Aspetti idrologici ed idrogeologici della sorgente Sanità di Caposele, alimentante l'Acquedotto Pugliese

Hydrological and hydrogeological features of the Sanità spring of Caposele, Southern Italy, which feeds the Pugliese aqueduct

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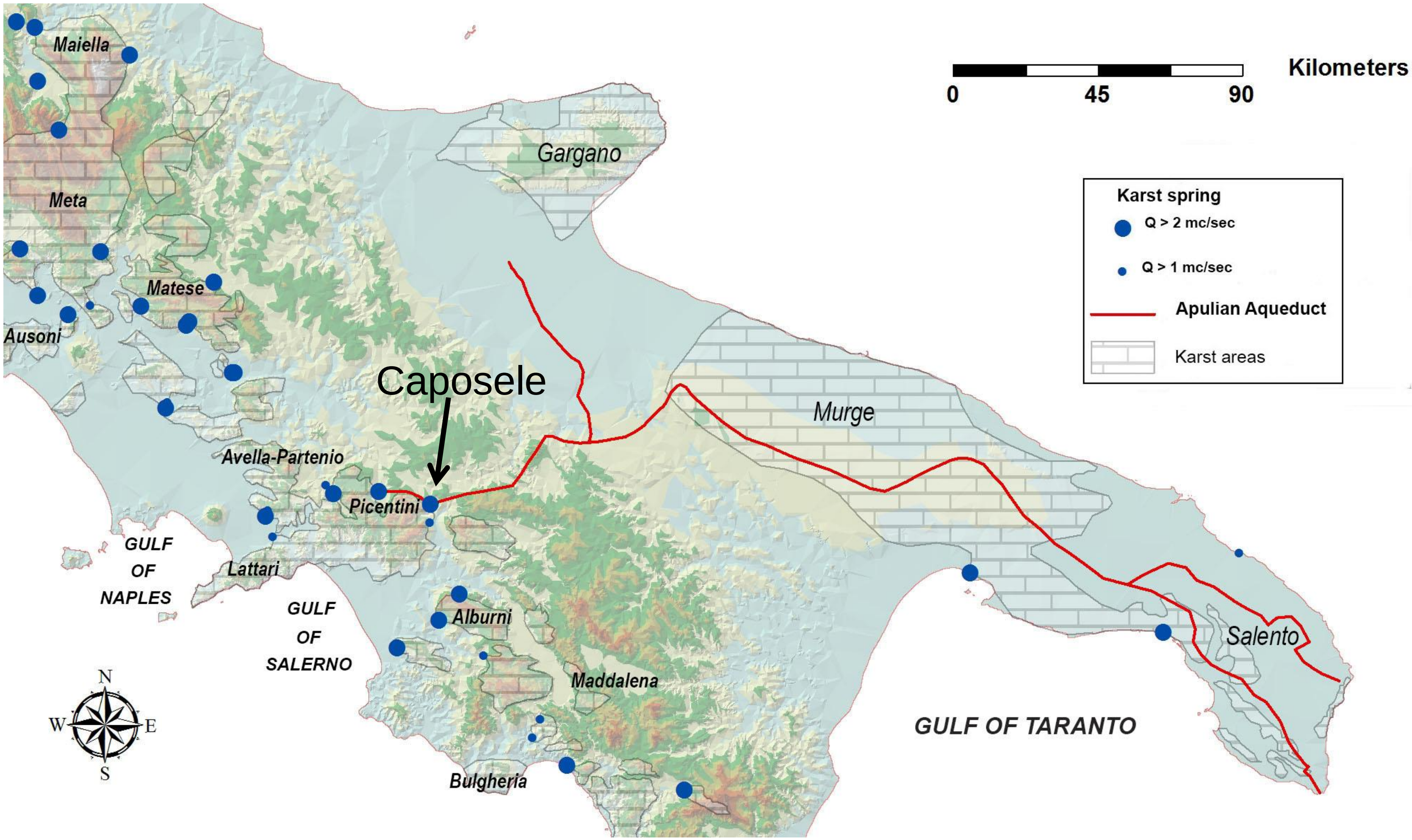
Piano Laceno (Mt. Cervialto), Caposele spring catchment

Caposele spring and Pugliese aqueduct



Pugliese aqueduct:
total lenght: more than 400 km
main gravity-channel (244 km long) up to Villa Castelli
93 bridges and 105 tunnels
Pavoncelli tunnel, 15.3 km
Murge tunnel, 16 km

Caposele spring:
elevation: 417 m a.s.l.
mean discharge ≈ 4 m^3/sec

Main historical points before the tapping

1868, Camillo Rosalba (engineer of the Public Works Office)

1901, first studies and surveys in the area of Sanità springs (supported by a financing of the central state, one million lire).

1902, the consortium "Acquedotto Pugliese" (State and other local authorities) was formed, with full powers on the construction and future management.

1906, begin the excavation of the tunnel crossing (Pavoncelli) and subsequently those of the main channel up to Villa Castelli.

