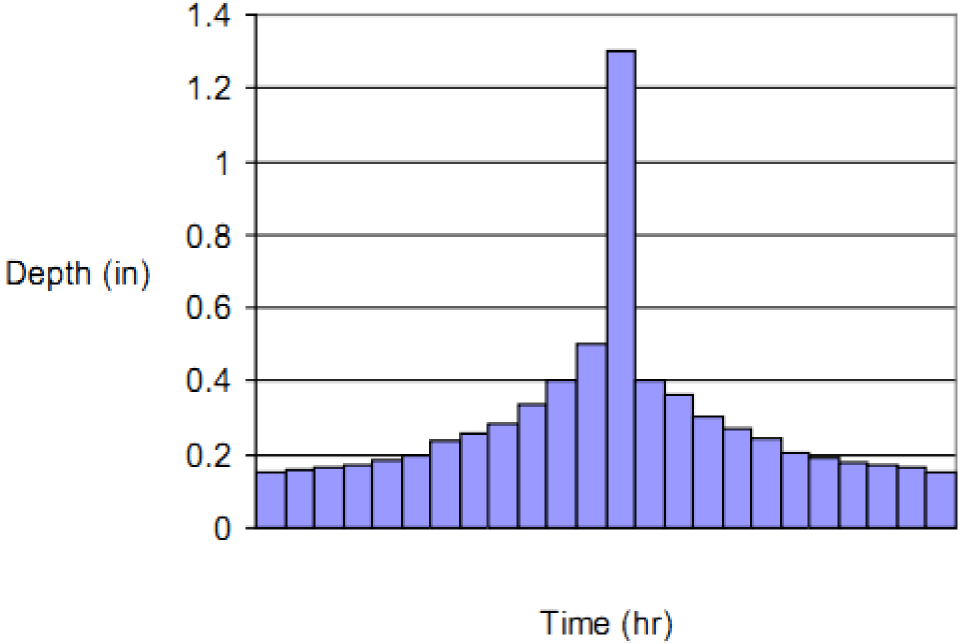
- Không khí chuyển động đối lưu cưỡng bức;
- Nhiệt độ không khí ở trên cao giảm *(định luật khí lý tưởng*: nhiệt độ giảm khi áp suất không khí giảm).
- Không khí lạnh đi ở tốc độ khô cho đến khi đạt đến điểm sương.
- Khi không khí đạt đến điểm sương, độ ẩm tương đối đạt 100% và mây hình thành.
- Khi không khí tiếp tục bay lên, không khí lạnh đi với tốc độ ẩm ướt, gây ra kết tủa vì không khí lạnh hơn không thể giữ được lượng ẩm dư thừa.

6.1. Precipitation

Ba bước cơ bản để hình thành kết tủa

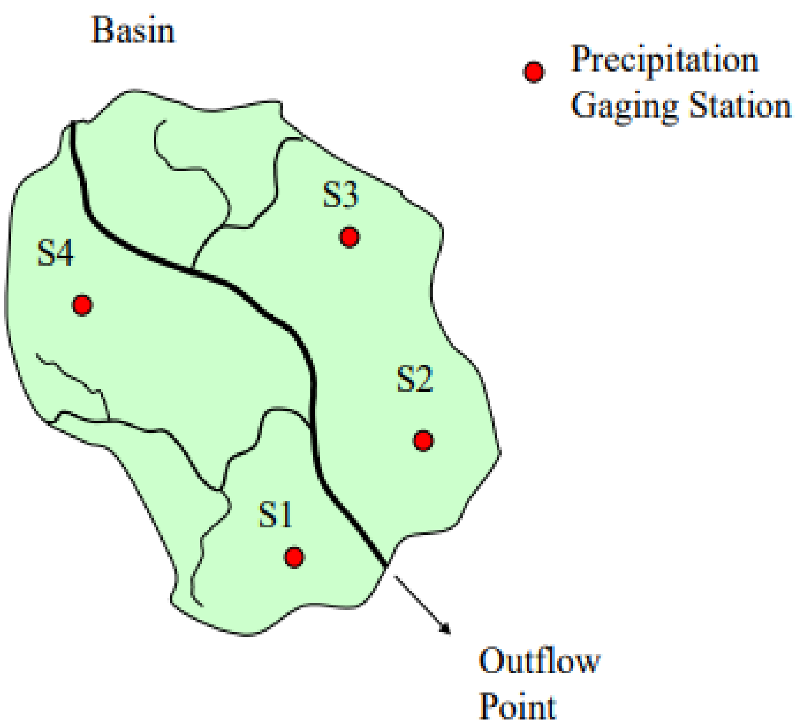
- tạo ra các điều kiện bão hòa trong khí quyển (thường là một số kiểu nâng không khí)
- sự thay đổi pha từ hơi sang lỏng (hình thành đám mây)
- sự phát triển của các giọt mưa đến kích thước có thể kết tủa (có thể vượt qua vận tốc đi lên)

a. Phương pháp biểu đồ mưa



Mỗi tiểu lựu vực có 1 trạm đo mưa. Lượng mưa ở đây được xem là mưa bình quân lưu vực (phân bố đồng đều trên toàn lưu vực)

