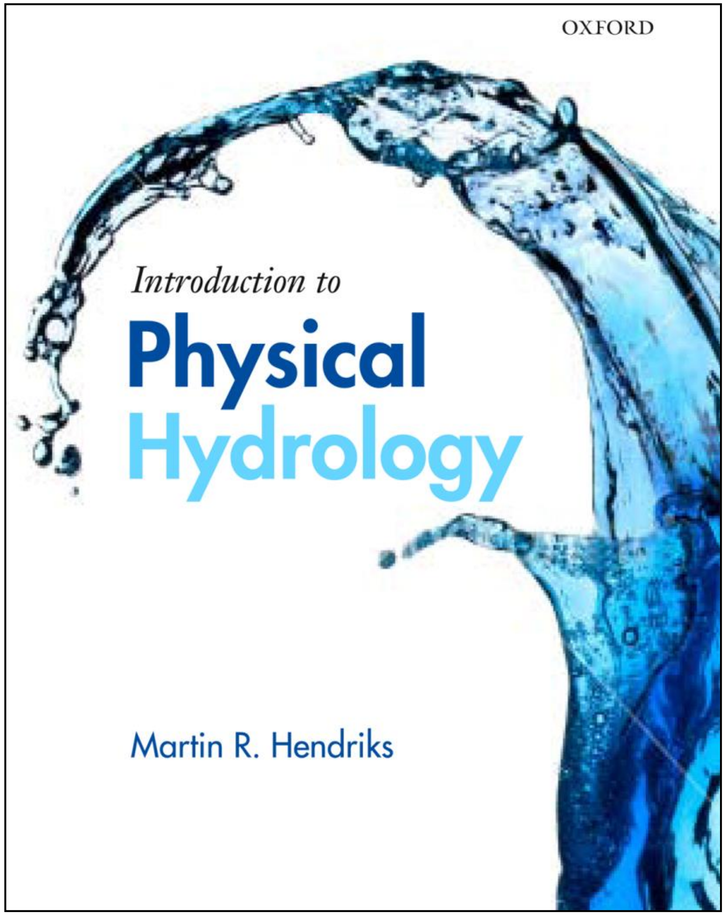
Atmospheric water



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Follow the book's didactic concept!

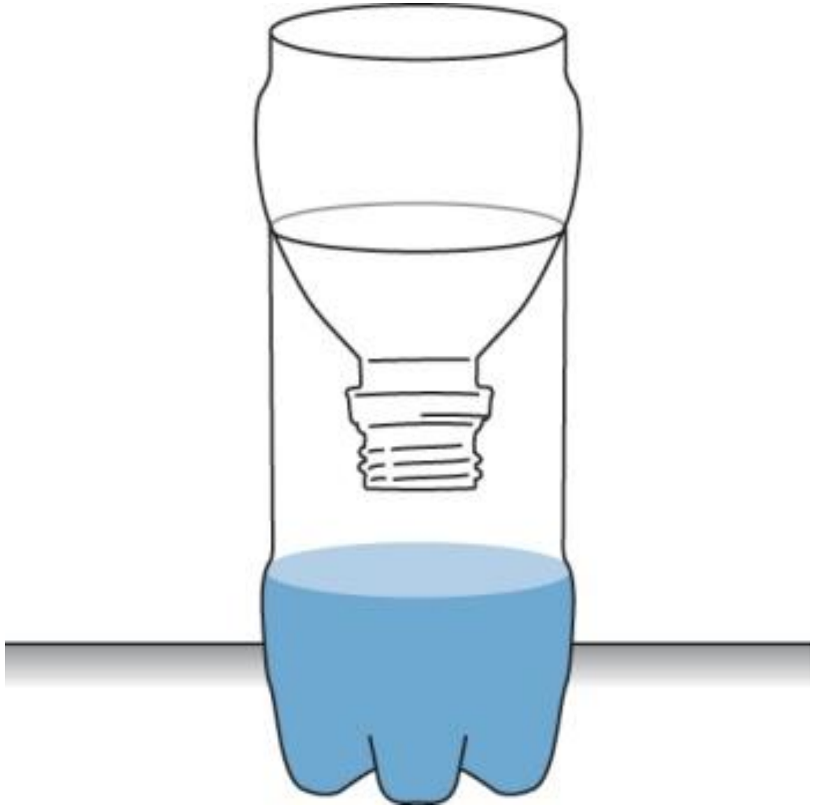
- Hydrological cycle
- Drainage basin
- Water balance

- Energy equation
- Flow equation
- Continuity equation

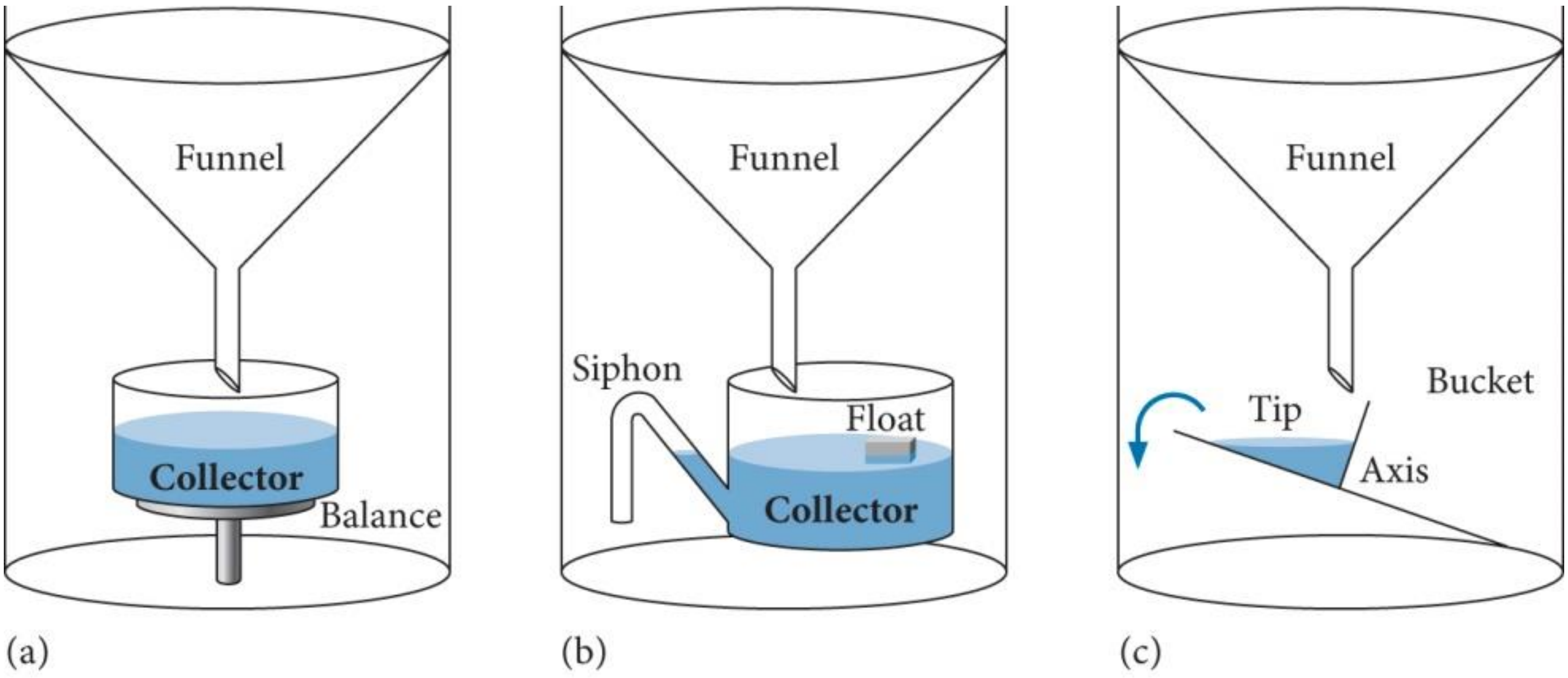
1. Introduction
2. **Atmospheric water**
3. Groundwater
4. Soil water
5. Surface water