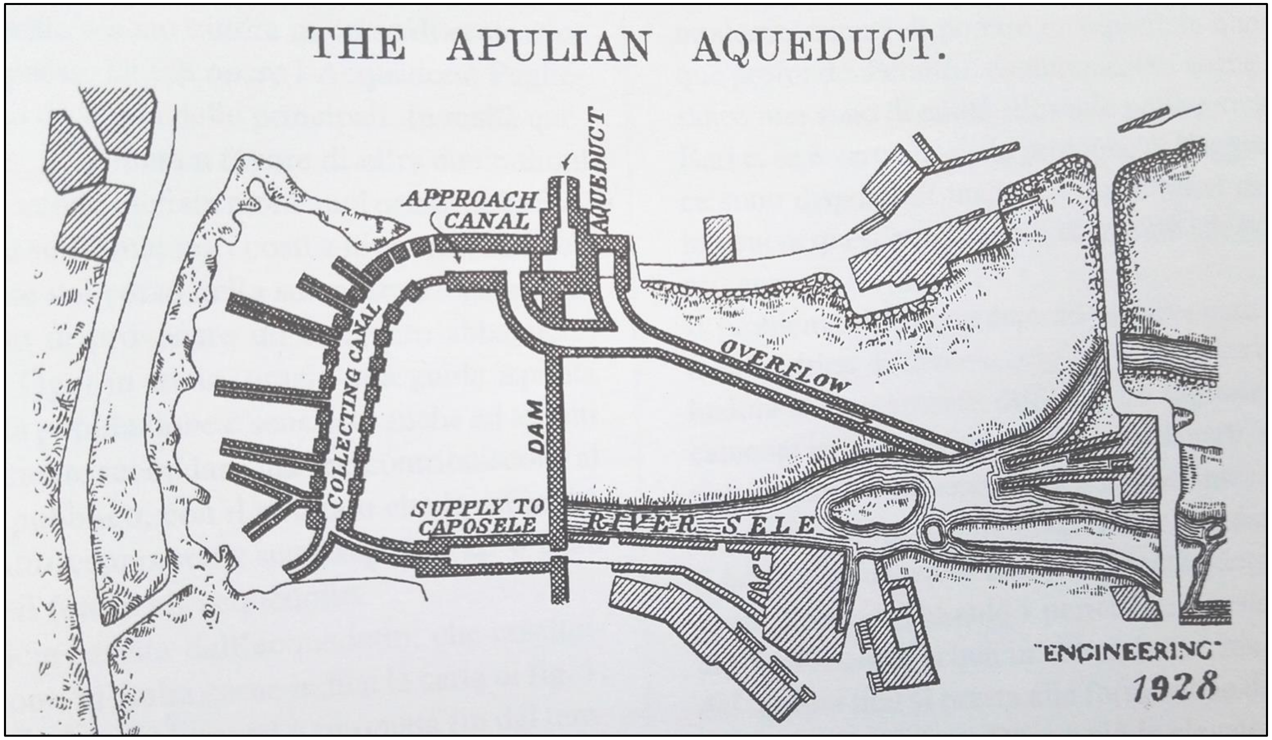
Main historical points of the tapping

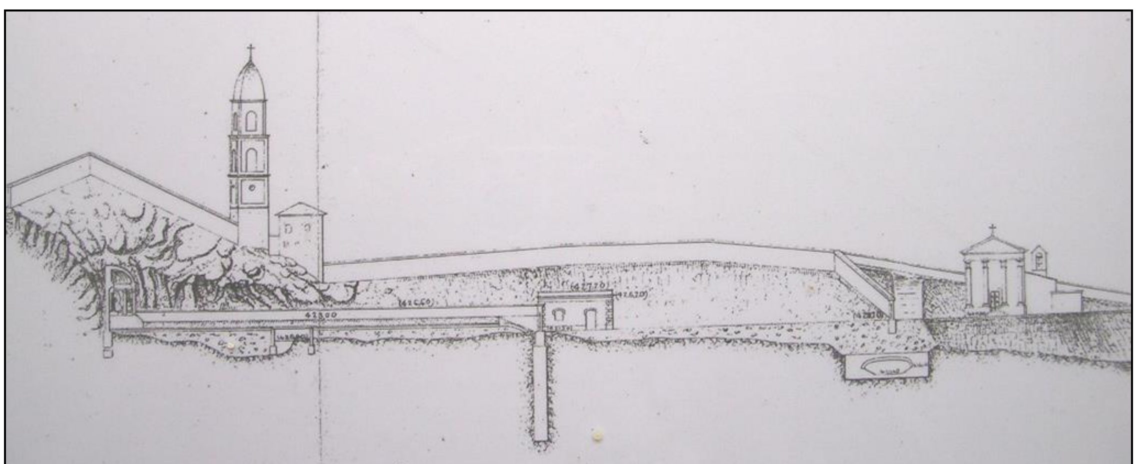
1915, arrival of spring water in Bari

1918, Brindisi

1927, Lecce

Main features of the tapping zone



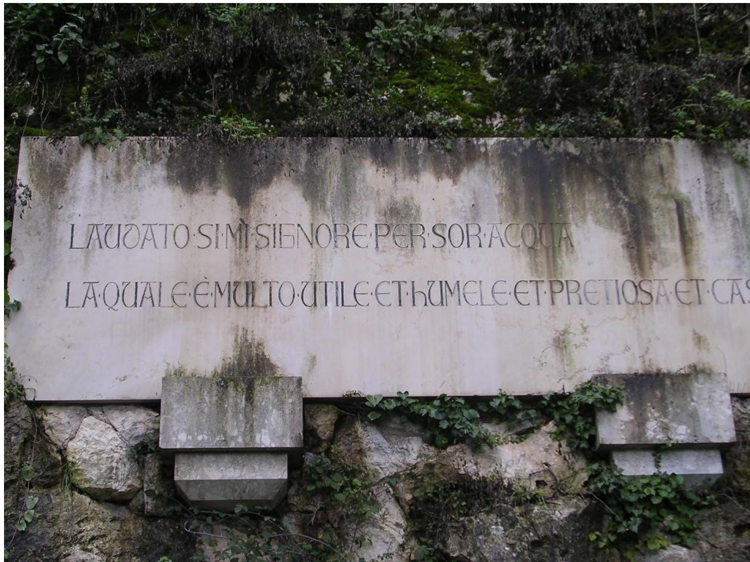


Caposele spring view

Main channel in the tapping area

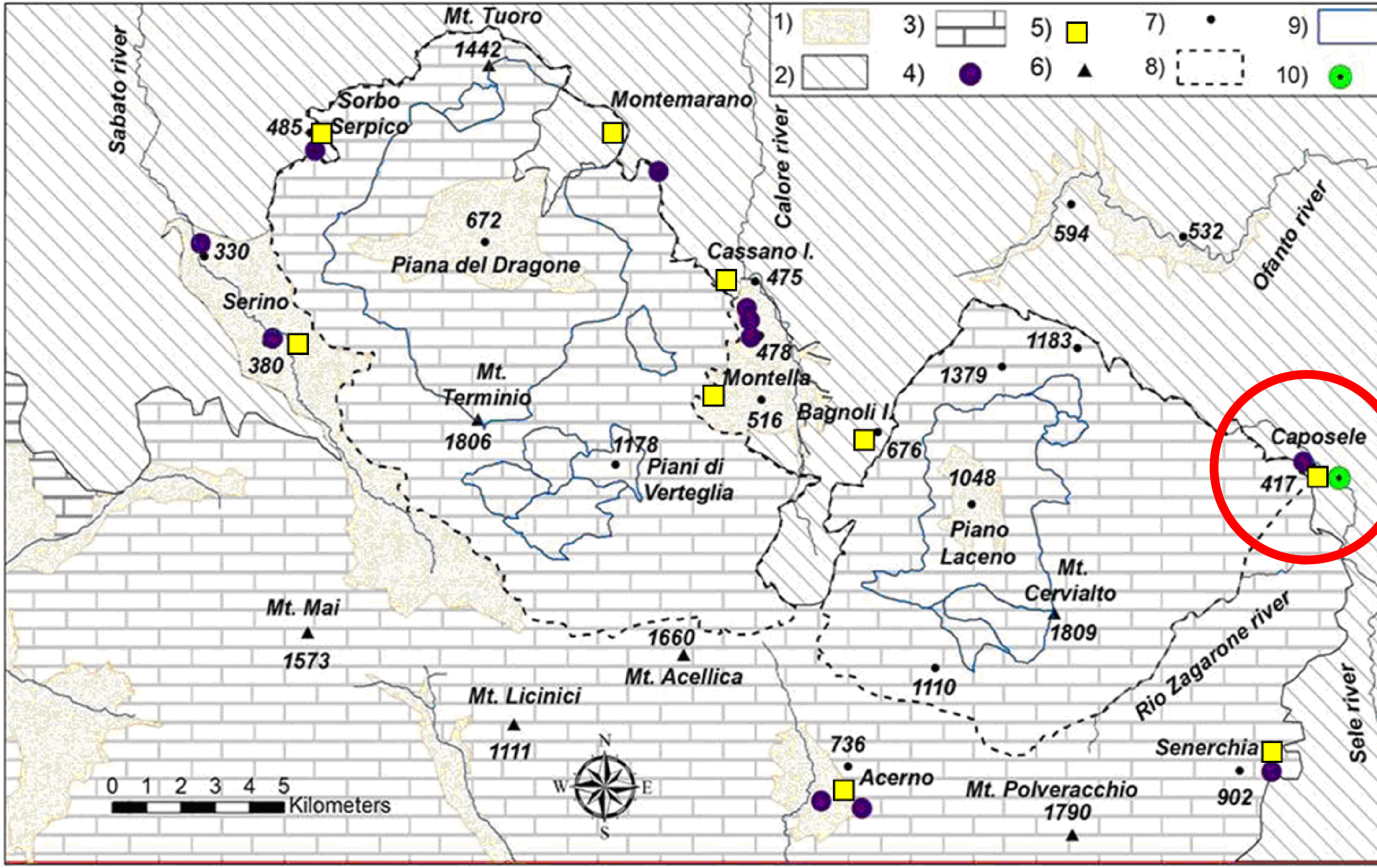
Caposele spring view

Beginning of the last century (≈1900)



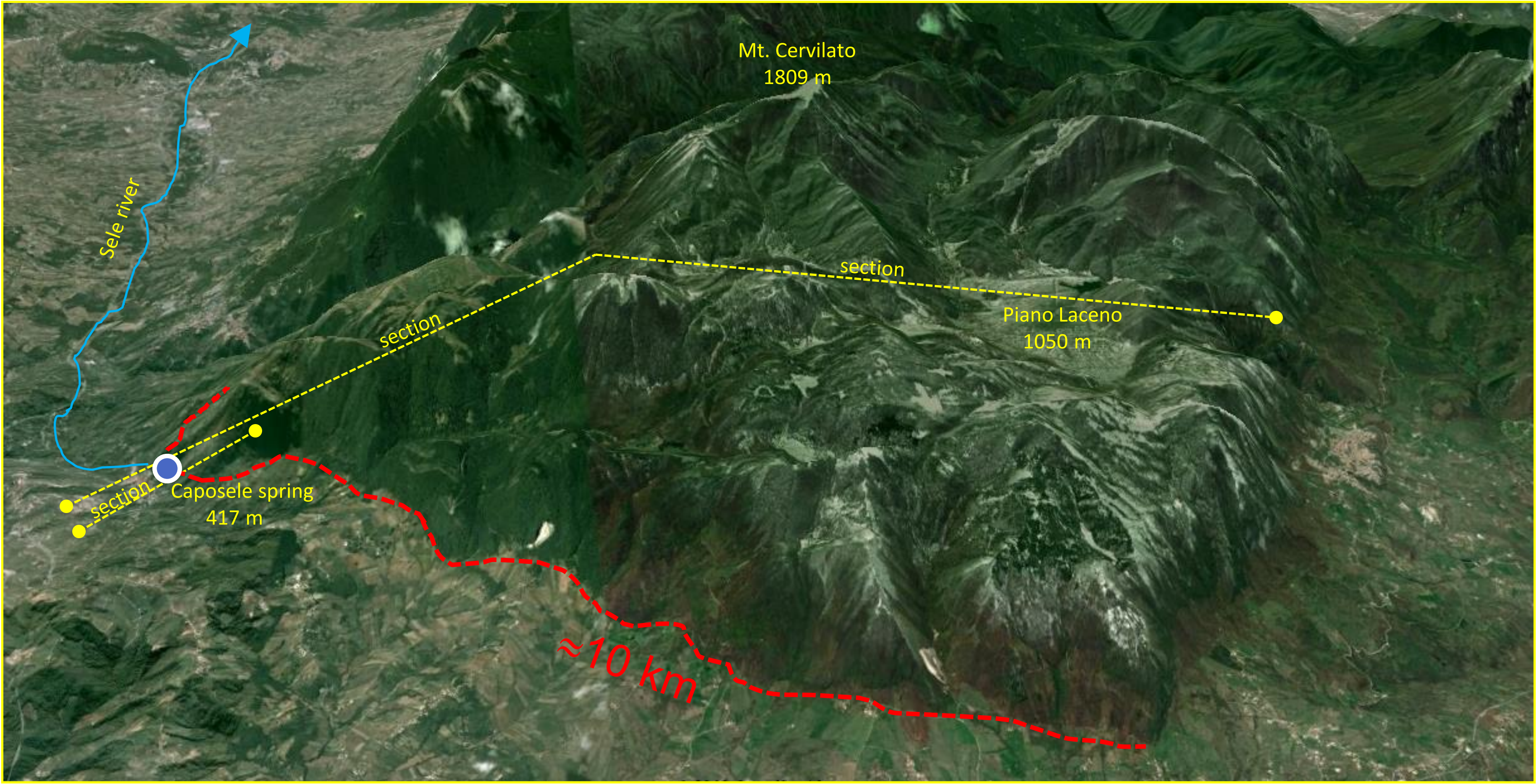
Caposele spring view
currently

Hydrogeological sketch of north-eastern sector of Mt. Picentini



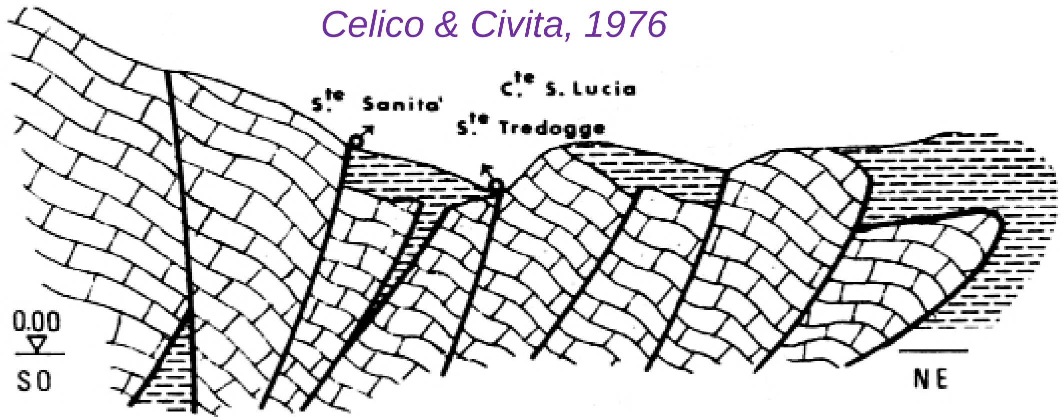
1) Continental mantle (Quaternary); 2) argillaceous complex and flysch sequences (Paleogene–Miocene); 3) calcareous-dolomite series (Jurassic–Miocene); 4) main karst spring; 5) village; 6)mountain peak; 7) elevation (m a.s.l.); 8) Spring catchment ; 9) endorheic area; 10) river gauge.

