FACH HOCHSCHULE LÜBECK

Hydrology
Evaporation

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Content

Objectives

To learn about ...

- types of evaporation
- estimation of evaporation
- measurement of evaporation

Basics to understand evaporation

- Physical background
- Hydrological Relevance
- Application

Evaporation
Relevance

Evaporation is a major component of the water balance accounting for about 60 to 70 % of the annual water balance in mid-latitudes and up to 99 % in arid climates. It is therefore of imminent importance to estimate evaporation for ...

- irrigation projects
- management of water resources under changing climate
- management of reservoirs

Evaporation only plays a very minor in relation to floods. Only in very long rivers in arid zones evaporation has a significant effect on discharge along the river profile.

Physical background

Atmospheric parameters

with

$$m = \frac{\rho_v}{\rho_d}$$

$$q = \frac{\rho_v}{\rho}$$

$$rF = \frac{m}{m^*}$$

m	Mixing Ratio
ρ_v	vapour density
ρ_d	density of dry air
ρ	$\rho = \rho_v + \rho_d$
q	specific moisture content
m^*	Mixing ratio
rF	specific moisture content

Vapour pressure
Dependency on temperature

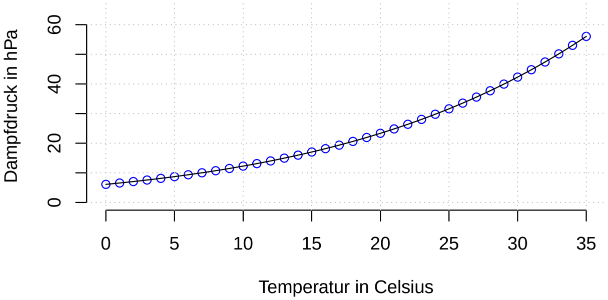


Figure: Vapour pressure as a function of temperature

Vapour pressure

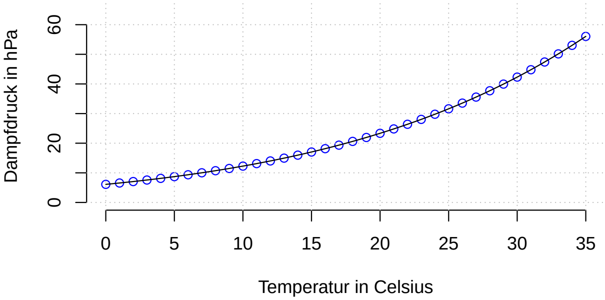


Figure: Vapour pressure calculated with Python

Programming in Python

```
import numpy as np
import matplotlib.pyplot as plt
# Create an array of 100
# linearly-spaced points from 0 to 35
T = np.linspace(0,35,350)
es = 6.11*10^(7.48*T/(237+T))
plt.plot(T,es)
plt.savefig('figure/Tes.png')
```

Programming in R

```
T<-seq(0,35,1.0)
es<-6.11*10^(7.48*T/(237+T))
plot(T,es,xlab="Temperature in Celsius",
ylab="Vapour pressure in hPa",
xlim=c(0, 35), ylim=c(0, 65),
pch=1, lty=1, col="blue", axes=FALSE)
axis(1, seq(0,35,5))
axis(2, seq(0,65,10))
grid (NULL,NULL, lty = 3, col = "grey")
curve(6.11*10^(7.48*x/(237+x)), add = TRUE)
```

Relative Humidity

Relative humidity rF is the percentage of actual humidity e_a in relation to potential humidity e_s at temperature T:

$$rF = e_a / e_s \ [\%]$$

The moisture **saturation deficit** d is defined as:

$$d = (e_s - e_a) \text{ in } [hPa]$$

Factors

Evaporation depends on . . .

- Air exchange, wind, advection
- Moisture saturation deficit of air
- Available energy as obtained from the energy balance

Key physical parameters are temperature and relative humidity. Wind speed is a parameter for air exchange and advection. Energy balances are only included in physical formulae, most empirical formulae rely on temperature, relative humidity and wind speed, some also on seasonal indices.