b. Arithmetical Average Method

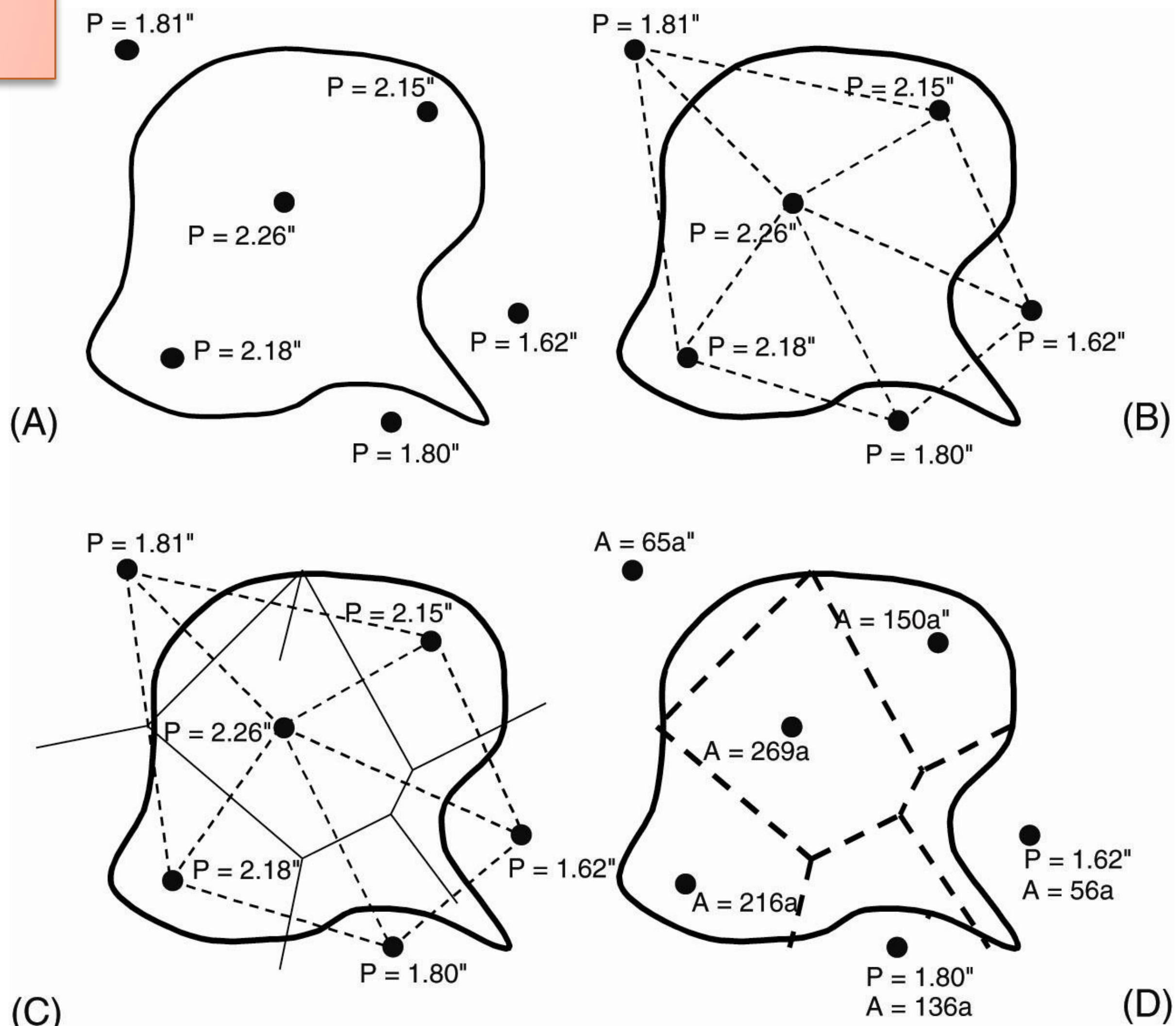


$$P_{avg} = \frac{\sum_{i=1}^{m} P_i}{m} = \frac{P_1 + P_2 + P_3 + P_4}{4}$$

Phương pháp đơn giản rule of thumb

c. Phương pháp đa giác Thiessen

6.1. Precipitation



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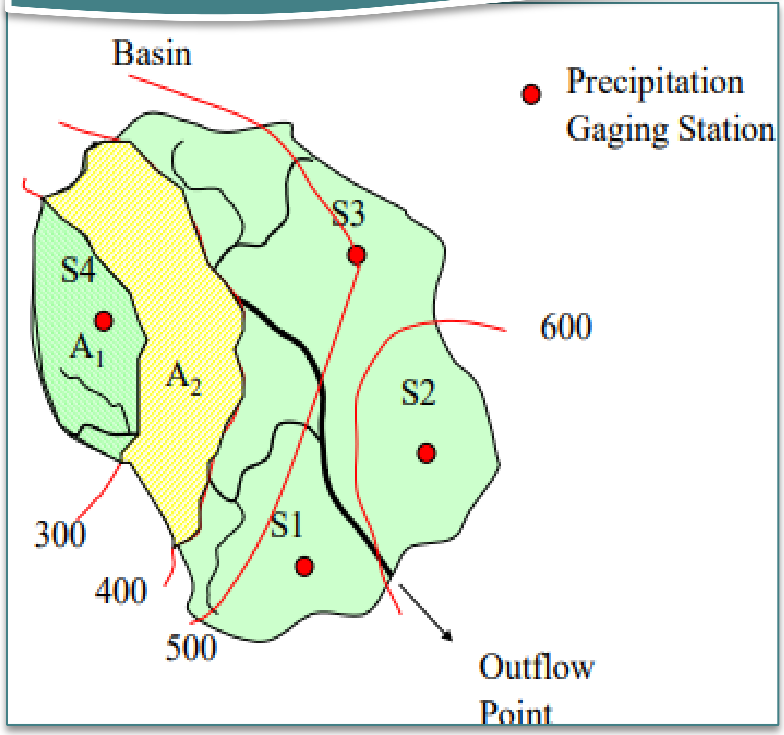
d. Isohyetal Method