3D view of the Cervialto massif

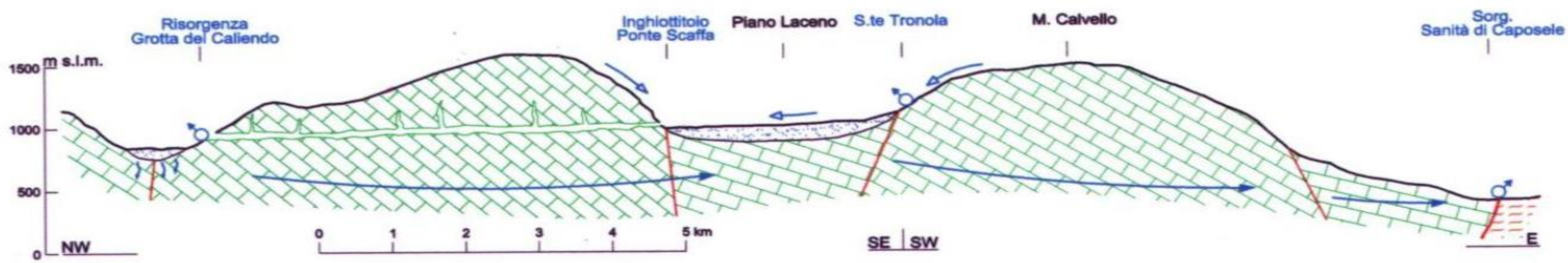


Hydrogeological cross-section

Celico & Civita, 1976

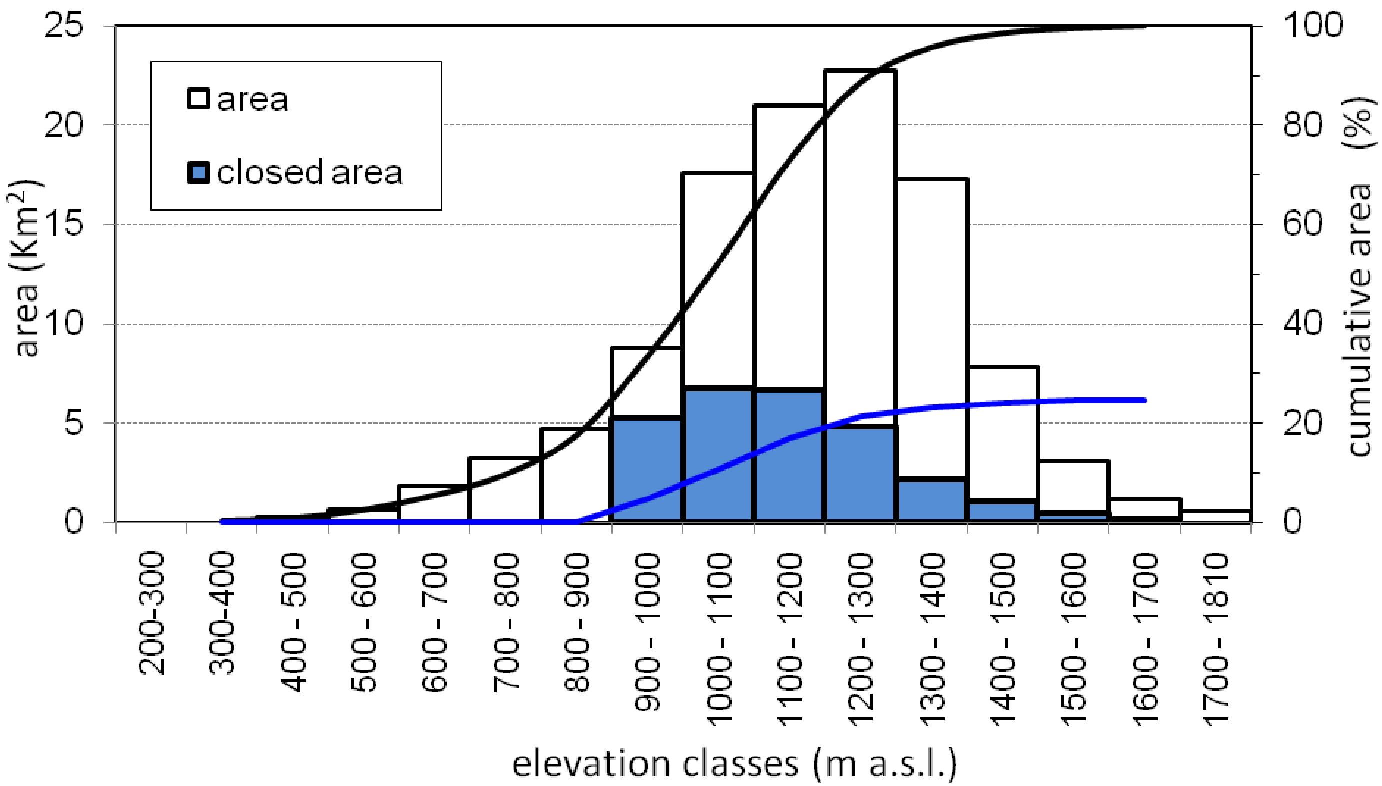


Aquino et al., 2005



Class elevation distribution

hydrogeological spring catchment, 110 km²



elevation mean: 1173 m   spring elevation : 417 m
rock thickness (mean) above the spring: 756 m

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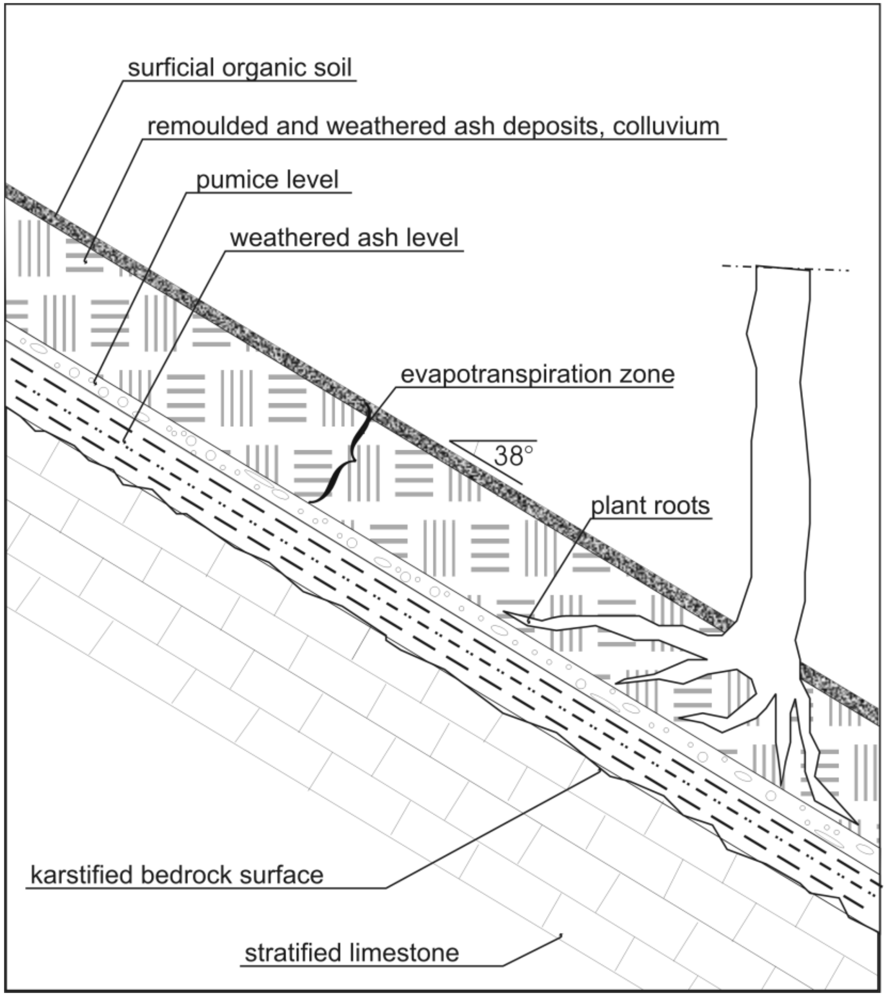
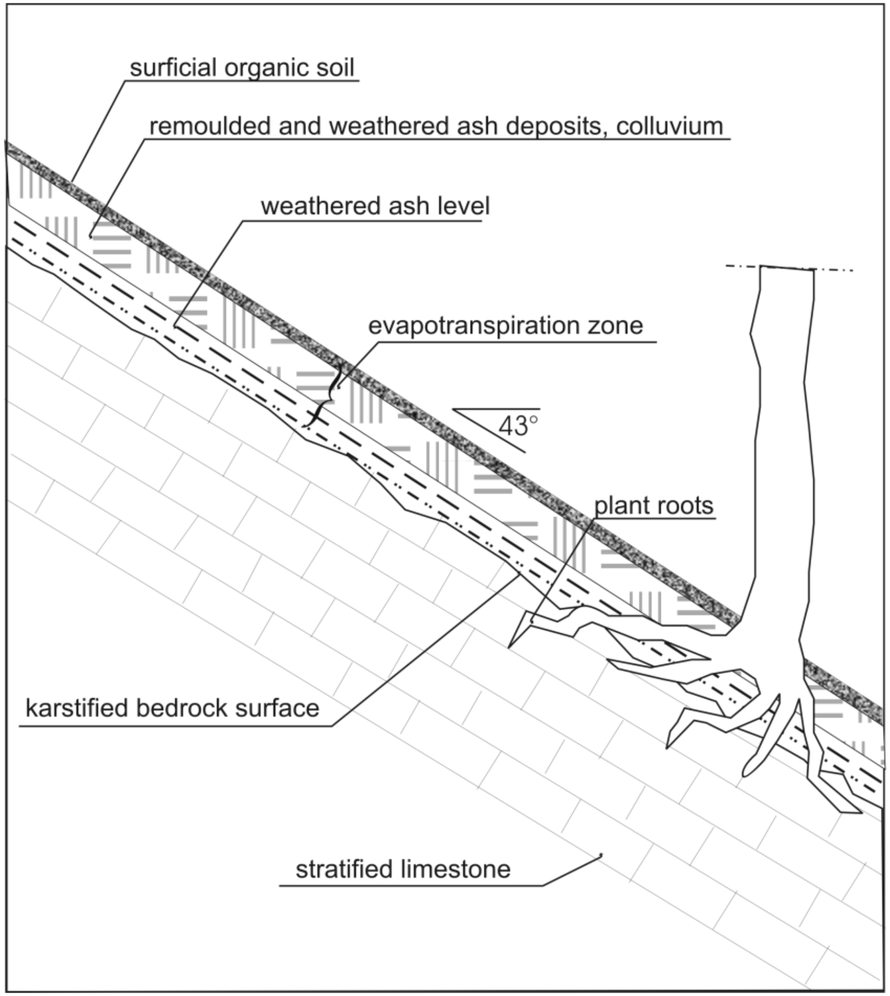
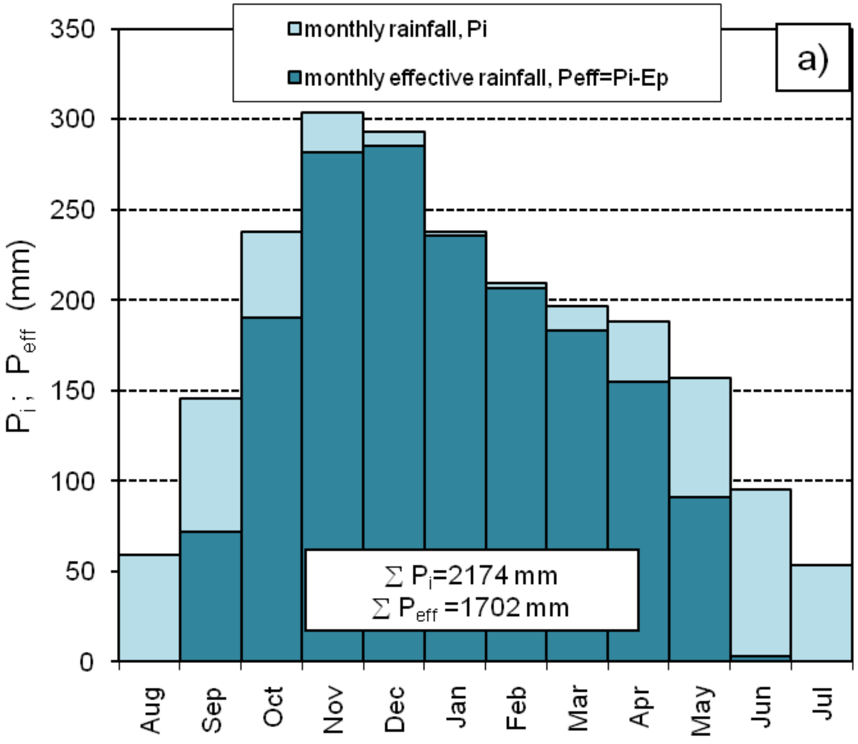
Schematic soil-profile of Campania slopes