Methods for the Estimation or Measurement of Evaporation

Estimation Methods
Overview

- Dalton-type
- Empirical formulae
- Penman-Monteith
- Water balance of basins or
- Class A-pan, evaporimeters
- Sap flux
- Eddy flux correlation
- Hydrodynamic wind profile
- Bowen ratio
- Energy balance

Dalton Formula

One of the earliest approaches to estimate evaporation has been proposed by Dalton (1802) [1]. The formula proposed relates evaporation to saturation deficit $E_s - E_a$ and an advection term a.

$$E = f_D * (e_s - e_a)$$

with evaporation E in mm, saturated vapour pressure e_s and actual vapour pressure e_a. The factor f_D depends on wind speed.

Empirical formulae Blaney-Criddle

The Blaney-Criddle formula relies on day length and temperature:

$$E_t = (0.142 * T_a + 1.095) * (T_a + 17.8) * k * d$$

with

E_t	potentia evaporation in cm/month,
T_a	air temperature in degrees Celsius
k	empirical factor
d	monthly factor of actual to average day length

Haude formula

[2] proposed and adaption of the Dalton formula to regional conditions in Germany. The same author proposed advection term factors for Egypt. For the application of this formula measurements of temperature and relative humidity at 2 p.m. are needed.

$$E = f_H * [e_s(T_{14}) - rF_{14} * e_s(T_{14})] \tag{1}$$

For a green lawn in October $f_H = 0.2$.

Table: Haude Factors

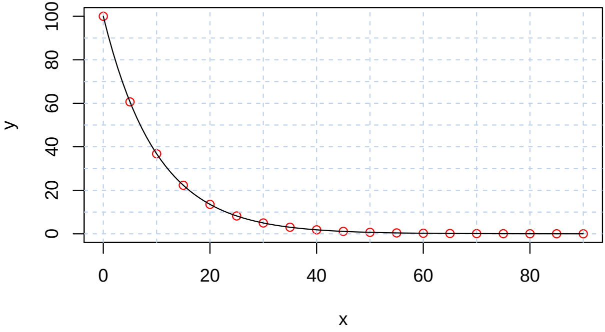
Month	pasture	lawn	corn	deciduous trees	pine trees
Jan	0.2	0.2	0.11	0.01	0.08
Feb	0.2	0.2	0.11	0.01	0.04
Mar	0.25	0.23	0.11	0.04	0.14
Apr	0.29	0.24	0.17	0.10	0.35
May	0.29	0.29	0.21	0.23	0.30
Jun	0.28	0.29	0.24	0.28	0.34
Jul	0.26	0.28	0.25	0.32	0.31
Aug	0.25	0.26	0.26	0.26	0.25
Sep	0.23	0.23	0.21	0.17	0.20
Oct	0.22	0.20	0.18	0.10	0.13
Nov	0.20	0.20	0.11	0.01	0.07
Dec	0.20	0.20	0.11	0.005	0.05

Instruments and Methods

Measurement of Evaporation
Class A pan

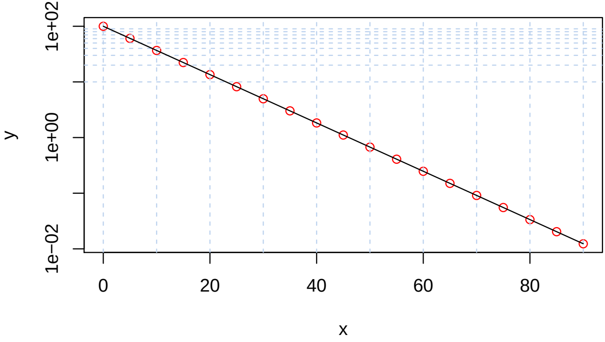
- Wood as support 15 cm
- Defined diameter 120.7 cm
- Water level 5-7 cm below rim
- Water depth ca. 25 cm
- Measurement of rainfall
- Wave protection
- Protection against animals (grid)

Linear Graph
R code for xy-scatter graph



Logarithmic

R-code for log xy-scatter graph



[1] J. Dalton.

Experiments and observations to determine whether the quantity of rain and dew is equal to the quantity of water carried of by the rivers and raised by evaporation; with an enquiry into the origin of springs.

Mem. Lit. Philos. Soc. Manchester, V(II):346–372, 1802.

[2] W. Haude.

Zur praktischen Bestimmung der aktuellen und potentiellen Evaporation und Evapotranspiration.

Dt. Wetterdienst, 1954.