$$P_{avg} = \sum_{i=1}^{m} w_i P_i \text{, where } \sum_{i=1}^{m} w_i = 1$$

but the weights are defined by the contour map area as shown below and P_i is the representative contour.

6.2. Evaporation

Bốc hơi phụ thuộc vào:
- Bức xạ Mặt Trời;
- Độ ẩm không khí;
- Nhiệt độ không khí;
- Tốc độ gió;
- Áp suất khí quyển

Evaporation is determined based on:
- water budget
- energy budget
- empirical formulae
- pan-evaporation data

- Tổn thất do bay hơi có thể rất đáng kể ở bất kỳ vị trí nào
- Sự thất thoát do bay hơi từ đất có thể được kiểm soát bằng cách sử dụng nhiều loại lớp phủ khác nhau hoặc bằng giải pháp hóa học

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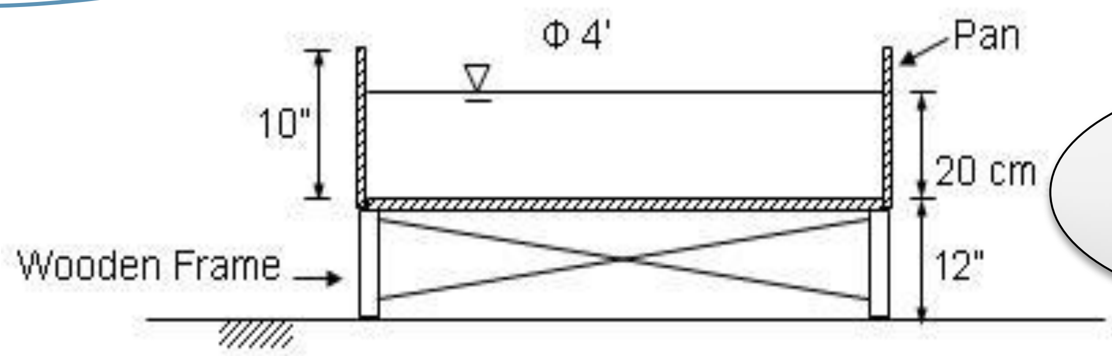
6.2. Evaporation

Trong cơn bão, gradient áp suất hơi giảm và lượng bốc hơi thường không đáng kể

Evaporation varies from day to day

Daily evaporation in Sri Lanka varies from 1 to 10 mm/day but on average it is taken as 4 mm/day