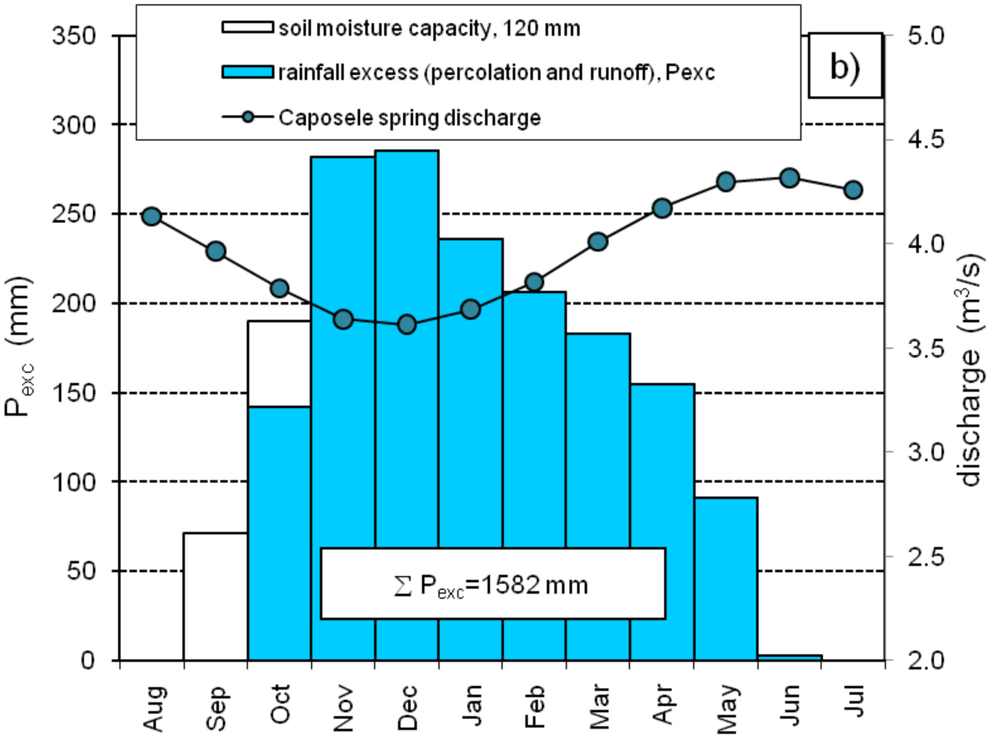




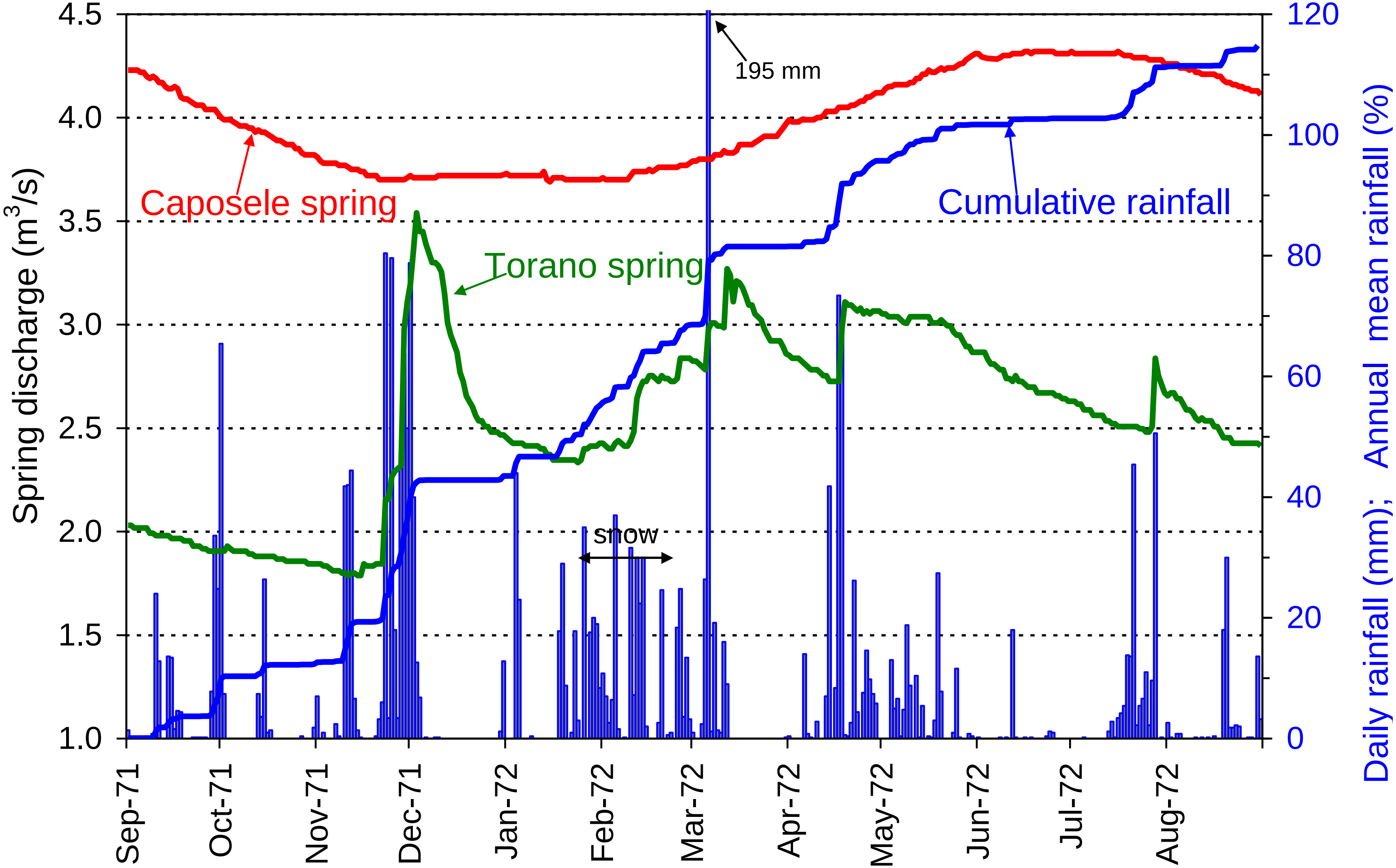
Main climatic features: long-term mean monthly values

Thornthwaite balance, Montevergine, 1270 m a.s.l.





Daily values during a wet year



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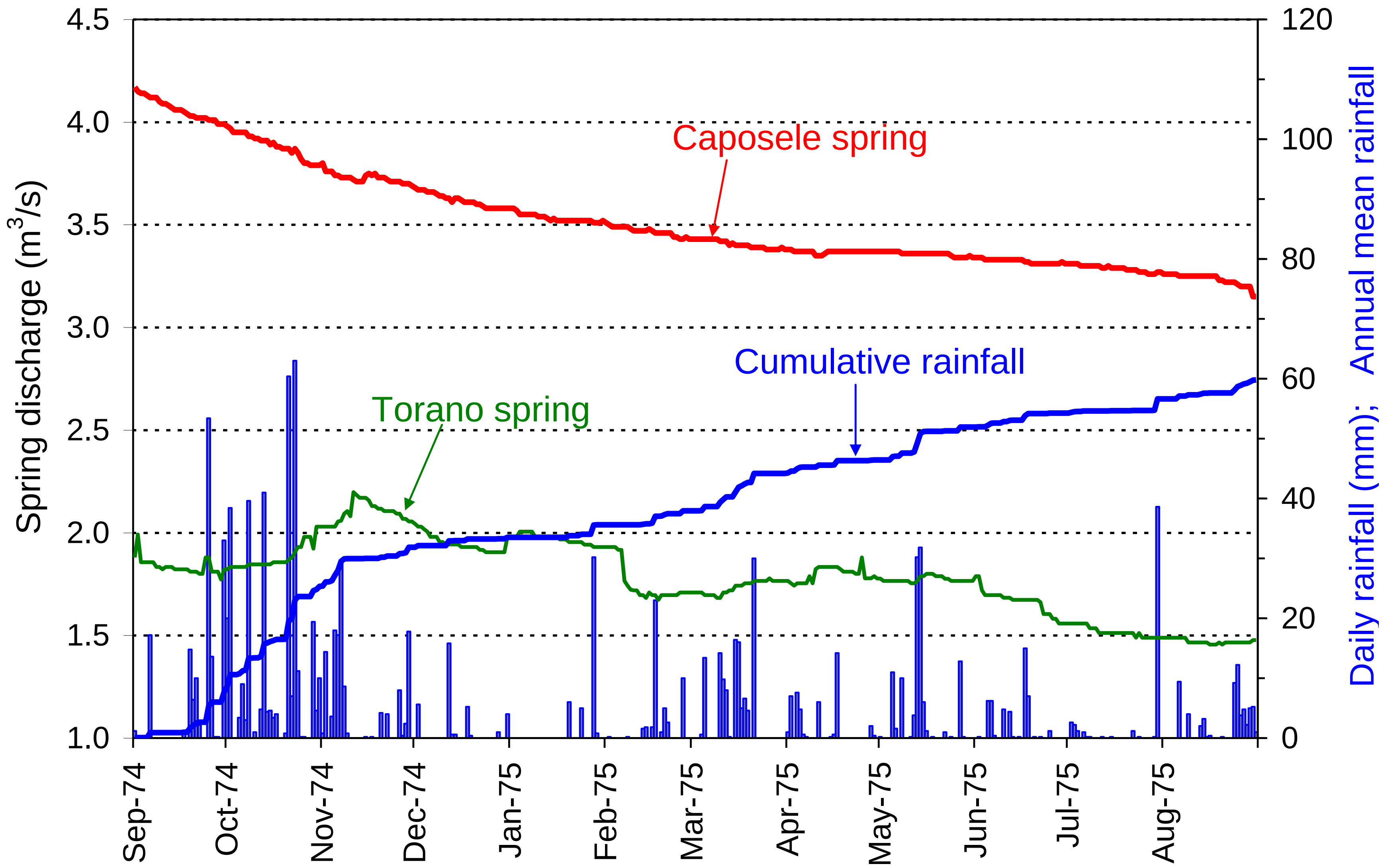
Daily values during a dry year