Exercises

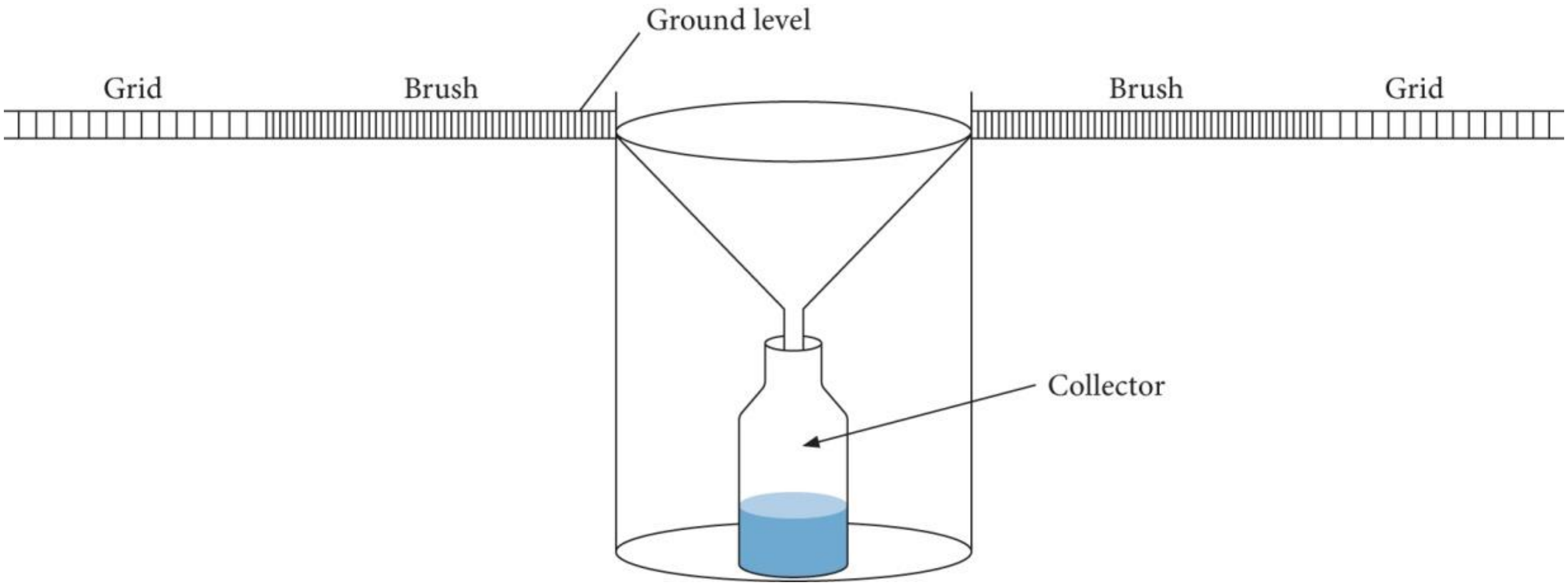
Measuring precipitation



Measuring precipitation

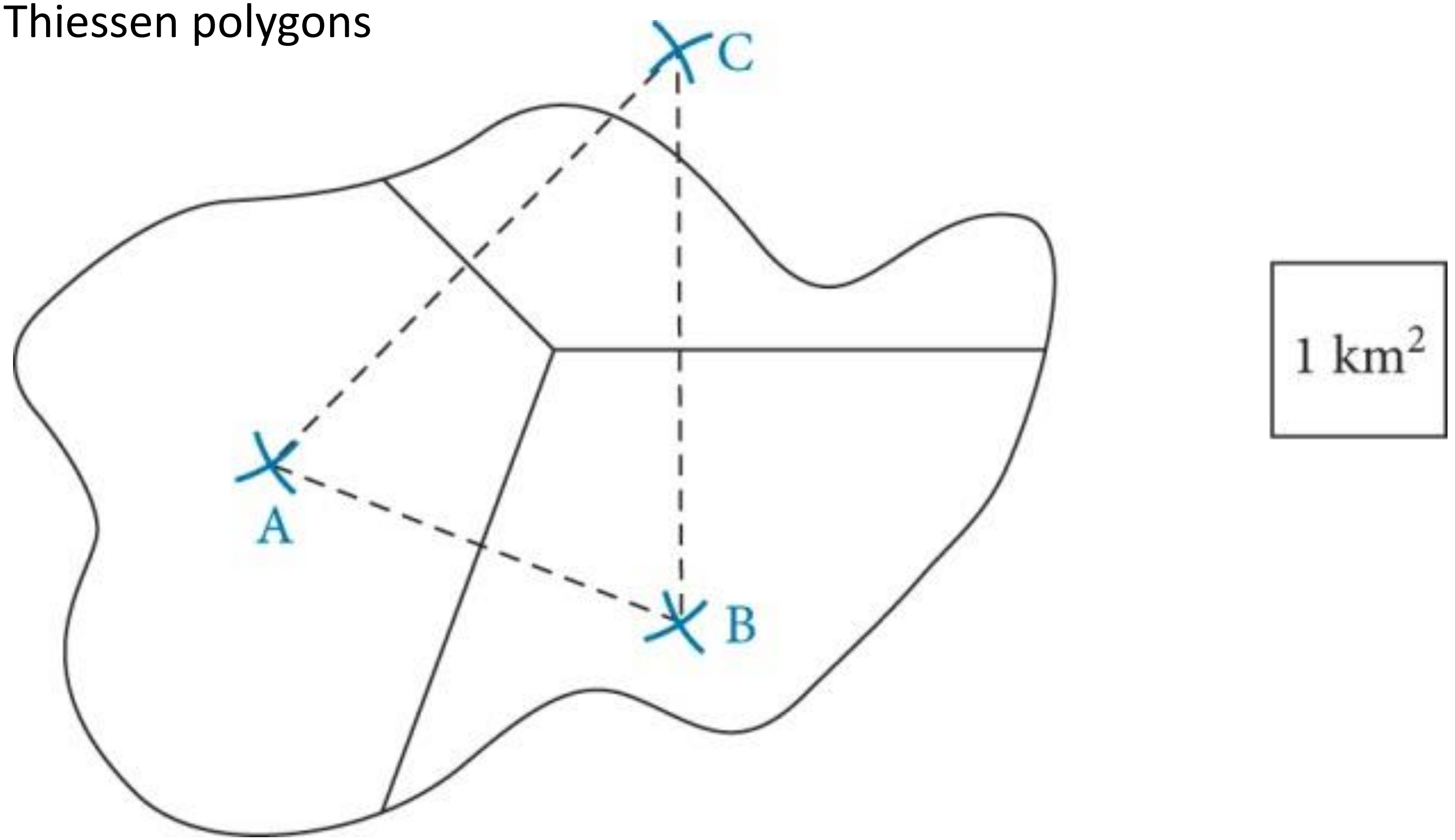


Measuring precipitation