Evaporation Pans

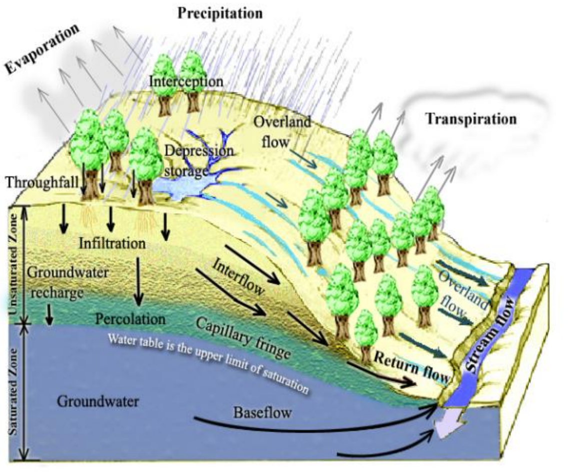


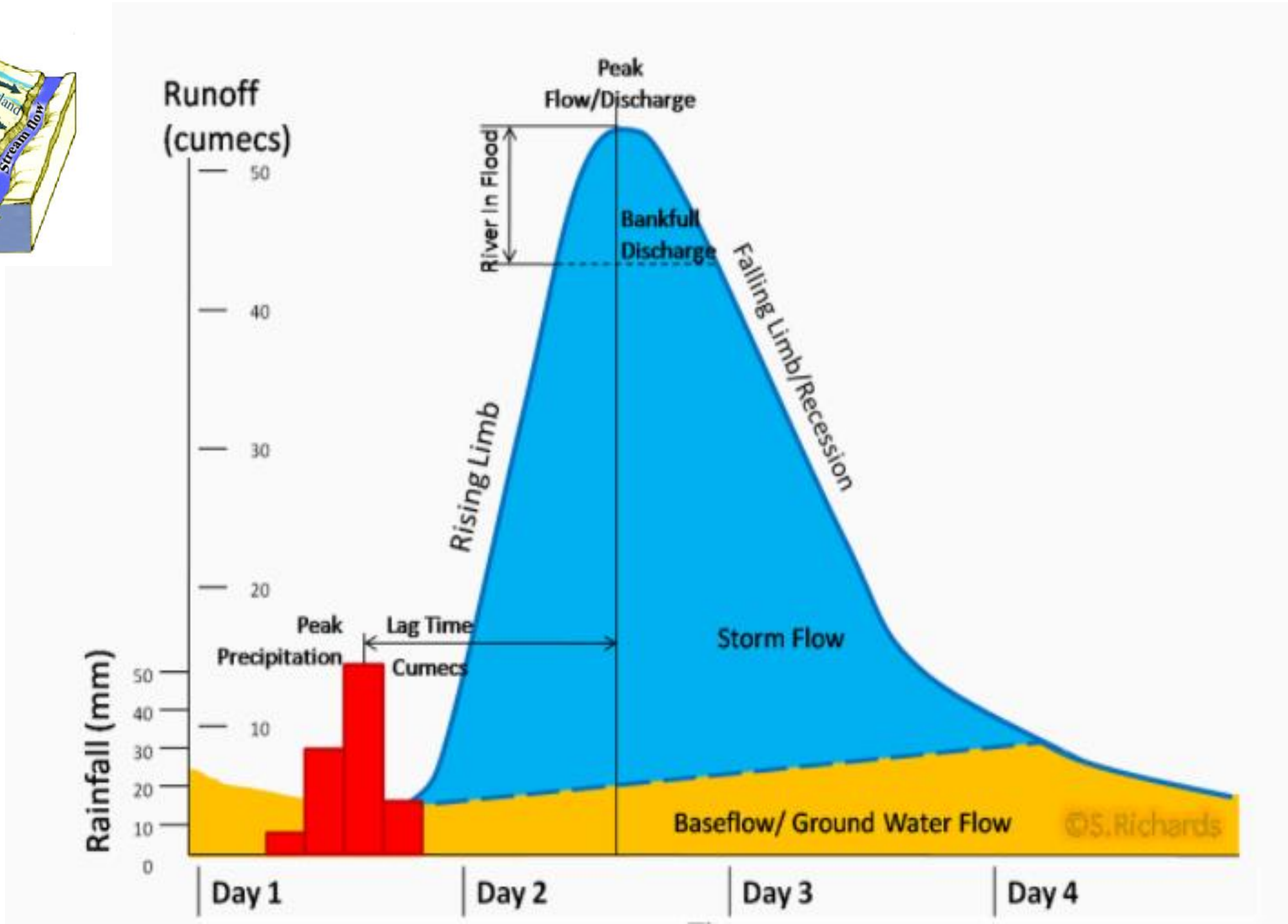
Most widely used method

A standard evaporation

Chậu loại A tiêu chuẩn của cục thời tiết: không sơn, bằng sắt mạ kẽm, đường kính 4 - ft (122 cm), sâu 10 inch (25,4 cm), thùng chứa hình tròn, được gắn 12 inch trên mặt đất trên một khung gỗ