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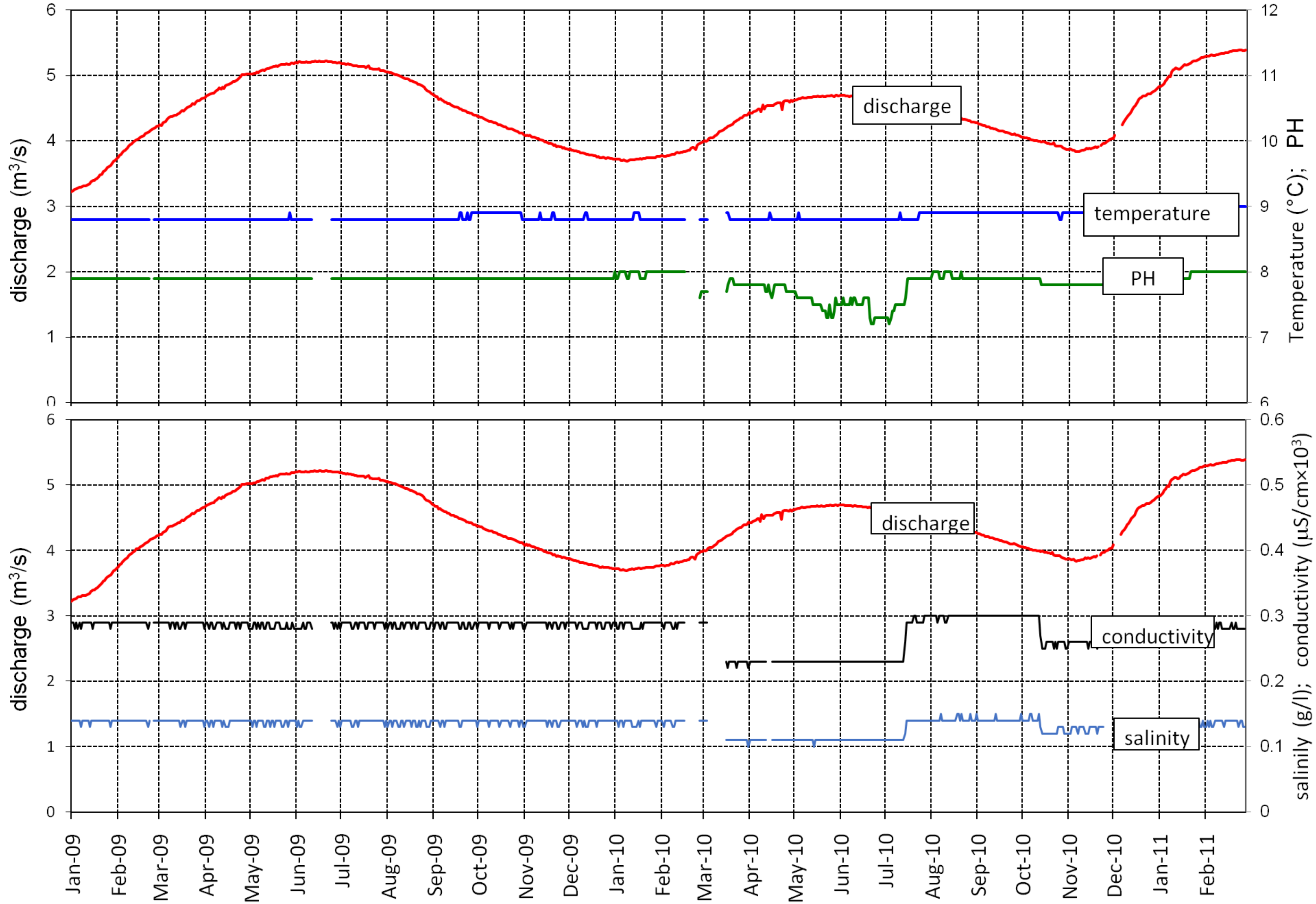
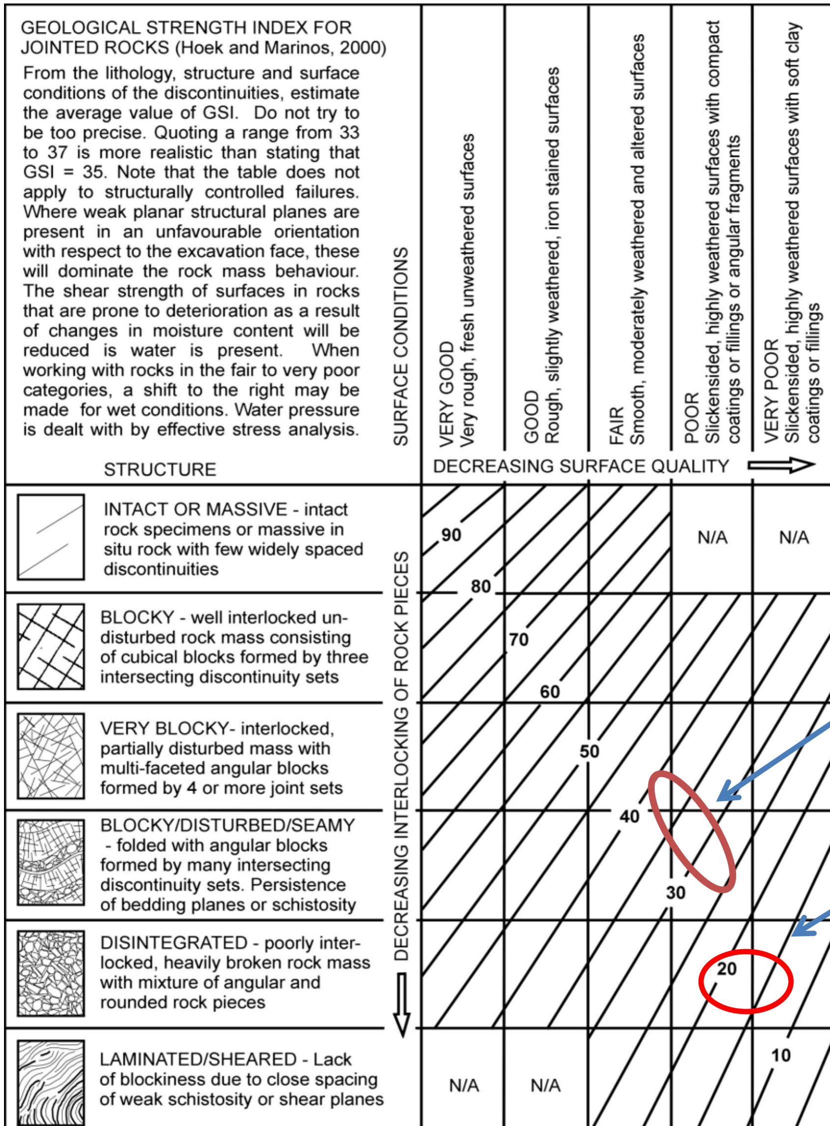
Physical and chemical characteristics of springwater

1 Jan 2009 – 27 Feb 2011



Factors controlling the shape of the hydrograph

Rock mass conditions, Cervialto rock outcropping

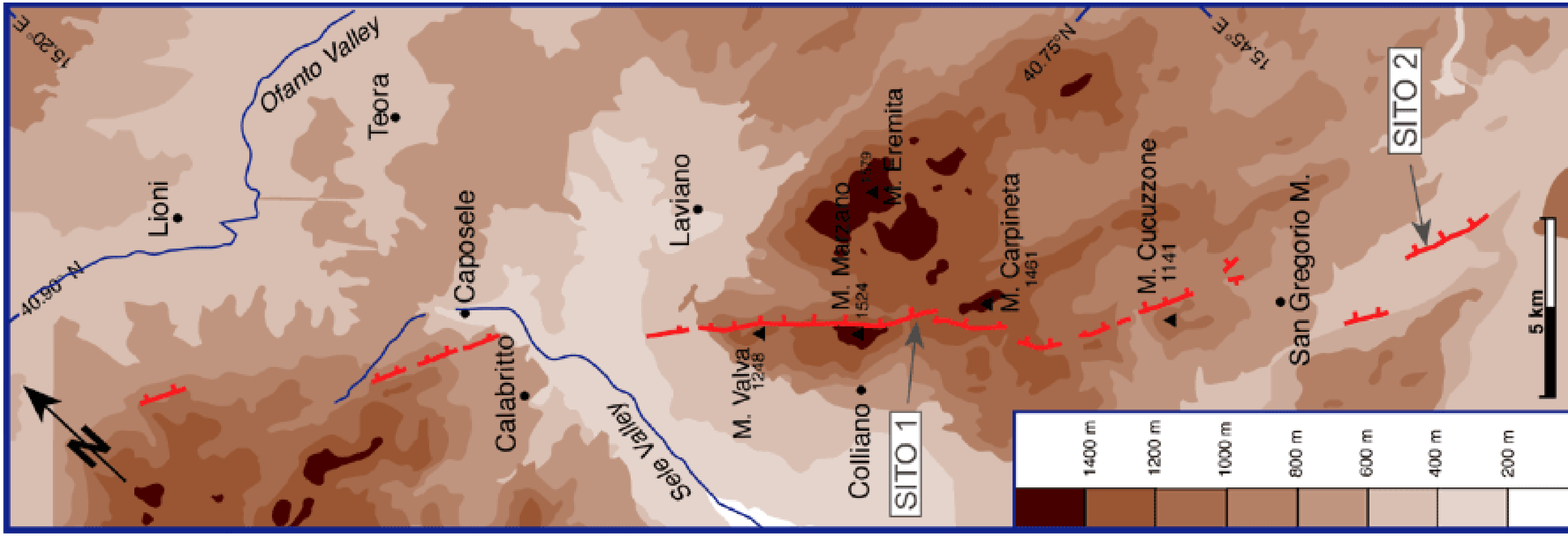


ZONA CINIELLO

CONTRADA DEL PASTORE

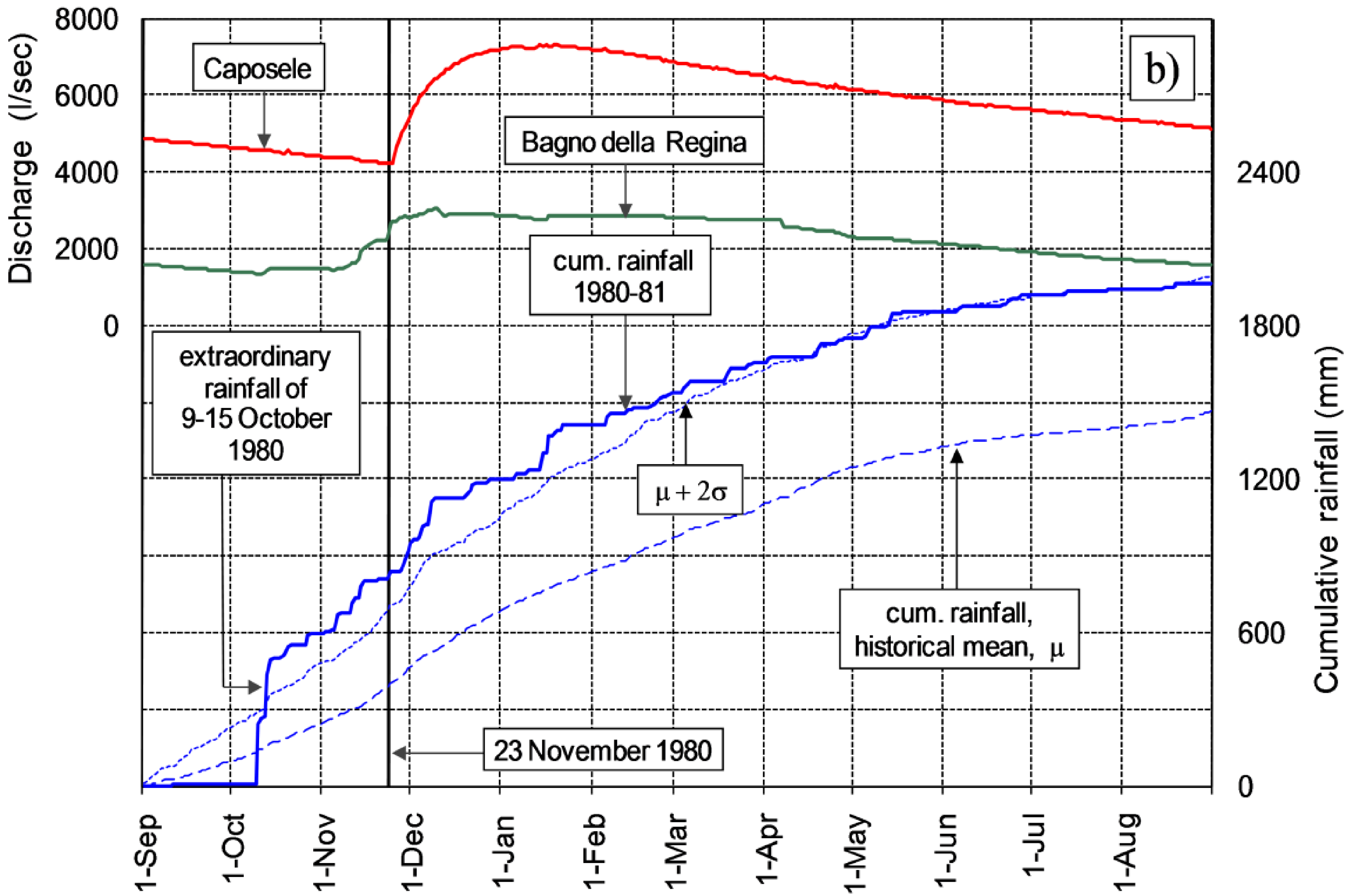
Factors controlling the shape of the hydrograph

fault scarp induced by 1980 Irpinia earthquake



http://legacy.ingv.it/roma/attivita/sismologia/sorgentesismica/esempi/irpinia/irpinia.html

The effect of 23 November1980 earthquake (Ms=6.9)