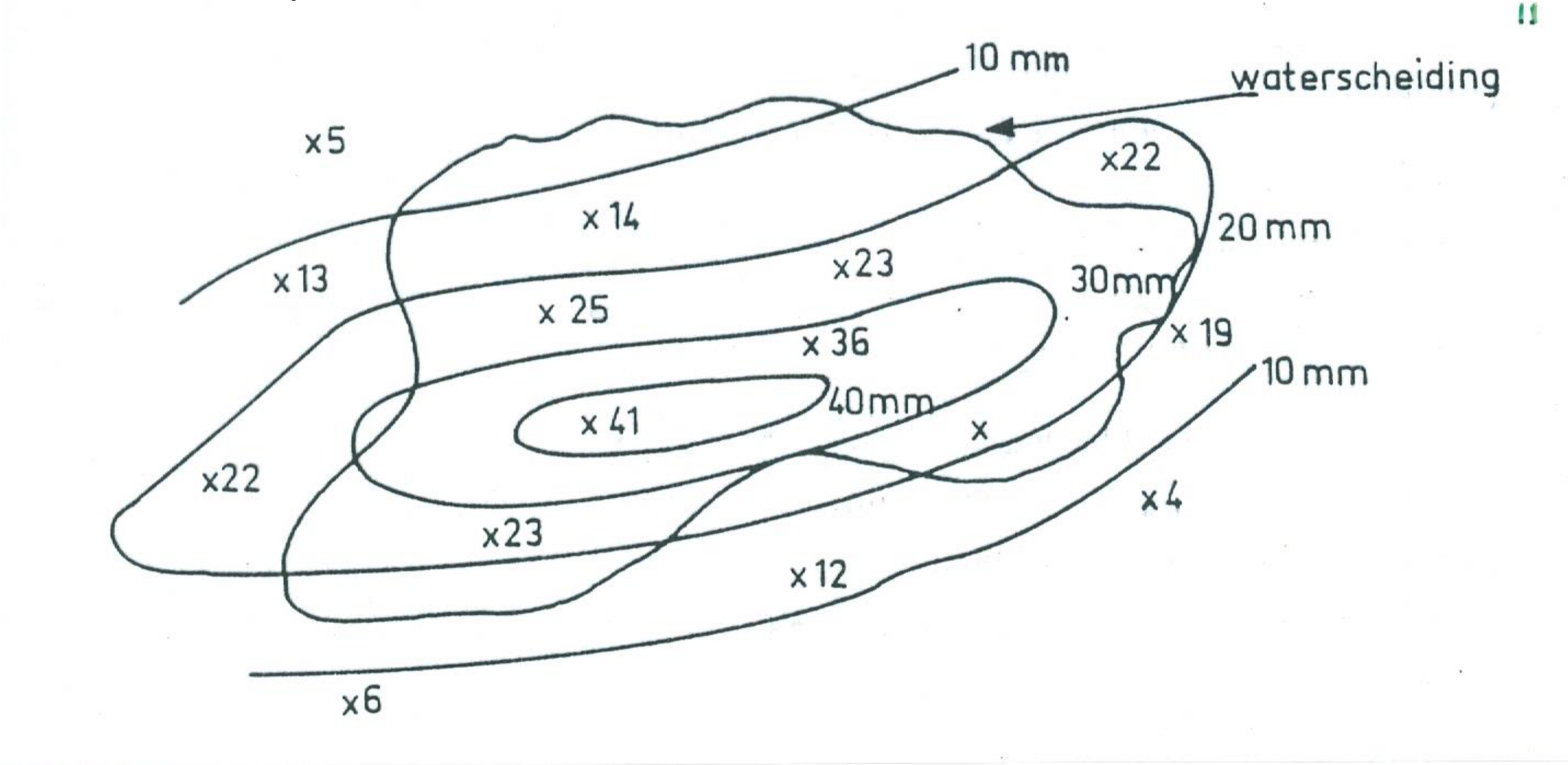
Areal precipitation

Thiessen polygons



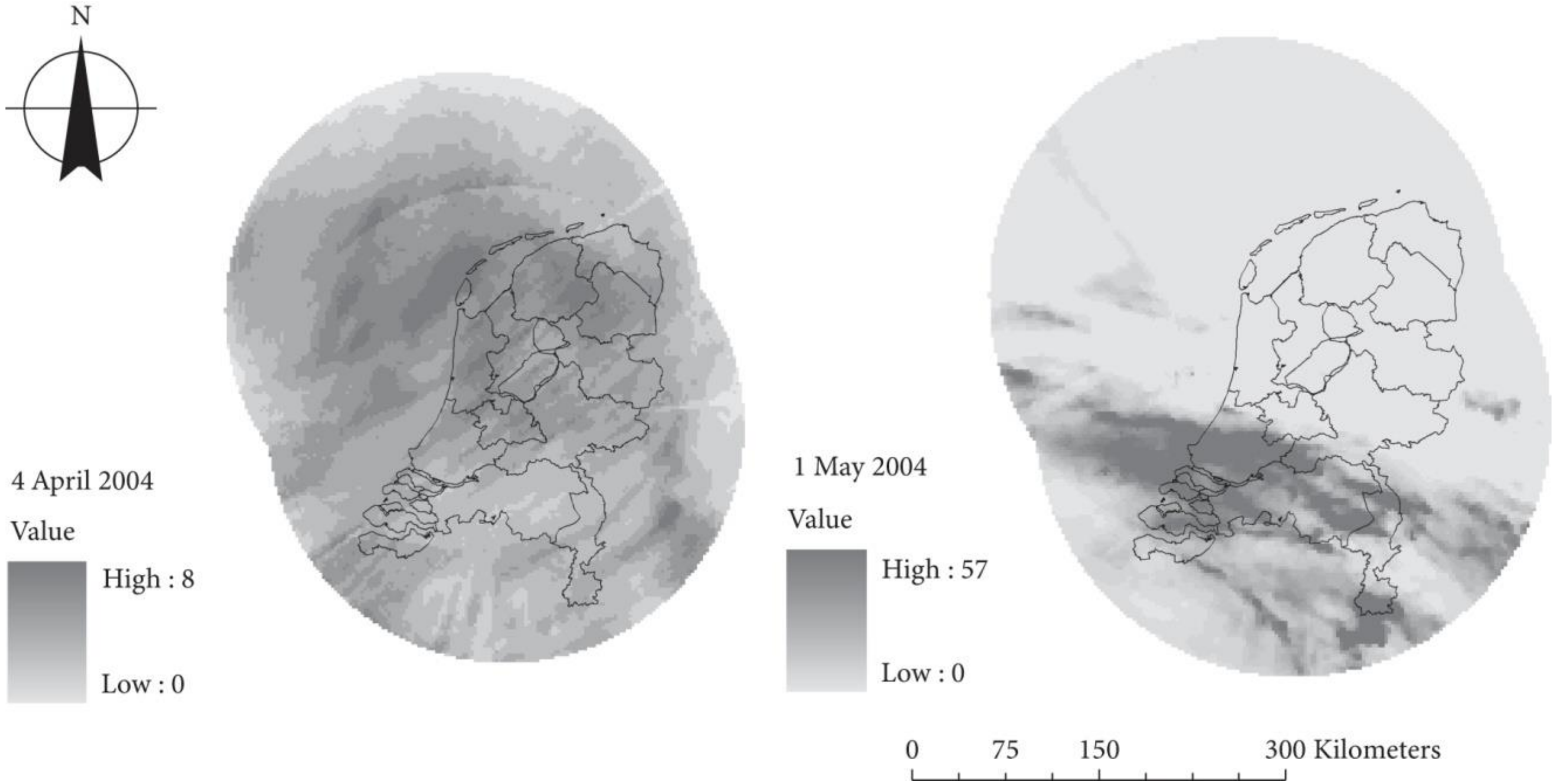
Areal precipitation

Isohyetal method