6.3. Storm hydrograph





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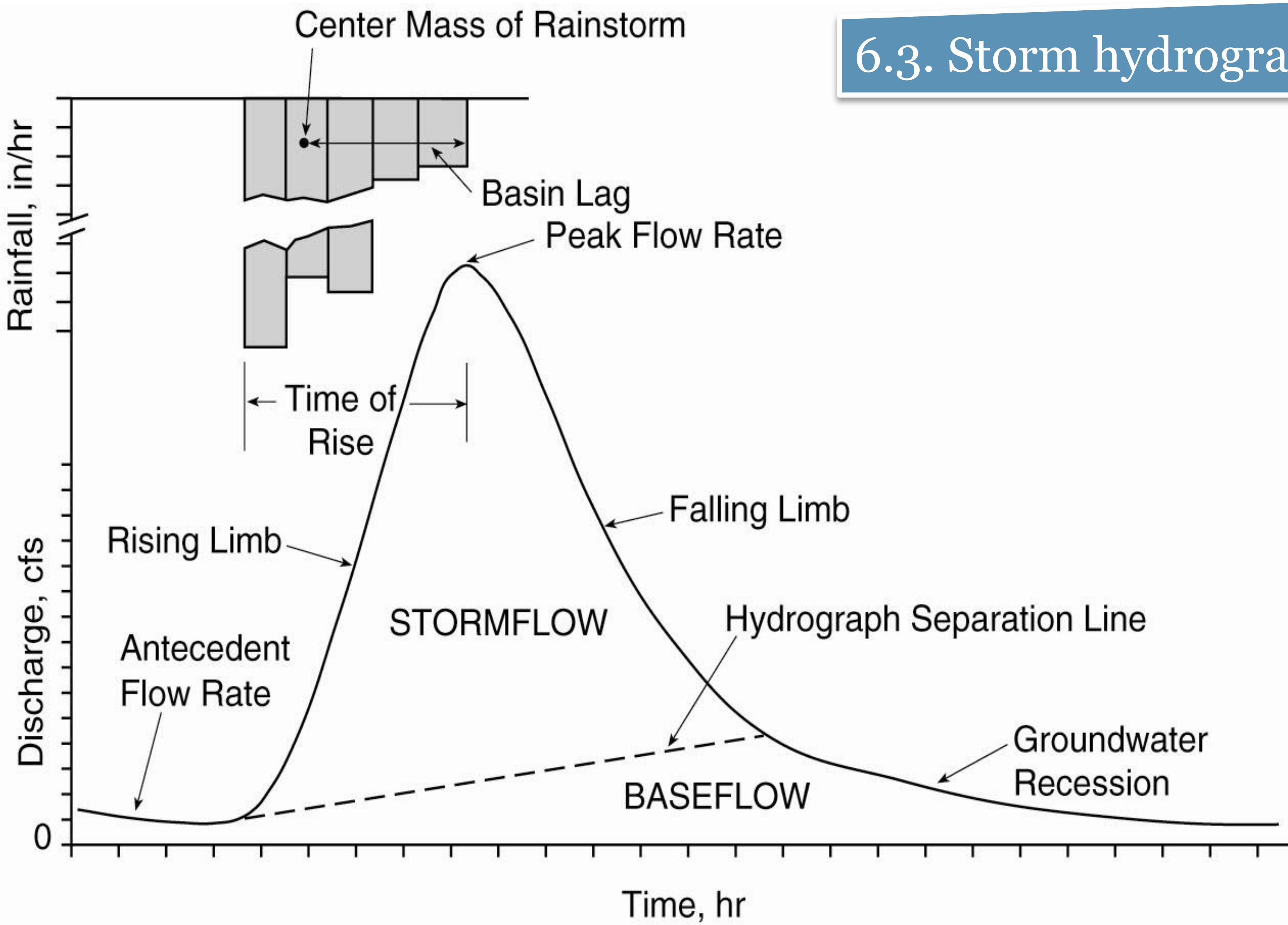