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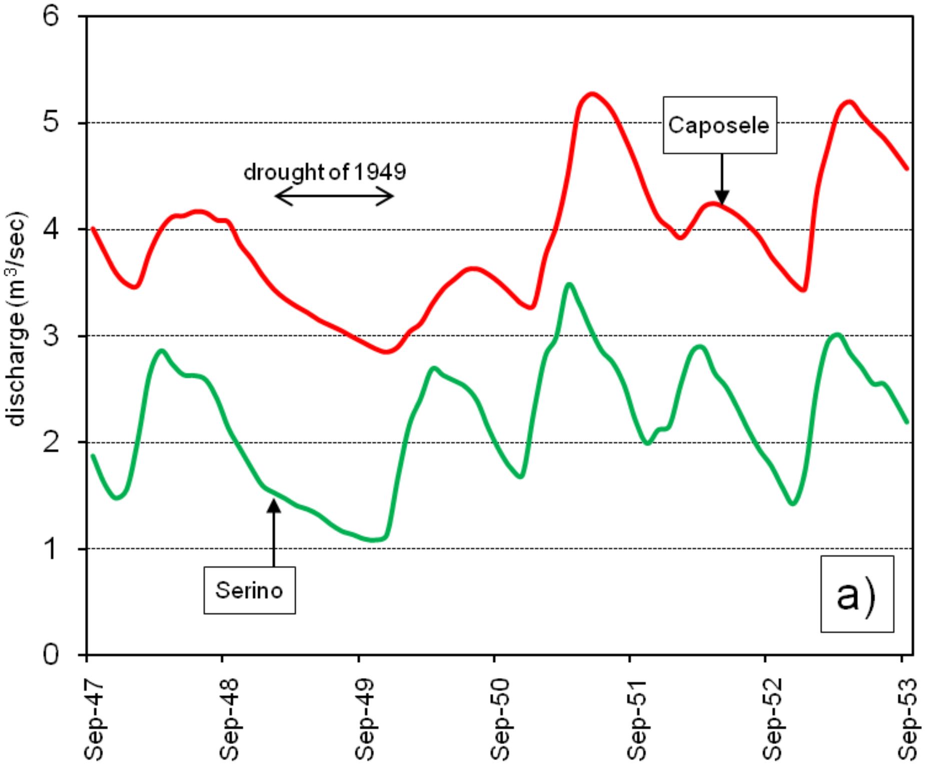
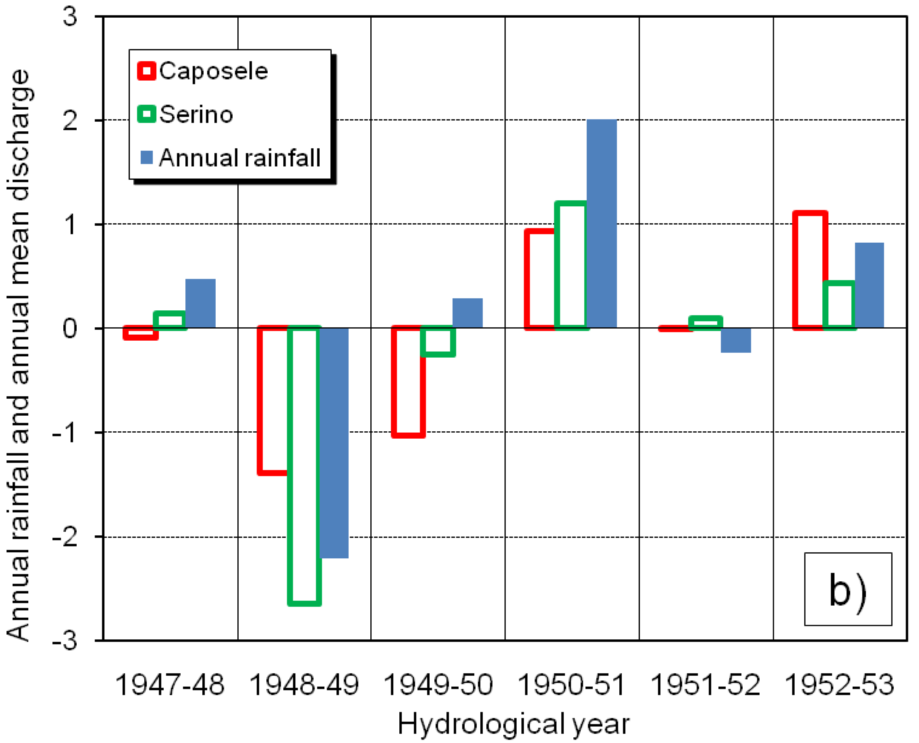
The effect of drought on the following years

Daily spring discharge



Annual rainfall and annual mean discharge standardised values



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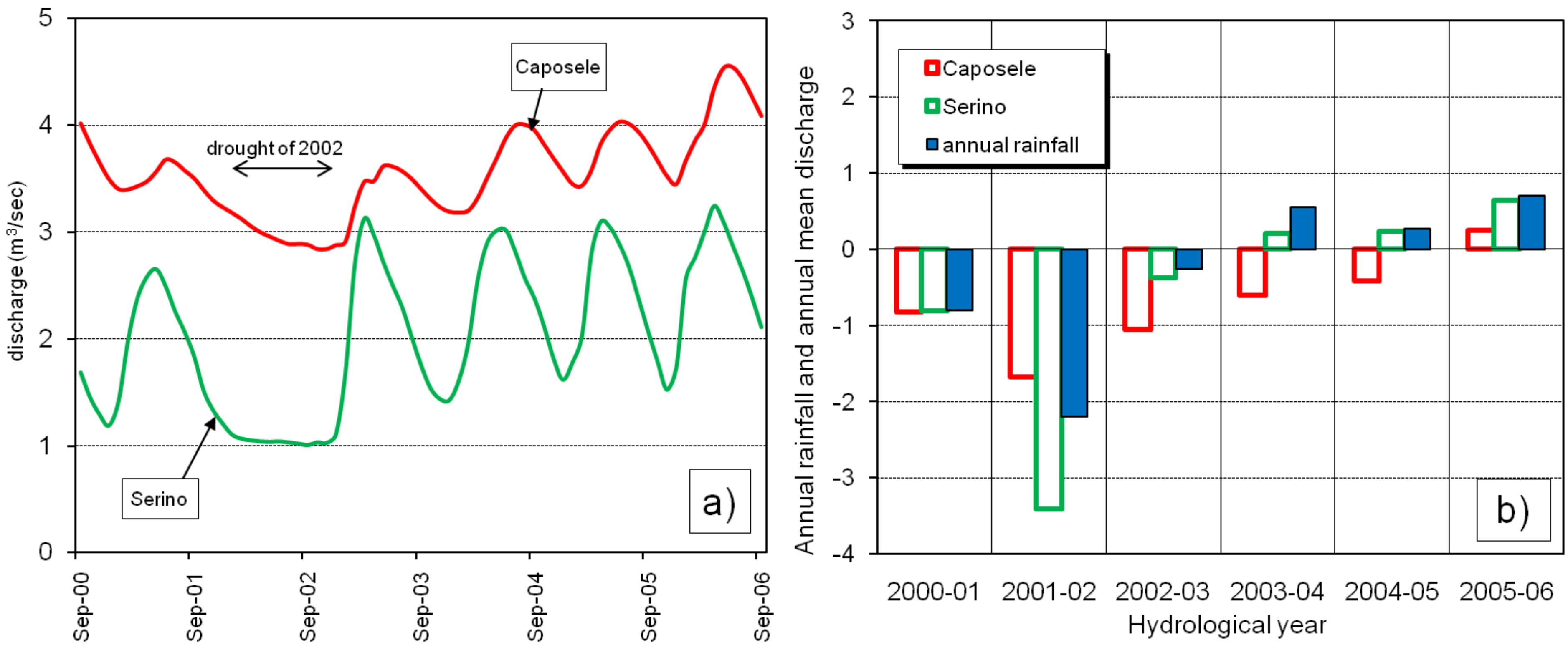
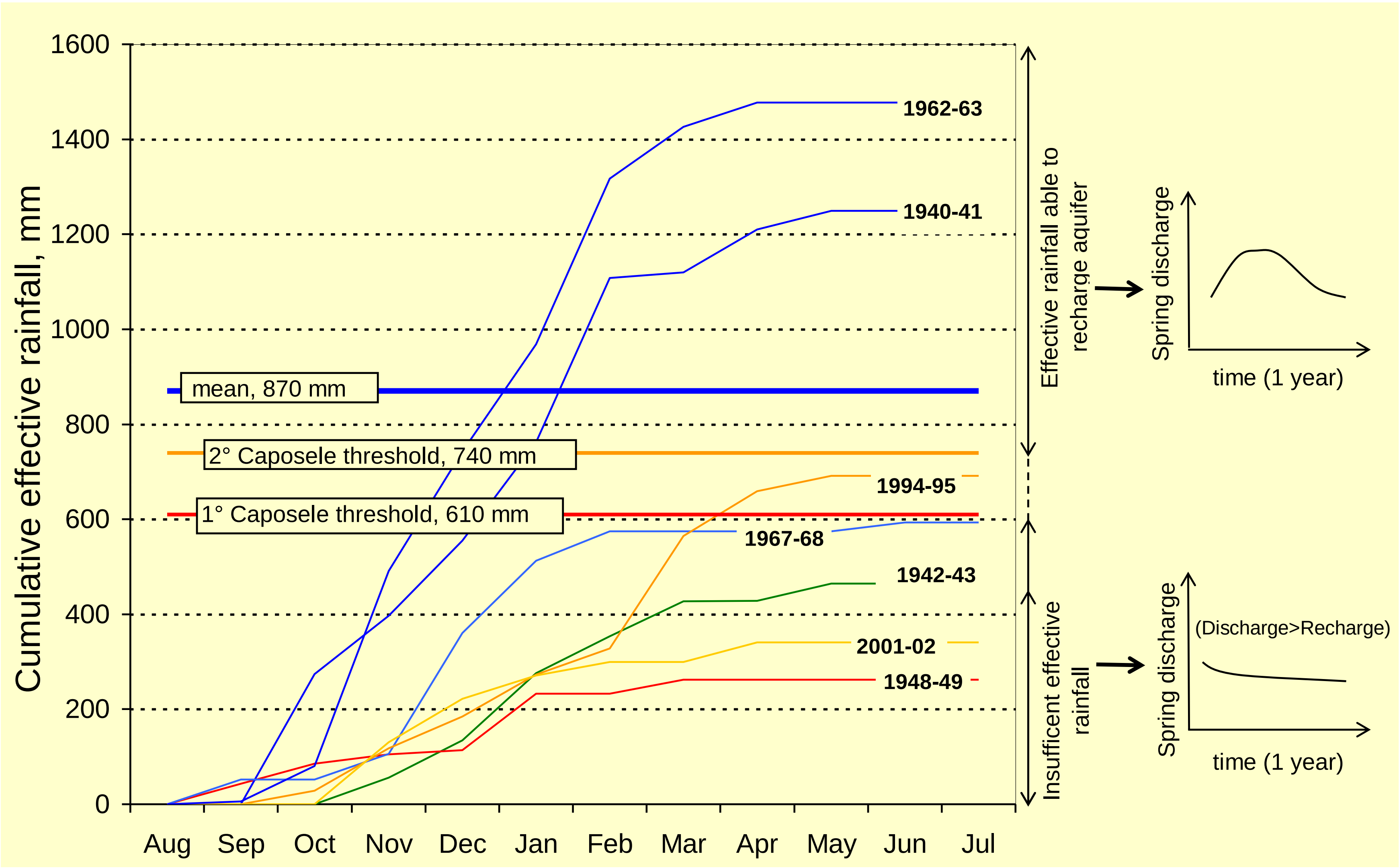
The effect of drought on the following years