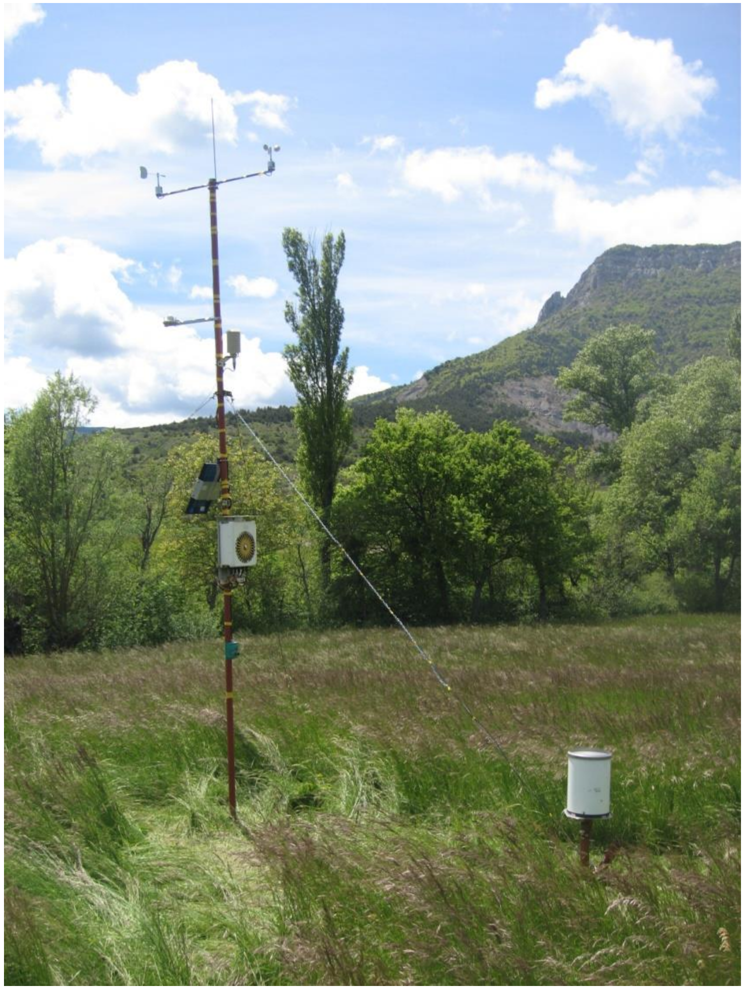
Areal precipitation

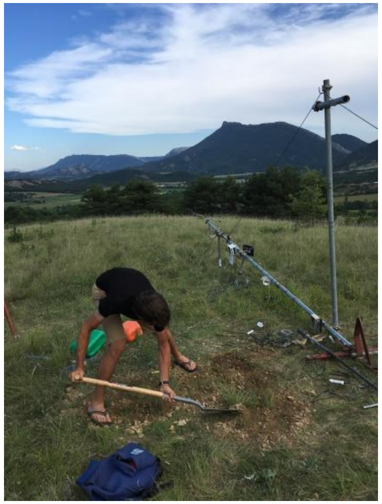
From observations by radar stations



After Schuurmans et al. (2007)