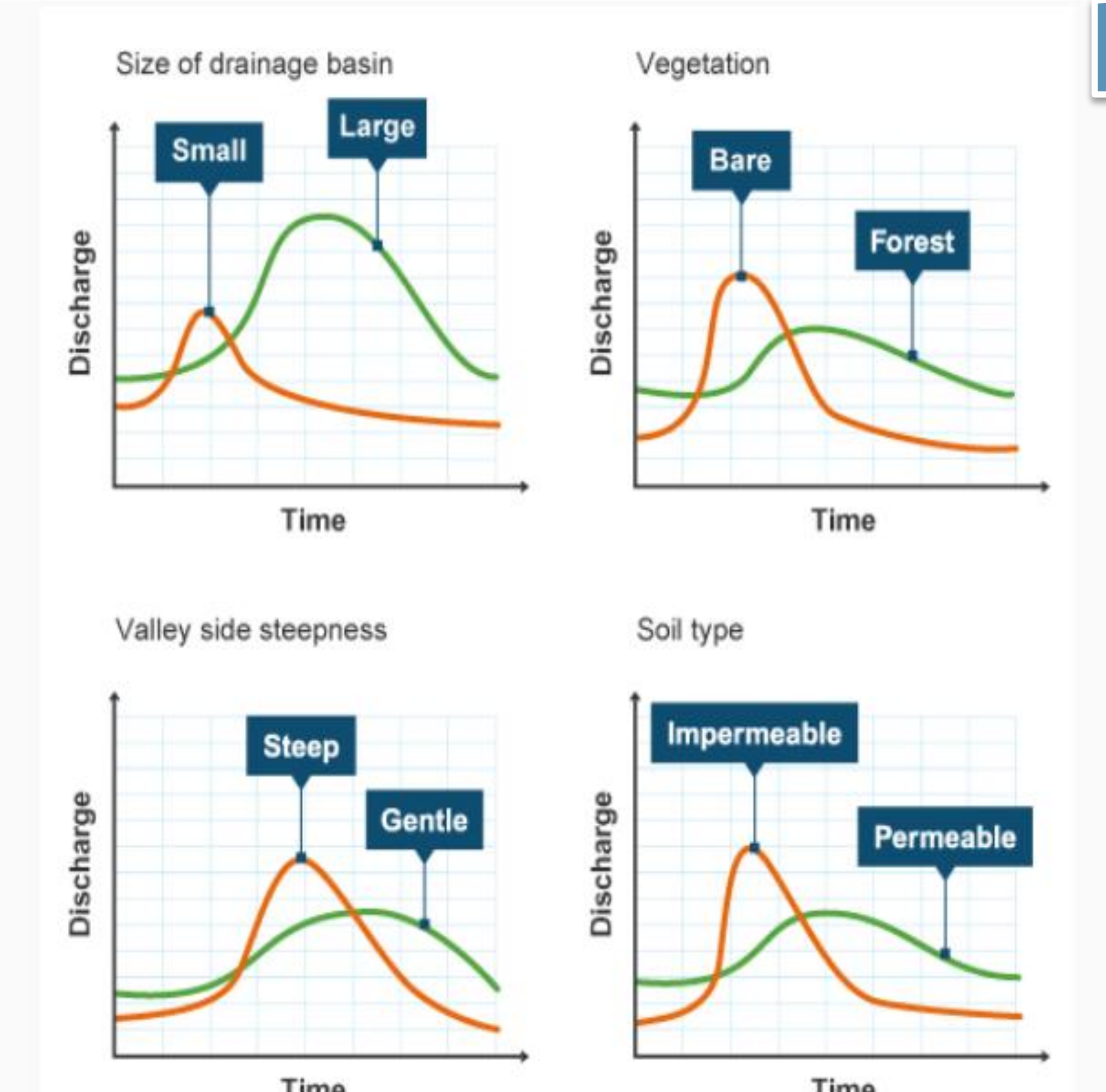
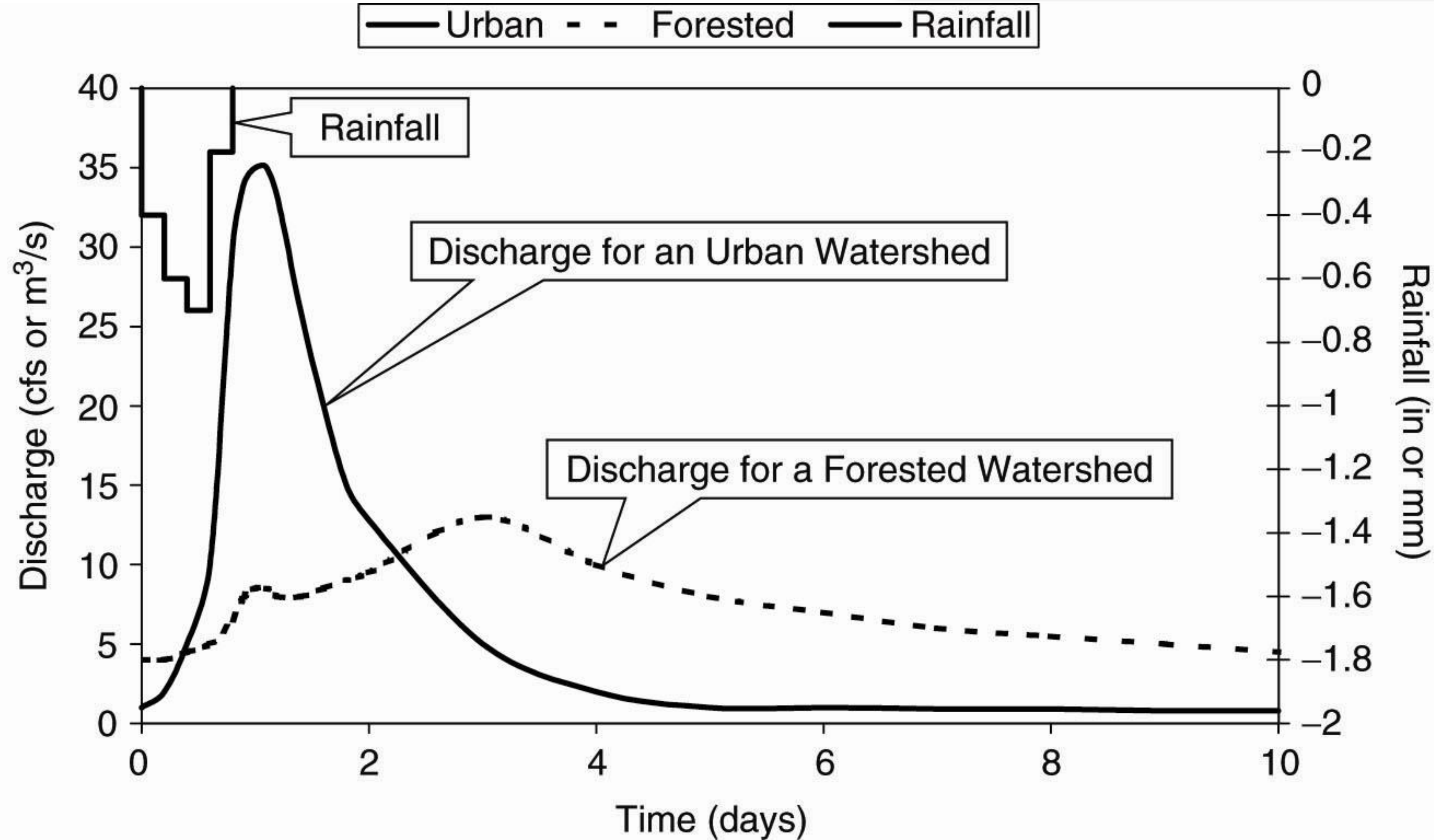


