**Second Exam Unsaturated Zone Hydrology (60% of grade).**
**Monday January 29, 14.00-17.00, AARD C008**

**Question 1 (10)**

a) Explain why a fine topsoil on top of a coarse subsoil can result in fingering
b) Give three factors which influence the infiltration into macropores
c) Explain the influence of macropores on: infiltration, runoff, soil moisture content

**Question 2 (15)**

Assume a homogeneous, isotropic soil on a hillslope with constant soil moisture content in the soil. After one hour the wetting front has reached a depth of half a meter.
a) What is (approximately) the direction of the infiltration at the wetting front? Explain.
b) What is (approximately) the direction of the infiltration at the soil surface? Explain.
c) Fill out the table coming from Sinai and Dirksen (2006). Indicate if the horizontal component of the lateral flow is >, =, <, ≤, or ≥ is then 0! Explain your choices..

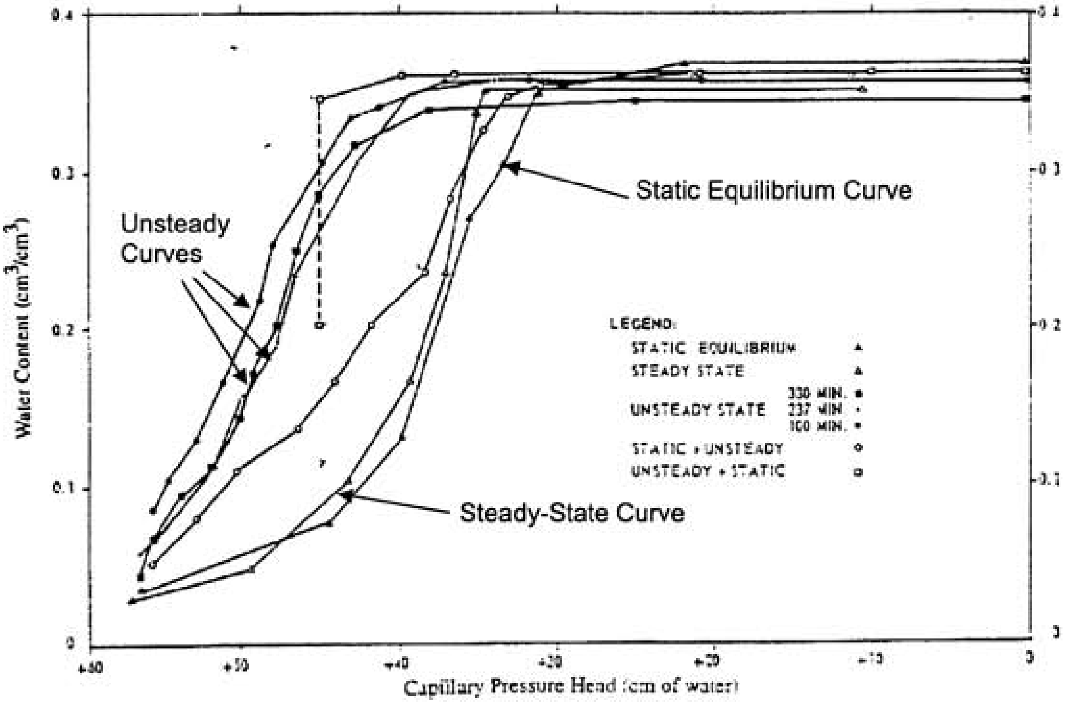
Table 2. Direction of lateral flow due to rainfall dynamics in isotropic soil and in the upper soil layer

| | | Direction of lateral flow component, $q_x$ | | |
|---|---|---|---|---|
| | | Darcian flow | | |
| Rainfall dynamics | Change in rainfall rate $\partial R/\partial t$ | Isotropic soil | Anisotropic or layered soil | Non-Darcian flow due to rainfall distribution |
| Wetting | >0 | $q_x = 0$ | $q_x < 0$ | $\overline{q_x}$ |
| Steady | 0 | $q_x > 0$ | $q_x = 0$ | $\overline{q_x}$ |
| Recession | <0 | $q_x > 0$ | $q_x > 0$ | $\overline{q_x}$ |
| Drainage | 0 | $q_x = 0$ | $q_x > 0$ | $\overline{q_x}$ |

$q_x$ = horizontal flow component of lateral flow; $\overline{q_x}$ time average of $q_x$ ;
$q_x > 0$ = lateral flow downslope from vertical
$q_x < 0$ = lateral flow upslope from vertical
$q_x = 0$, vertical flow