Cumulative rainfall and spring hydrograph shape



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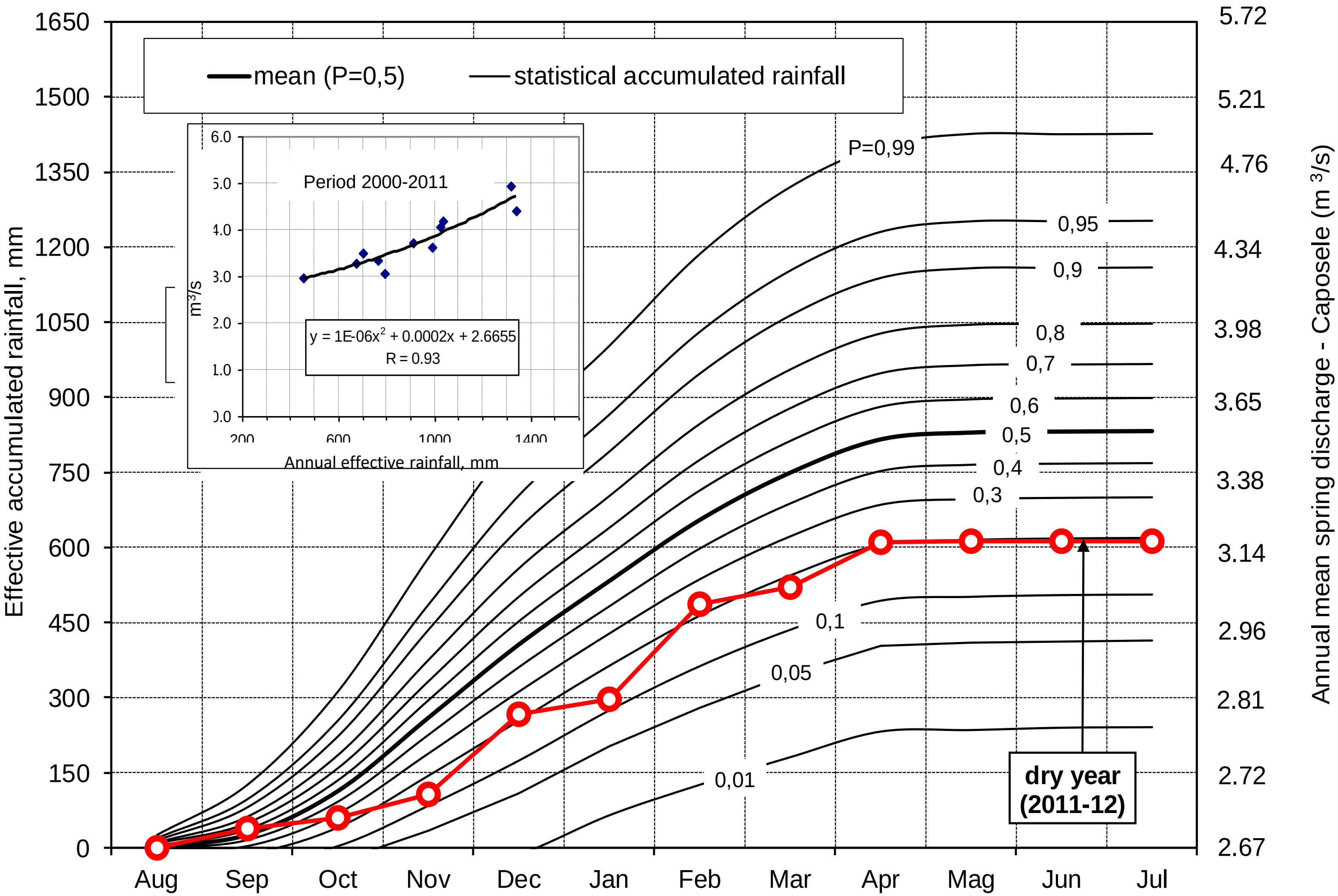
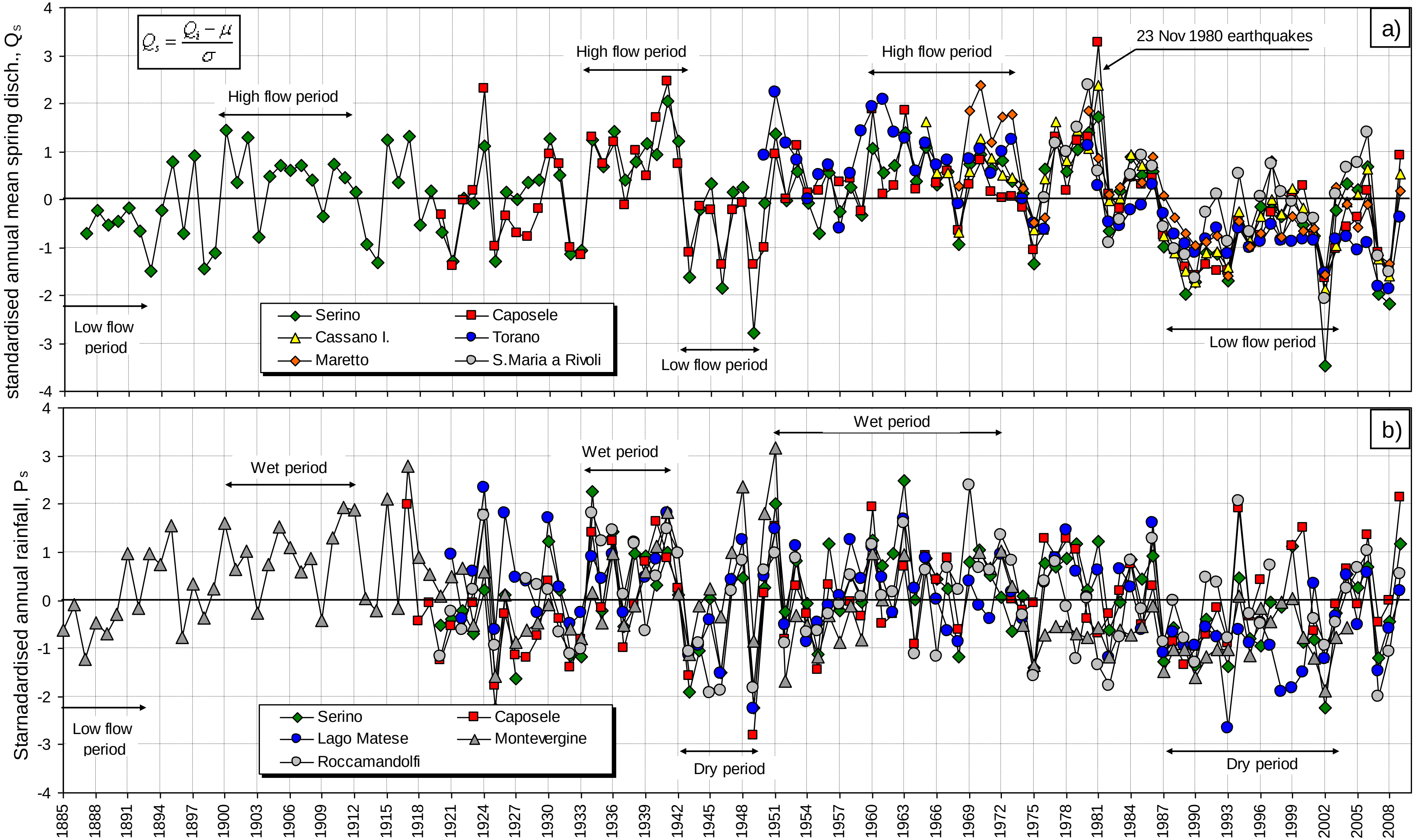
Statistical approach to forecast spring discharge

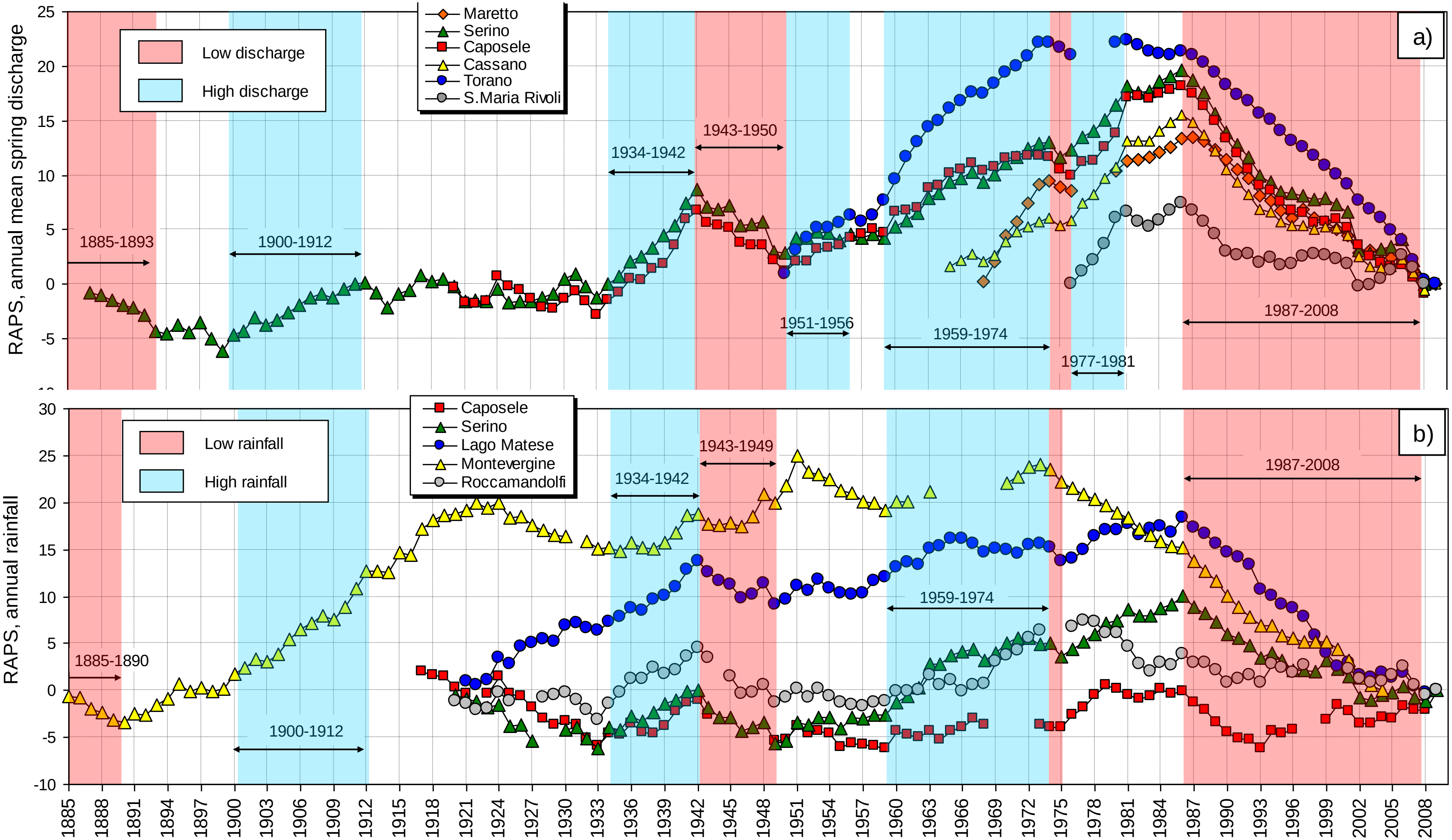


Trend and fluctuation of spring discharges and rainfall



Fiorillo F., Guadagno F.M. (2012) - *Long karst spring discharge time series ……* – Env. Earth Sciences