6.3. Storm hydrograph

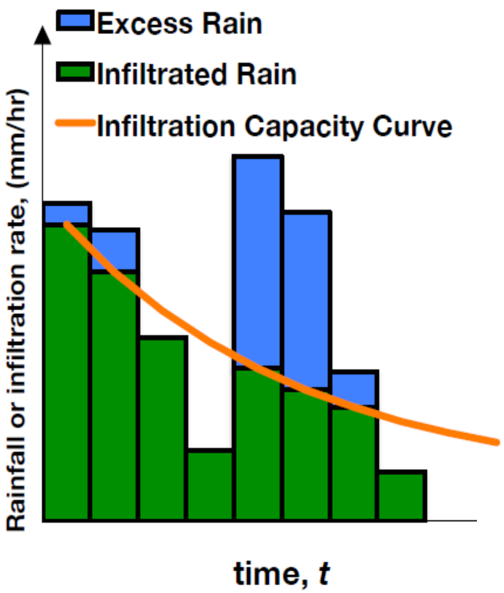


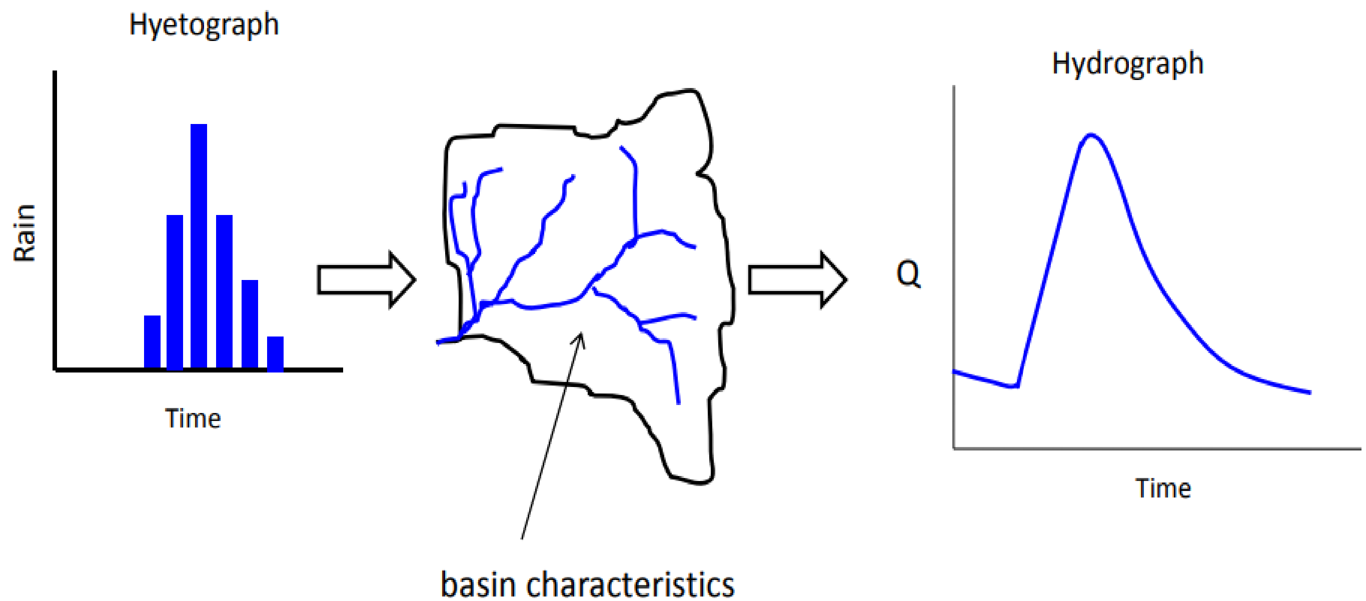
- Lượng mưa càng nhiều ➔ lưu lượng càng lớn;
- lưu vực lớn ➔ lưu lượng lớn hơn;
- lưu vực dài và hẹp -> xả ổn định, lưu vực lớn và đối xứng -> xả nhanh.
- Đô thị hóa và phá rừng đều làm gia tăng tăng dòng chảy trên đất liền vì nó là bề mặt không thấm nước.

6.3. Storm hydrograph



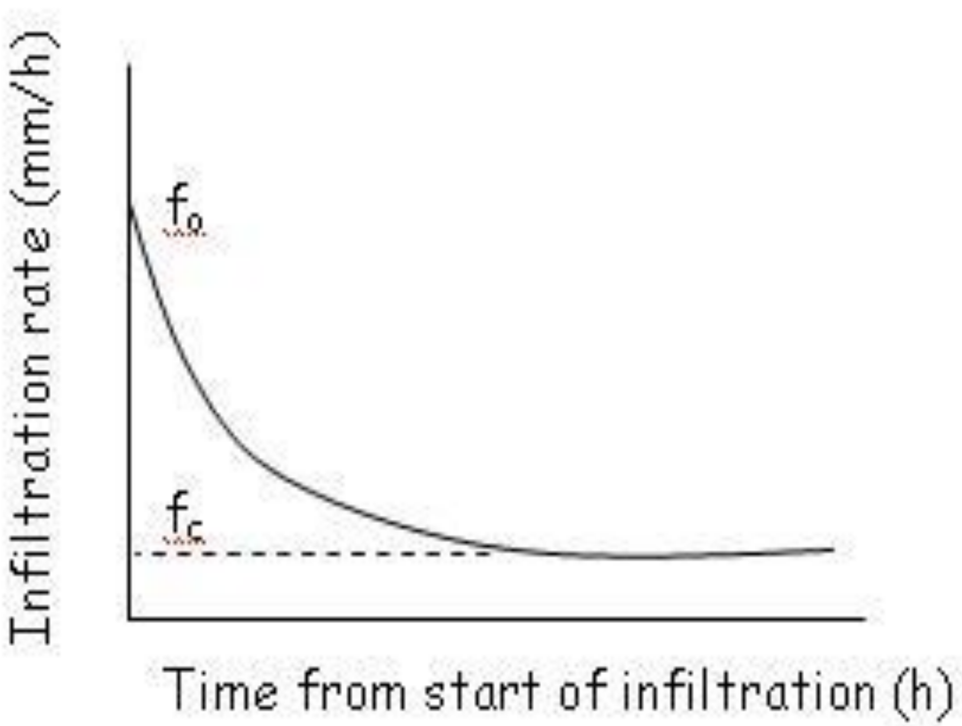
6.4. Lượng mưa hiệu quả (Excess rainfall)