**Question 3 (5)**

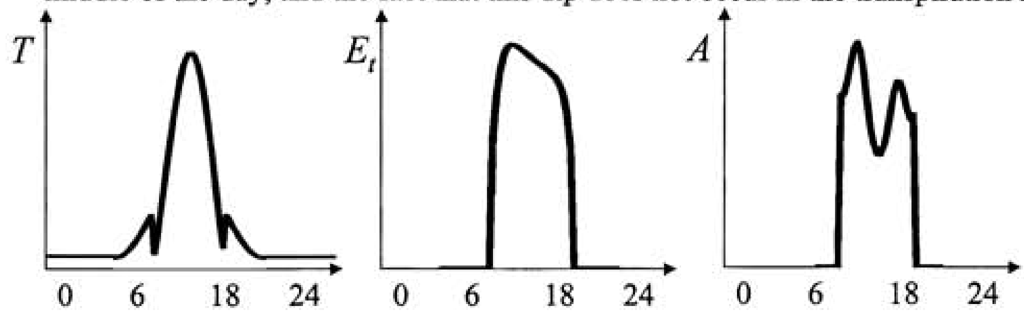
Ate Visser et al present a paper in which they perform real time forecasting of water tables and soil moisture profiles. They also use data-assimilation.
a) Why should data-assimilation be used in online hydrological forecasting applications?
b) What kind of data-assimilation do Visser et al. use; explain how it works?


Unsteady Curves
Static Equilibrium Curve
Steady-State Curve
LEGEND:
STATIC EQUILIBRIUM
STEADY STATE
UNSTEADY STATE 330 MIN. 237 MIN. 100 MIN.
STATIC + UNSTEADY
UNSTEADY + STATIC
Water Content (cm³/cm³)
Capillary Pressure Head (cm of water)
0.4
0.3
0.2
0.1
0
+60
+50
+40
+30
+20
+10
0

**Question 4 (15)**

a) Discuss how soil moisture content controls the transpiration and carbon assimilation of a plant. Include stomatal control in the answer.

b) The figure below shows the variation of leaf temperature $T$, leaf transpiration $E_t$ and carbon assimilation $A$ over a single day during a situation with soil moisture stress. Explain the observed variation of the three variables (including the variation in leaf temperature at the beginning and at end of the day, the dip in assimilation rate in the middle of the day, and the fact that this dip does not occur in the transpiration rate).




**Question 5 (15)**

***Topp et al.* (1967)** carried out drainage experiments to measure the retention curve (i.e. the water content- capillary head relationship) for a sandy soil with size fractions ranging from 0.10 mm to 0.5 mm. Dry soil was packed into a rectangular container 2.54 by 1.0 cm and 7.6 cm high. The soil had a bulk density of 1.69 g/cm$^3$ and a total porosity of 0.365. The water content was varied by increasing the gas phase pressure and allowing water to leave the sample from the bottom of the column. Water content and pressure head were measured at a point in the middle of the column simultaneously. The drainage water content- capillary head relationship, starting at saturation, was determined by one of the following methods: (i) static equilibrium, (ii) steady-state flow, or (iii) unsteady-state flow. In each method, the sample was drained until a capillary pressure head of about 56 cm was reached. Plots of water content as a function of capillary pressure head are given in the Figure below. In the static equilibrium procedure, a series of equilibrium states was established at successively higher gas phase pressures. The time required to reach equilibrium at a given water content was around 1000 and 4000 minutes for high and low water contents, respectively. In the steady-state method, vertical downward steady-state flow was established in the sample at approximately unit hydraulic gradient at a series of increasing gas phase pressures. The time required to reach steady state at a given water content varied between 300 and 600 minutes. As seen in Figure 5, data points from equilibrium and steady-state experiments fall very close to each other. In the unsteady-state experiments, starting from the saturated state, an outflow of water from the sample was induced by increasing the gas pressure in steps of 1 to 2 cm of water at frequent time intervals. The total time used to go from the saturated state to a capillary pressure of 56 cm of water, was varied in three different runs from 100 to 237 to 330 minutes. This procedure obviously results in dynamic capillary pressure curves.

a) How do you explain the difference between different curves? What is the equation for the case of dynamic capillary pressure?

b) Use this data to calculate the dynamic coefficient $\tau$.