Meteorological station





Relative humidity (*RH*)

$$RH = \frac{e_{\mathrm{a}}}{e_{\mathrm{s}}}$$

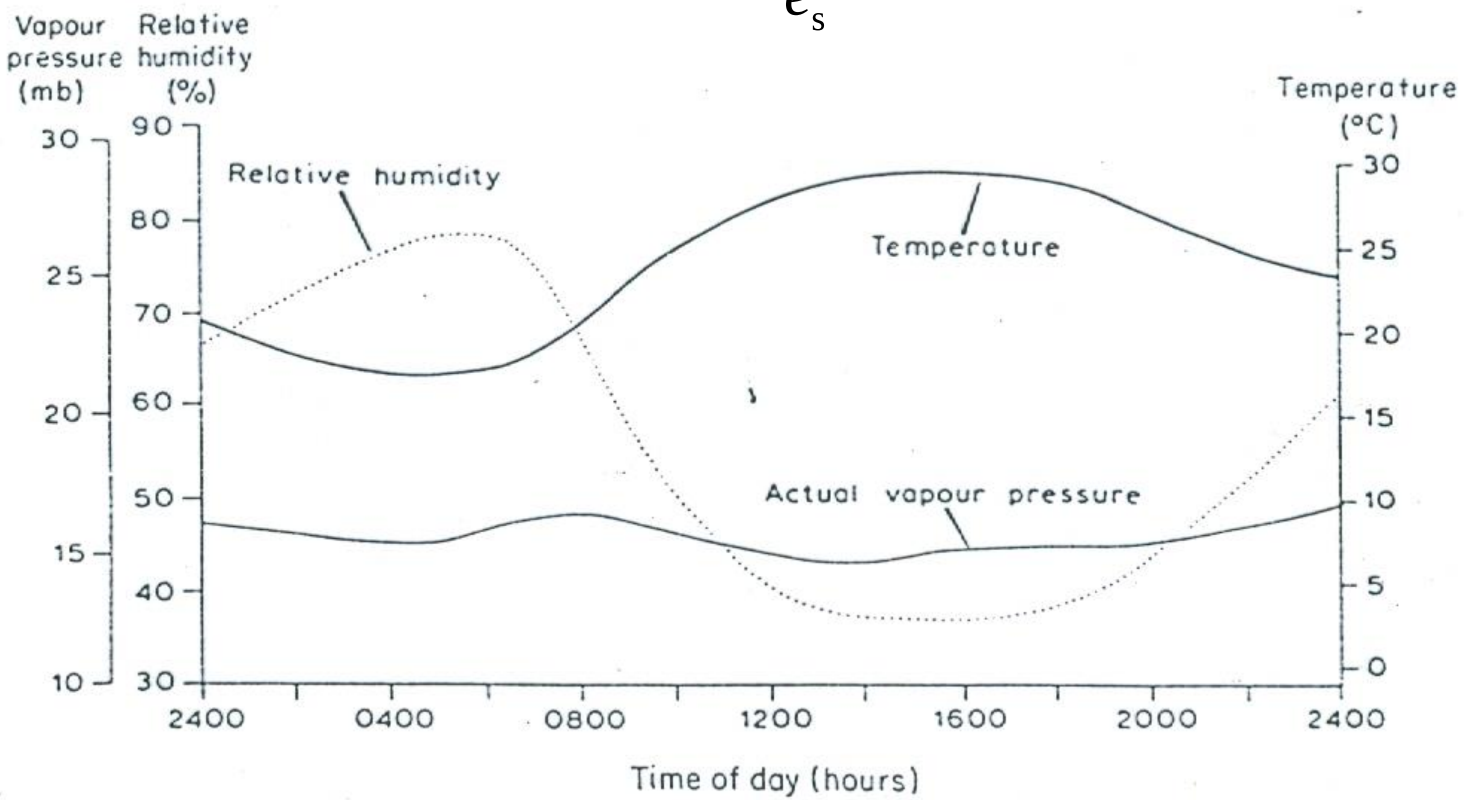


Figure 4.3 *An example of the diurnal variation of vapour pressure, relative humidity and air temperature* (*from an original diagram in ASCE, 1949*).

Saturation vapour pressure table

Saturation Vapor Pressure Table					
Temperature (deg F)	Temperature (deg C)	Saturation Vapor Pressure (mb)	Temperature (deg F)	Temperature (deg C)	Saturation Vapor Pressure (mb)
-30	-34.4	0.3	40	4.4	8.4
-29	-33.9	0.4	41	5.0	8.7
-28	-33.3	0.4	42	5.6	9.1
-27	-32.8	0.4	43	6.1	9.4
-26	-32.2	0.4	44	6.7	9.8
-25	-31.7	0.4	45	7.2	10.2
-24	-31.1	0.5	46	7.8	10.6
-23	-30.6	0.5	47	8.3	11.0
-22	-30.0	0.5	48	8.9	11.4
-21	-29.4	0.5	49	9.4	11.8
-20	-28.9	0.6	50	10.0	12.3
-19	-28.3	0.6	51	10.6	12.7
-18	-27.8	0.6	52	11.1	13.2
-17	-27.2	0.7	53	11.7	13.7
-16	-26.7	0.7	54	12.2	14.2
-15	-26.1	0.7	55	12.8	14.8
-14	-25.6	0.8	56	13.3	15.3
-13	-25.0	0.8	57	13.9	15.9
-12	-24.4	0.9	58	14.4	16.4

