Exercise week 5 – Evapotranspiration

Exercise 1, on paper

1. **Question:** Which variables need to be computed before implementing the equation? Which measurements are needed? What are the units of the different terms? **Solution:**

   To implement the FAO-PM equations one needs to first compute: the net radiation R_n in MJ/m^2/d, the gradient of the saturated vapor pressure curve Δ in kPa/°C, the vapor pressure deficit VPD in kPa. To compute these terms and the FAO-PM equation, one needs measurement of: incoming radiation R_i (MJ/m^2/d), wind speed at 2 meters u_2 (m/s), temperature T (°C), relative humidity R_h (–).

2. **Task:** Compute ET_0 for a hypothetical day where [...]

   Solution: The formulas are:

   - R_n [MJ/m^2/d] = 86400/10^6 R_n [W/m^2]
   - $e_{as} = 0.611\, exp(\frac{17.27\, T}{237.3+T})$ [kPa]
   - $VPD = e_{as}\,(1 - R_h)$ [kPa]
   - $\Delta = 4098 \frac{e_{as}}{(T+237.3)^2}$ [kPa/°C]
   - $ET_0 = \frac{0.408\, \Delta\, R_n + \gamma \frac{900}{T+273}\, u_2\, VPD}{\Delta + \gamma(1+0.34\, u_2)}$ [kg/m^2/d]

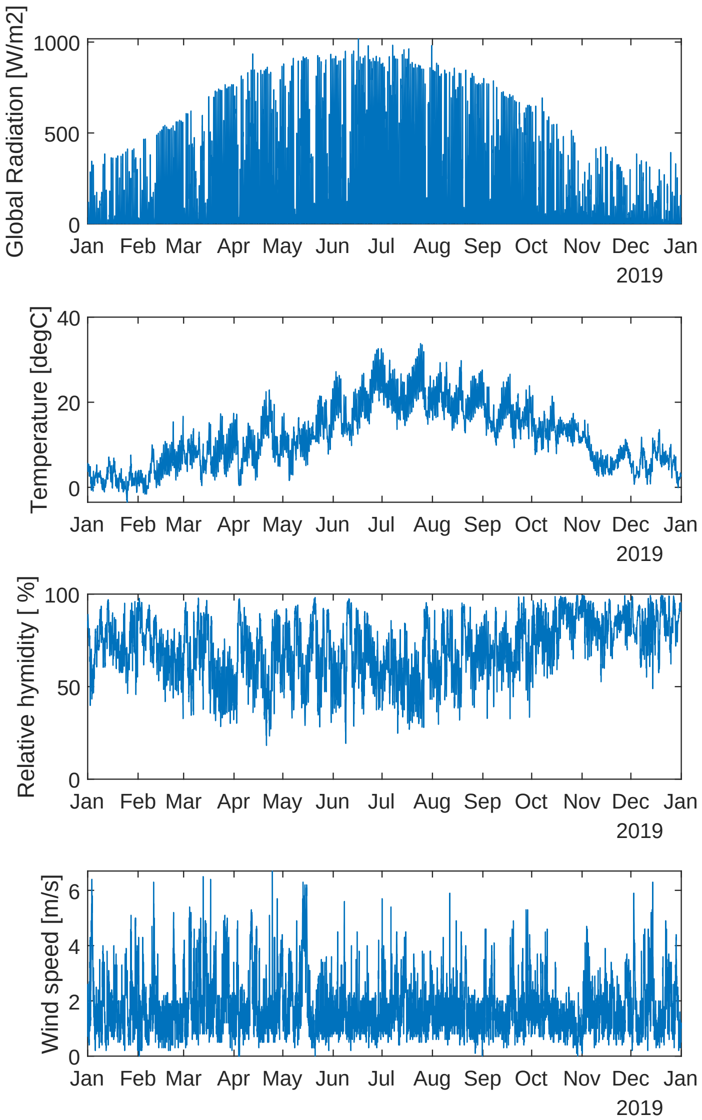
   Using the given data and the psychometric constant $\gamma = 0.066$ kPa/°C, one gets $R_n = 12.96$ MJ/m^2/d, $e_{as} = 2.06$ kPa, $VPD = 0.25$ kPa, $\Delta = 0.13$ kPa/°C, $ET_0 = 3.29$ kg/m2/d (equivalent to mm/d)

Exercise 2, on a computer

1. **Task:** Import the meteorological data downloaded from MeteoSwiss for year 2019

   Solution: The data is described in the file `meteo_pully_2019_legend.txt` and in particular at lines 40–43.

