Background from previous courses

If you still master the contents of the course Atmosphere-Vegetation-Soil Interactions (AVSI), you can skip *most* of the text below (except the practical notes on the FAO-method) and continue to the section called 'Procedure'. Part of the information below is needed for today's exercise, other parts are only relevant for the second day of data analysis.

1.1. Reference evapotranspiration

The theory on combination methods to estimate evapotranspiration has been dealt with in the course Atmosphere Vegetation Soil Interactions. You will need your book 'Transport in the Atmosphere-Vegetaton-Soil Continuum', or can consult the book chapters online (login at the library may be required).

The main equations used to estimate evapotranspiration are repeated here:

Penman-Monteith: $$L_v E = \frac{s(Q*-G)}{s+\gamma\left(1+\frac{r_c}{r_a}\right)} + \frac{\frac{\rho c_p}{r_a}\left(e_{\mathrm{sat}}(\overline{T}_a)-\overline{e}_a\right)}{s+\gamma\left(1+\frac{r_c}{r_a}\right)}$$

Priestley-Taylor: $$L_v E = \alpha_{PT}\frac{s}{s+\gamma}(Q*-G)\ (\text{with } \alpha_{PT} = 1.26)$$

Makkink: $$L_v E = 0.65\frac{s}{s+\gamma}K\downarrow$$

1.2. Terminology

To reduce the confusion we will list here the definitions as they are used here (where we mainly follow Moors (2002)).

- The total evapotranspiration E consists of:
  - Transpiration (*T*): the part of the total water vapour flux that enters the atmosphere from the soil through the vegetation (stomata and cuticula).
  - Evaporation of intercepted water (E_{int}): evaporation of water that has been intercepted by plants.
  - Soil evaporation (E_{soil}): evaporation of water from the soil (the soil may either be saturated or partly dry).
- Optimal evapotranspiration E_{opt} is the theoretical evapotranspiration that would occur if a given vegetation, completely covering the soil is exposed to prevailing meteorological conditions (without affecting the meteorological conditions). This quantity is often referred to as potential evapotranspiration (E_{pot}). However, very often no reference is made to a specific vegetation and the use of a concept of ´the potential evapotranspiration´ then becomes useless.
- Reference evapotranspiration E_{ref}: is the theoretical evapotranspiration that would occur if a well-defined, theoretical vegetation, completely covering the soil is exposed to prevailing meteorological conditions (without affecting the meteorological conditions).

1.3. Methods for reference evapotranspiration

Internationally, the FAO method is widely used to estimate actual evapotranspiration based on a reference evapotranspiration determined using the Penman-Monteith equation. On the other hand, in the Netherlands the Makkink method is used, which has the advantage of simplicity and gives –for Dutch conditions– very similar results as the Penman-Monteith equation. The **reference vegetation** in the FAO method is short, well-watered grass with the following properties summarized in the table above.

Table 1 Overview of parameters to be used in the Penman-Monteith equation when applied in the FAO method for reference evapotranspiration.

Variable	Value or equation
Albedo	0.23
net longwave radiation	$L^* = L^{\downarrow} - L^{\uparrow} \approx \varepsilon_{\text{atm}} \sigma T_a^4 - \sigma T_a^4$, where T_a is the (absolute) air temperature and ε_{atm} is the atmospheric emissivity.
atmospheric emissivity	estimated as the sum of the clear sky emissivity and a cloud emissivity equal to 1: $\varepsilon_{\text{atm}} = (1 - f_{\text{cloud}})\varepsilon_{\text{atm,clear}} + f_{\text{cloud}}$, where f_{cloud} is the cloud fraction and the clear sky emissivity is estimated as $\varepsilon_{\text{atm,clear}} = c_1 + c_2\sqrt{e_a}$ with c_1 and c_2 being empirical constants with standard values of 0.52 and 0.065 $\text{hPa}^{-1/2}$ and e_a is the water vapour pressure in hPa.
vegetation height	0.12 m
displacement height	0.08 m
roughness length momentum	0.012 m
roughness length heat	0.0012 m
aerodynamic resistance	$r_a = \dfrac{\ln\left(\dfrac{z_u - d}{z_0}\right)\ln\left(\dfrac{z_T - d}{z_{0h}}\right)}{\kappa^2 \bar{u}(z)}$, where z_u and z_T are the height of windspeed and temperature observations. Note that this expression for r_a is valid for neutral conditions.
canopy resistance (daily mean data)	70 sm^{-1}
canopy resistance (short time interval data)	50 sm^{-1} at daytime, 200 sm^{-1} at nighttime
soil heat flux (daily mean data)	Neglected
soil heat flux (short time interval data)	0.1 times net radiation at daytime, 0.5 times net radiation at nighttime

Note that the cloud fraction can be estimated from the 'sunshine duration' in the KNMI data. Special attention needs to be paid to times when the sun is under the horizon as in that case no information on cloud amount is present. Hence, for the night time data probably the safest guess is to assume that cloud fraction is 0.5. For daily sums, the relative sunshine duration can be computed from the duration of sunshine and day length. In Hupsel sunrise is at 3:51 UTC on May 10 and at 3:31 UTC on May 24; sunset is at 19:18 UTC on May 10 and at 19:38 UTC on May 24.