Evaporation types

- Interception evaporation
- Soil evaporation
- Transpiration

- Potential evaporation
- Actual evaporation

- Reference crop evaporation

- Pan evaporation
- Open-water evaporation

Evaporation pan

$E_{\text{open water}} = p \times E_{\text{pan}}$ p = pan coefficient

p on an annual basis ≅ 0.8

Evaporation rate

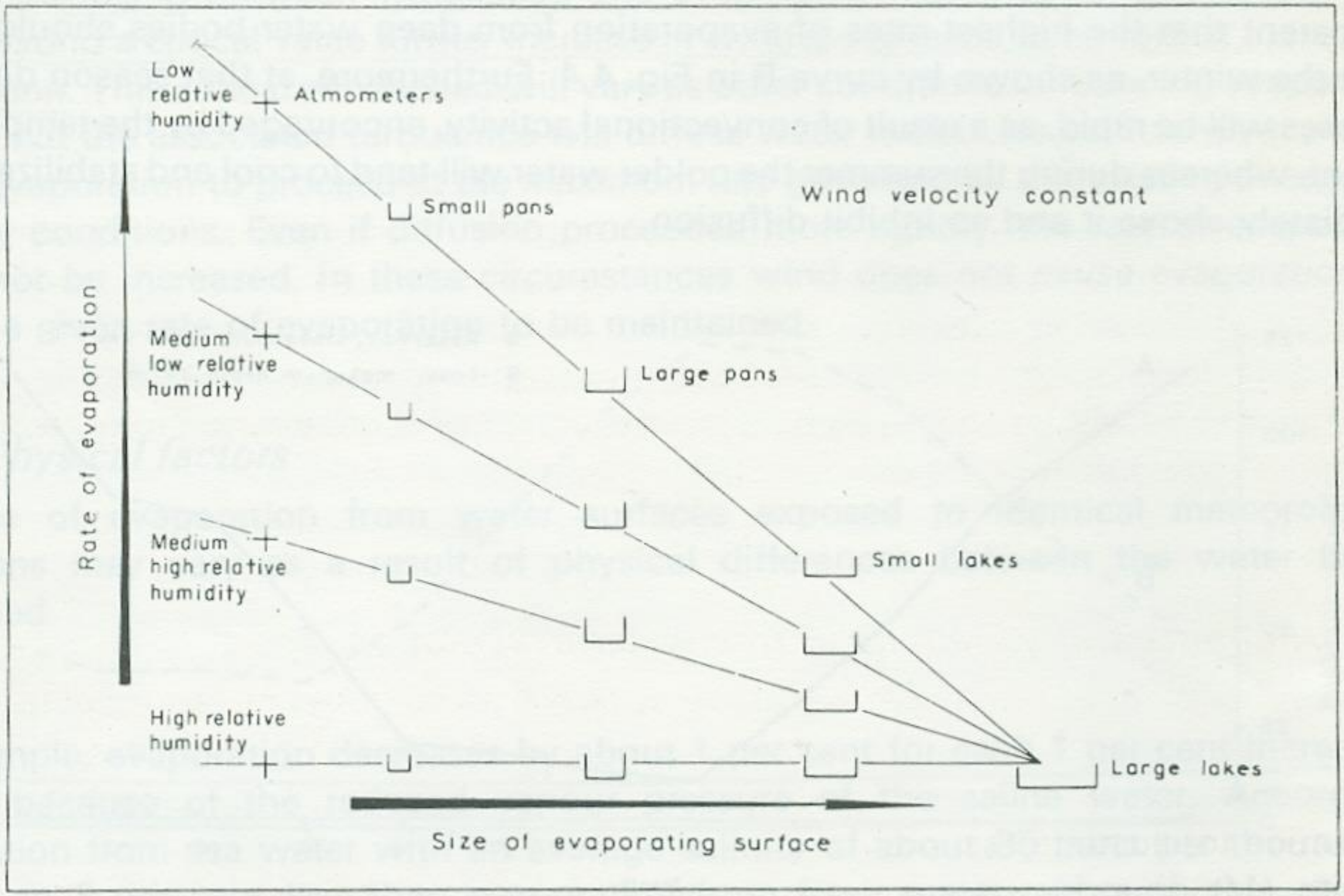
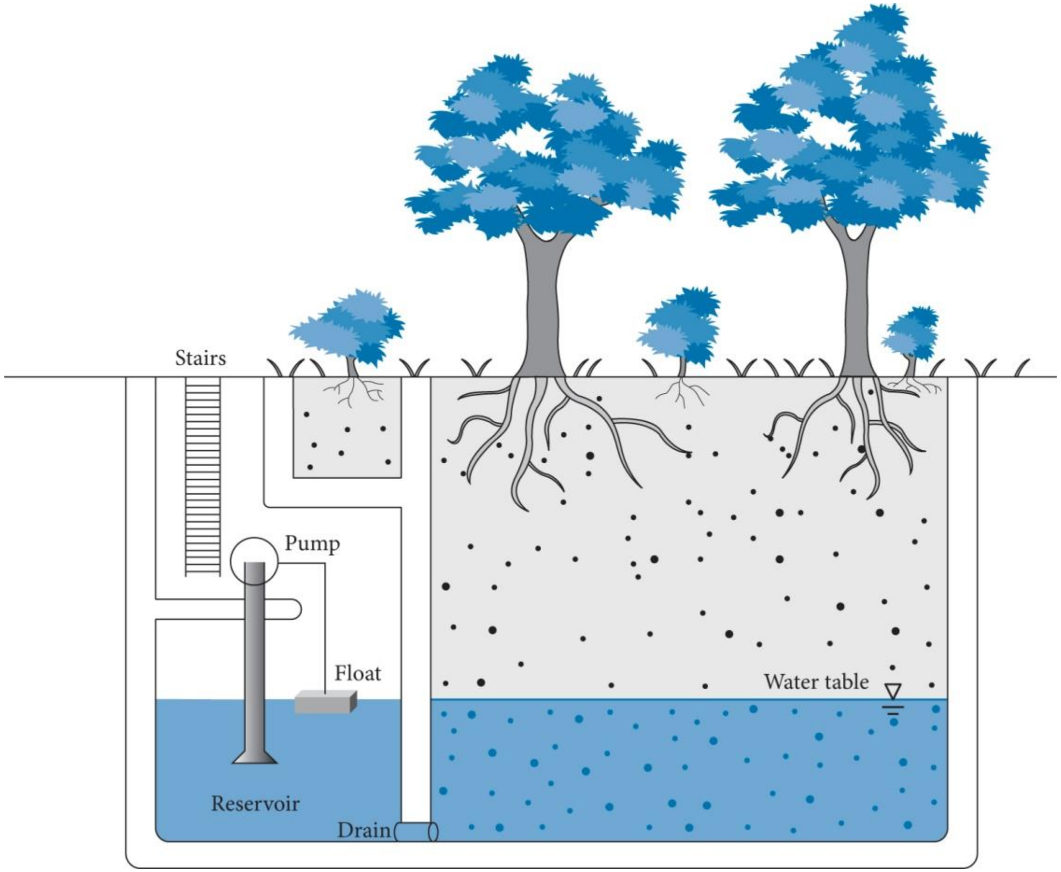


Figure 4.5 *The relationship between the rate of evaporation, the size of the evaporating surface and the relative humidity (from an original diagram by Thornthwaite and Mather, 1955).*

Lysimeter - Soil evaporation



Evaporation types

From higher to lower values (generally):