2. *Display meteorologic data in a plot*



3. **Task:** Compute a simplified net radiation as [...]

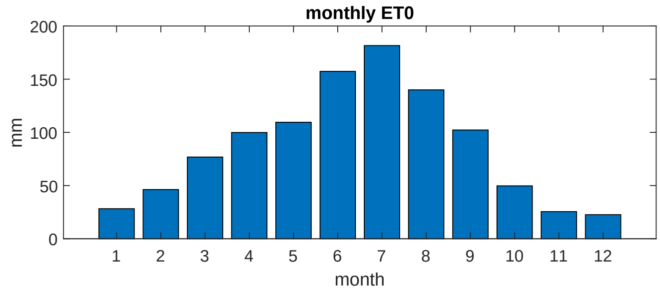
   Solution: The formula to compute R_n in $\mathrm{MJ/m^2/d}$ starting from the data is $R_n = 0.9\,R_g\,(1-0.23)\,86400/10^6$, where again the term $86400/10^6$ is needed to convert W into MJ/d.

4. **Task:** Compute ET_0 in mm/h for the entire year 2019

   Solution: Except for R_n, which is computed above, the formulas are the same as in the exercise on paper. Just note that the result is in mm/d so you need to divide by 24 to get ET_0 in mm/h.

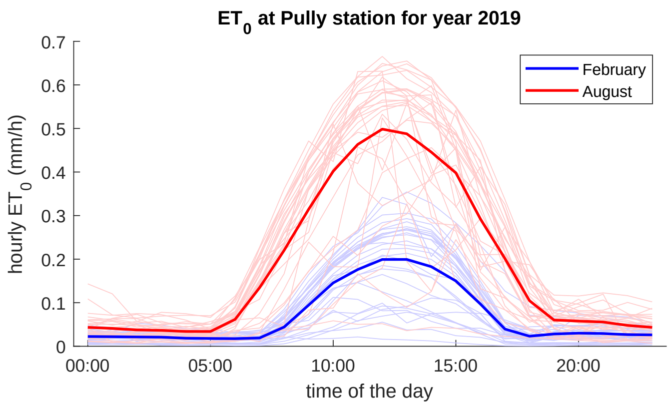
5. **Task:** Compute the total ET_0 (in units of mm) for each month.

   Solution: As for the exercise of week 1, you can take advantage of the function `month` applied to a datetime object. The monthly ET_0 is:



6. **Task:** Take the hourly ET_0 during February and August only. For each of these two months, plot the daily evolution of ET_0 during each day [...]

   Solution: A possible graphical representation of the results is:



7. **Question:** What are the main differences in ET_0 between February and August ? Why?

   Solution: ET_0 in February has a lower magnitude and occurs over a shorter period of the day compared to August. This is because these two months have very different meteorologic conditions: February has lower incoming radiation and temperature and higher relative humidity. To be more presicse, one could make a plot to compare the meteorologic conditions during these two months.

8. **Optional Question:** ET can be seen as the sum of a radiation-induced ET and a turbulence-induced ET. Which component is stronger in this dataset?

   Solution: The FAO-PM equation can be broken into two components:

   - $ET_{0r} = \frac{0.408\,\Delta\,R_n}{\Delta+\gamma(1+0.34\,u_2)}$ radiation term
   - $ET_{0a} = \frac{\gamma\frac{900}{T+273}\,u_2\,VPD}{\Delta+\gamma(1+0.34\,u_2)}$ aerodynamic term

A plot with the difference $ET_{0r} - ET_{0a}$ shows that radiation dominates most of the times, but there are occasional times when the aerodynamic is larger (values lower than 0 in the plot)