6.5. Thấm (Infiltration)

The movement of water through the ground surface into the soil and on downwards



Thấm phụ thuộc vào các yếu tố:

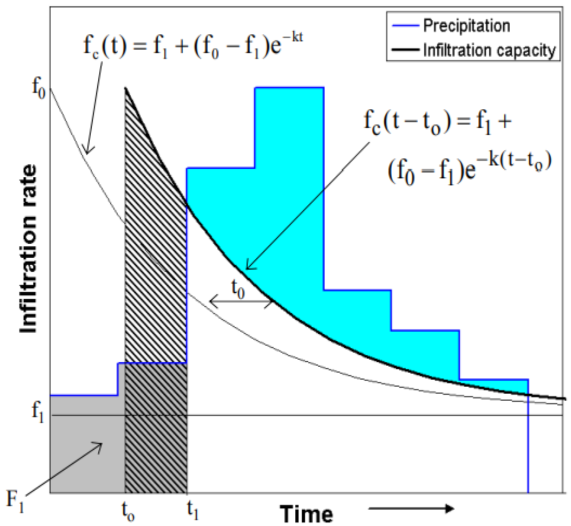
- soil type
- soil moisture
- Độ thấm của đất (soil permeability)
- ground cover
- drainage conditions
- depth of water table
- intensity and volume of precipitation

6.5. Thấm (Infiltration)

Các phương pháp tính thấm

- Phương pháp tốc độ thấm ban đầu và thấm ổn định (Intial and Constant Rate)
- Phương pháp chỉ số CN (SCS Curve Number)
- Phương pháp tính thấm Green và Ampt
- Phương pháp tính toán độ ẩm của đất (Soil Moisture Accounting)

Ví dụ về tính thấm (Horton)



Horton (1930s) studied infiltration process and suggested the following relationship for determining infiltration

$$f = f_c + (f_o - f_c)\, e^{-kt}$$

Where,

f = infiltration rate as a function of time, (depth/time)

fc = final or ultimate (equilibrium) infiltration rate

fo = initial infiltration rate

k = a constant representing the rate of decrease in infiltration capacity

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Ví dụ về tính thấm (Horton)

Horton Equation

One of the most widely used infiltration models is the three parameter equation developed by Horton (1939):

$$f = f_c + (f_o - f_c)\, e^{-\beta t}$$

where f is the infiltration rate at time t, f_0 is the infiltration rate at time zero, f_c is the final constant infiltration capacity and □ is a best fit empirical parameter. Horton's equation has seen widespread application in storm watershed models. The most commonly used model that uses Horton's method is the Environmental Protection Agency Storm Water Management Model (Huber, 1981).

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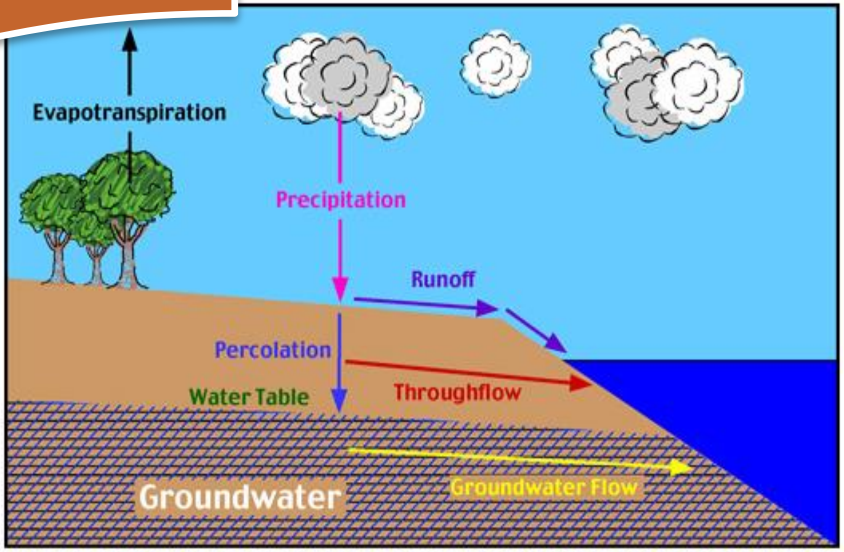
5.6. Streamflow

Streamflow = surface runoff + underground flow

flow through the soil in the zone of aeration (above the water table)

groundwater

River discharge (streamflow): Volume of water that flows past a point in a certain time



5.6. Streamflow

Soil Water Balance

A water balance equation describing these changes for any period of time is expressed as:

$$\Delta SM = P + IR - Q - G - ET$$

where ΔSM is the change in soil water storage in the soil profile, P is precipitation, IR is irrigation, G is percolation water, ET is evapotranspiration, and Q is surface runoff. All quantities are expressed as a depth (inches or mm) of water over a study area for a specific period of time.