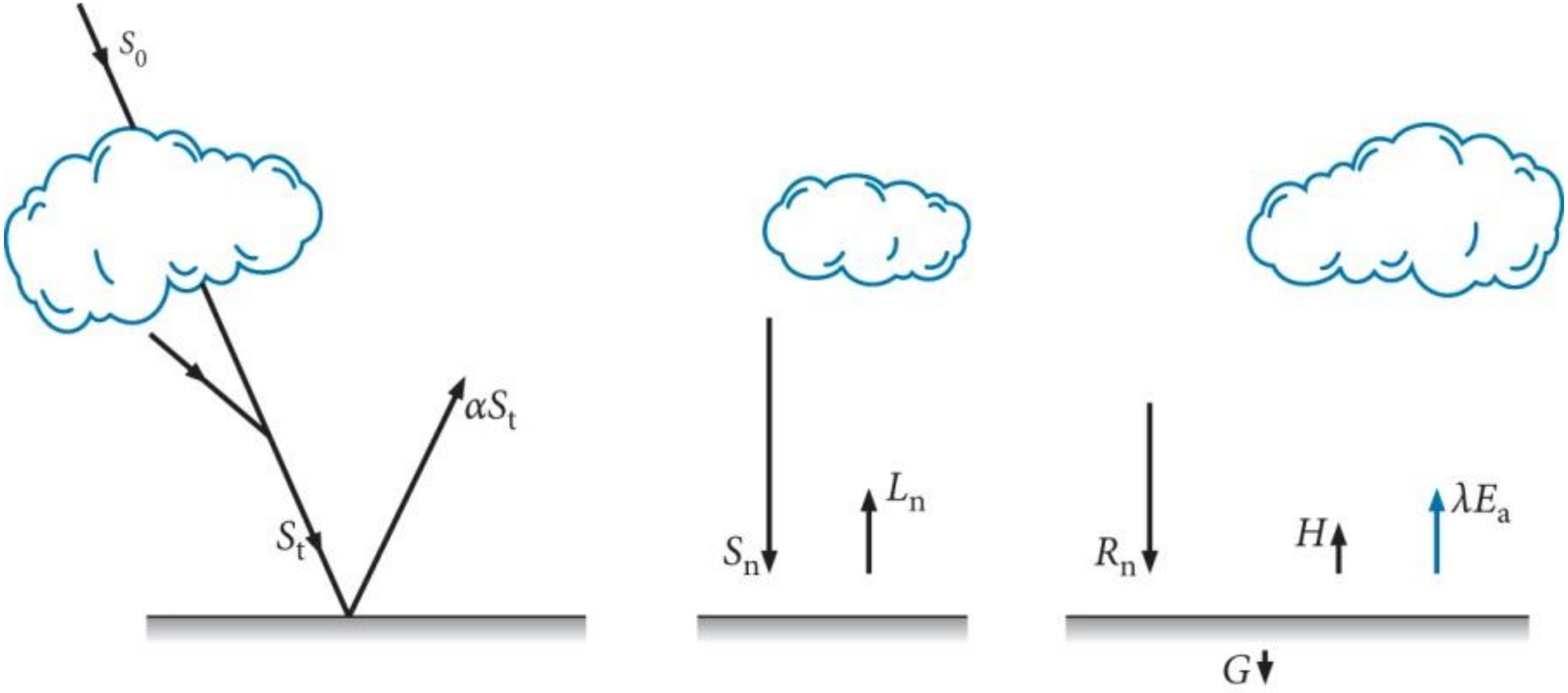
1. Pan evaporation
2. Open-water evaporation
3. Reference crop evaporation
4. Potential evaporation
5. Actual evaporation

All values are in mm day^{-1}!

Penman-Monteith equation

$$E_{\mathrm{a}} = 0.408 \times \frac{\Delta R_{\mathrm{n}} + \dfrac{105.028\,(e_{\mathrm{s}} - e_{\mathrm{a}})}{r_{\mathrm{a}}}}{\Delta + 0.067\left(1 + \dfrac{r_{\mathrm{s}}}{r_{\mathrm{a}}}\right)}$$

Energy balance

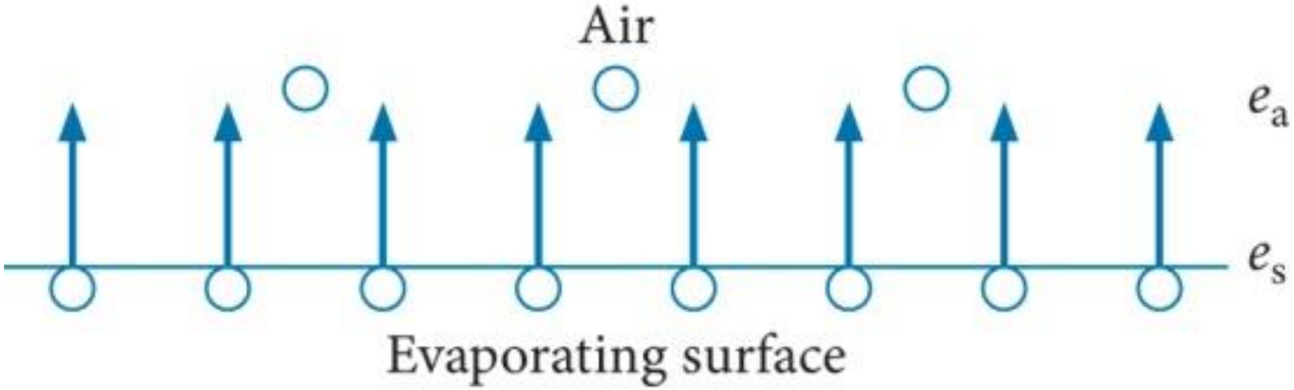


Absorbed shortwave radiation $S_n = (1 - \alpha)S_t$

Net radiation $R_n = S_n - L_n$

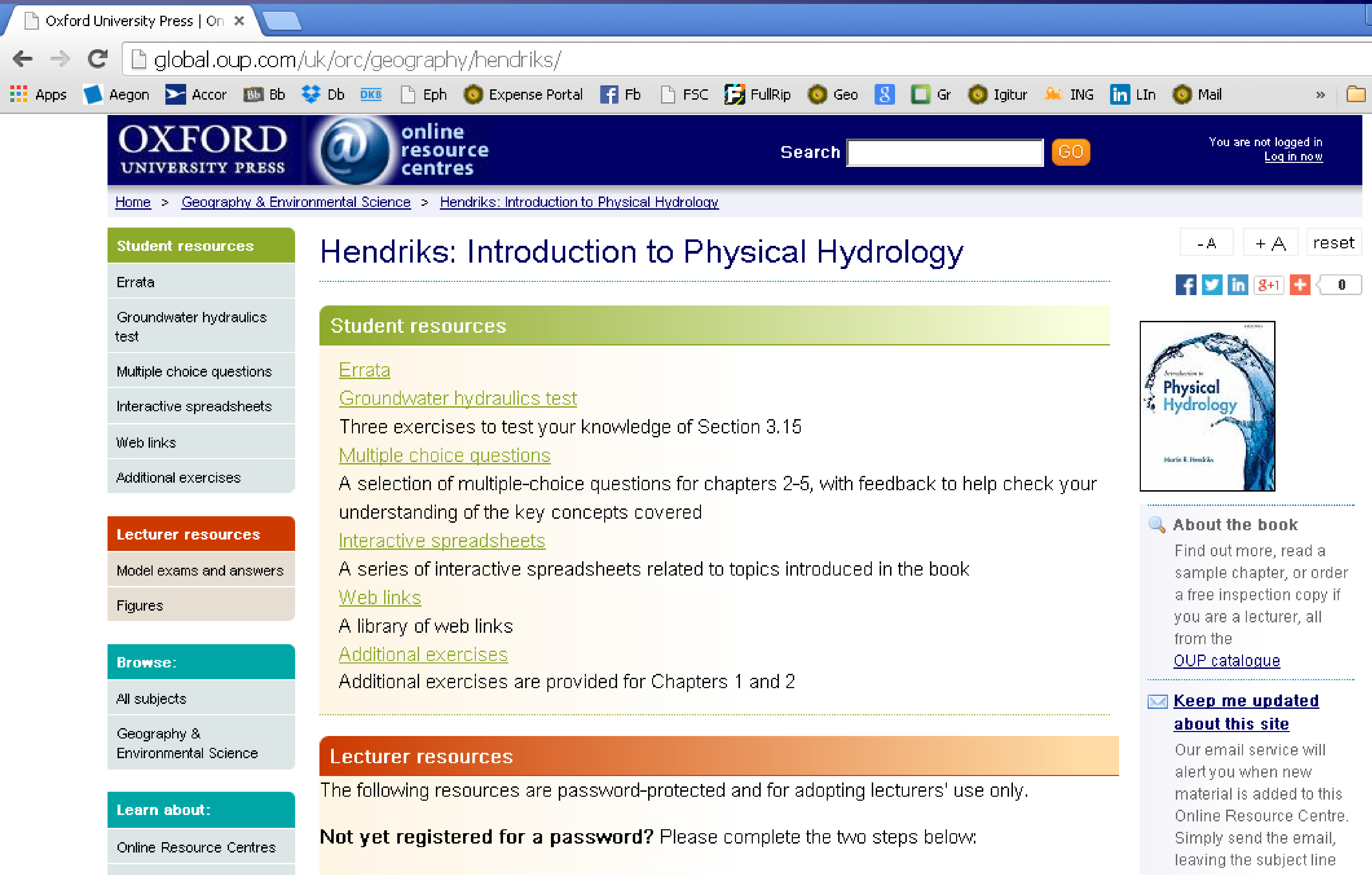
Non-radiative energy flux densities G, H, and λE_a: $R_n = G + H + \lambda E_a$

Atmospheric demand



saturation deficit $e_s - e_a$

Online Resource Centre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Three exercises to test your knowledge of Section 3.15

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A selection of multiple-choice questions for chapters 2-5, with feedback to help check your understanding of the key concepts covered

Interactive spreadsheets

A series of interactive spreadsheets related to topics introduced in the book

Web links

A library of web links

Additional exercises

Additional exercises are provided for Chapters 1 and 2

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The following resources are password-protected and for adopting lecturers' use only.

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Introduction to Physical Hydrology — Martin R. Hendriks

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Spreadsheet model: input

	A	B	C	D	E	F
1	**Introduction to Physical Hydrology - Martin R. Hendriks**					
2	**Table 2.2 Estimation of evaporation from a forest, grassland and open water surface using the Penman-Monteith equation**					
3						
4	**Equation parameters/variables**					
5	a_s (-)		0.25			
6	b_s (-)		0.50			
7	a_e (-)		0.34			
8	b_e ($kPa^{-0.5}$)		-0.14			
9	a_c (-)		0.25			
10	b_c (-)		0.75			$b_c = 1 - a_c$
11						
12	**Data**					
13	Air temperature, T (°C)		20.0			Thermometer
14	Relative humidity, RH (-)		0.75			Relative humidity sensor
15	Sun's short wave radiation, S_0 (MJ m^{-2} day^{-1})		37.50			Figure B2.12.2
16	Number of bright sunshine hours per day, n (hour)		8.15			Campbell-Stokes sunshine recorder
17	Total day length, N (hour)		16.3			Table B2.12.2
18						
19	**Land use data**	forest	grassland	open water		
20	Albedo, α (-)	0.15	0.23	0.08		Table B2.12.1
21	Aerodynamic resistance, r_a (s m^{-1})	5	69	110		Table 2.1
22	Surface resistance, r_s (s m^{-1})	150	69	0		Table 2.1

Spreadsheet model: output

ch02.7_Table_2.2.xls [Compatibility Mode] - Microsoft Excel

	A	B	C	D	E	F
24	**Calculations**					
25	Cloudiness fraction, n/N (-)		0.5			n and N from above
26	Saturation vapour pressure, e_s (kPa)		2.338			Equation B2.2.3
27	Actual vapour pressure, e_a (kPa)		1.754			Equation B2.2.4
28	Net radiation at the earth's surface, R_n (MJ m^{-2} day^{-1})	12.44	10.94	13.75		Equation B2.12.6
29	Gradient of the saturation pressure curve, Δ (kPa °C^{-1})		0.145			Equation 2.3
30						
31	**Evaporation (mm day^{-1})**	**2.6**	**3.6**	**4.9**		Equation 2.2
32						
33	Latent heat transfer from the earth's surface (MJ m^{-2} day^{-1})	6.33	8.87	12.03		Multiply the evaporation by λ
34	Sensible heat transfer from the earth's surface (MJ m^{-2} day^{-1})	6.10	2.07	1.72		Equation B2.12.7
35						
36						
37						
38						
39						
40						

FAO Penman-Monteith equation

Source: http://www.fao.org/docrep/X0490E/x0490e00.htm#Contents

Allen et al. (1998):

$$E_{\mathrm{rc}} = \frac{0.408\,\Delta\,(R_{\mathrm{n}} - G) + \gamma \dfrac{900}{T + 273} u_2\,(e_{\mathrm{s}} - e_{\mathrm{a}})}{\Delta + \gamma\left(1 + 0.34\,u_2\right)}$$

K_{c} = crop coefficient of a particular crop at a certain growth stage:

$$E_{\mathrm{p}} = K_{\mathrm{c}} \times E_{\mathrm{rc}}$$

References

Allen, R.G., Pereira, L.S., Raes, D., and Smith, M. (1998). Crop evapotranspiration. Guidelines for computing crop water requirements. FAO Irrigation and drainage paper 56. Food and Agriculure Organization of the United Nations (FAO), Rome. http://www.fao.org/docrep/X0490E/x0490e00.htm#Contents

ASCE (1949). Hydrology Handbook, American Society of Civil Engineers, New York.

Hendriks, M.R. (2010). Introduction to Physical Hydrology. Oxford University Press.

Schuurmans, J.M., Bierkens, M.F.P., Pebesma, E.J. and Uijlenhoet, R. (2007). Automatic prediction of high-resolution daily rainfall fields for multiple extents: the potential of operational radar. Journal of Hydrometeorology, 8, 1204-1224.

Thornthwaite, C.W. and Mather, J.R. (1955). The water balance. Publications in Climatology, 8, 1-86.