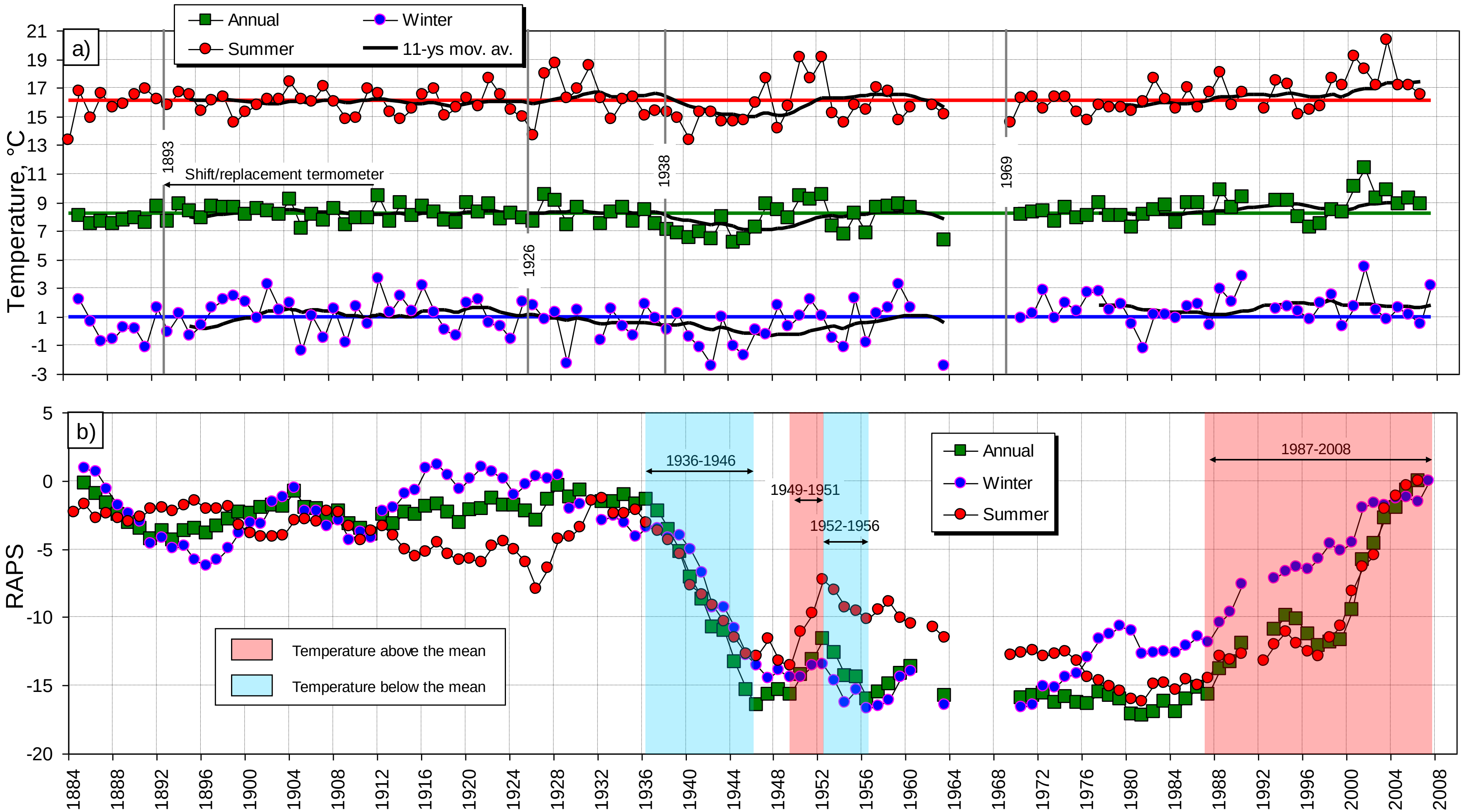
RAPS of time series (discharge and rainfall)



Fiorillo F., Guadagno F.M. (2012) - *Long karst spring discharge time series* …… – Env. Earth Sciences

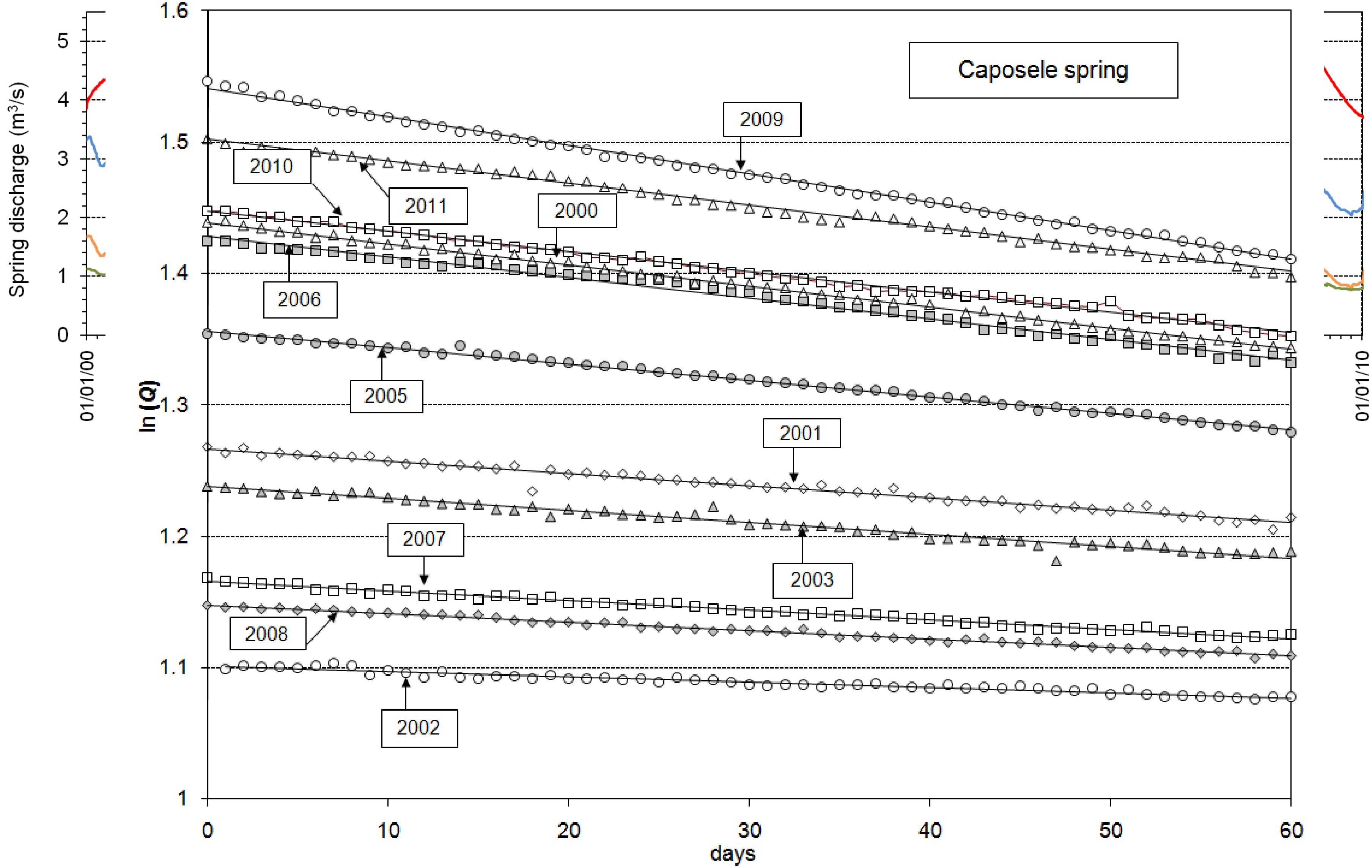
Temperature trend, Montevergine station, 1270 m a.s.l.

Period 1884 - 2008



Bucci et al. (2015) - *Winter survival of microbial contaminants in soil…* – J. Env. Sciences

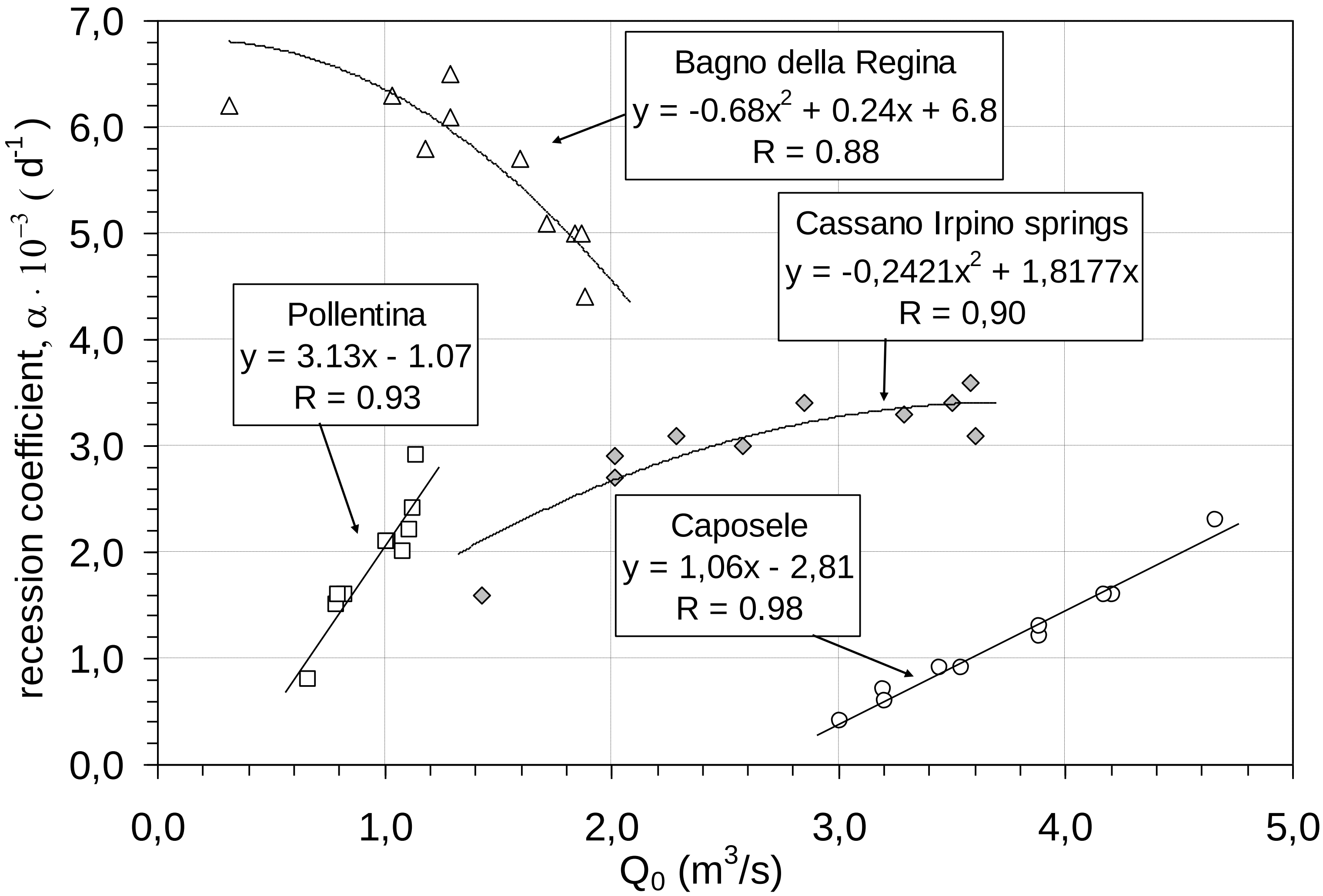
Aquifer behavior during dry periods (recession)



Fiorillo F., Revellino P., Ventafridda G. (2012) - *Karst aquifer drainage during dry periods*. J. of Cave and Karst Studies

Aquifer behavior during dry periods (recession)

dependence of the recession coefficient on Q_0



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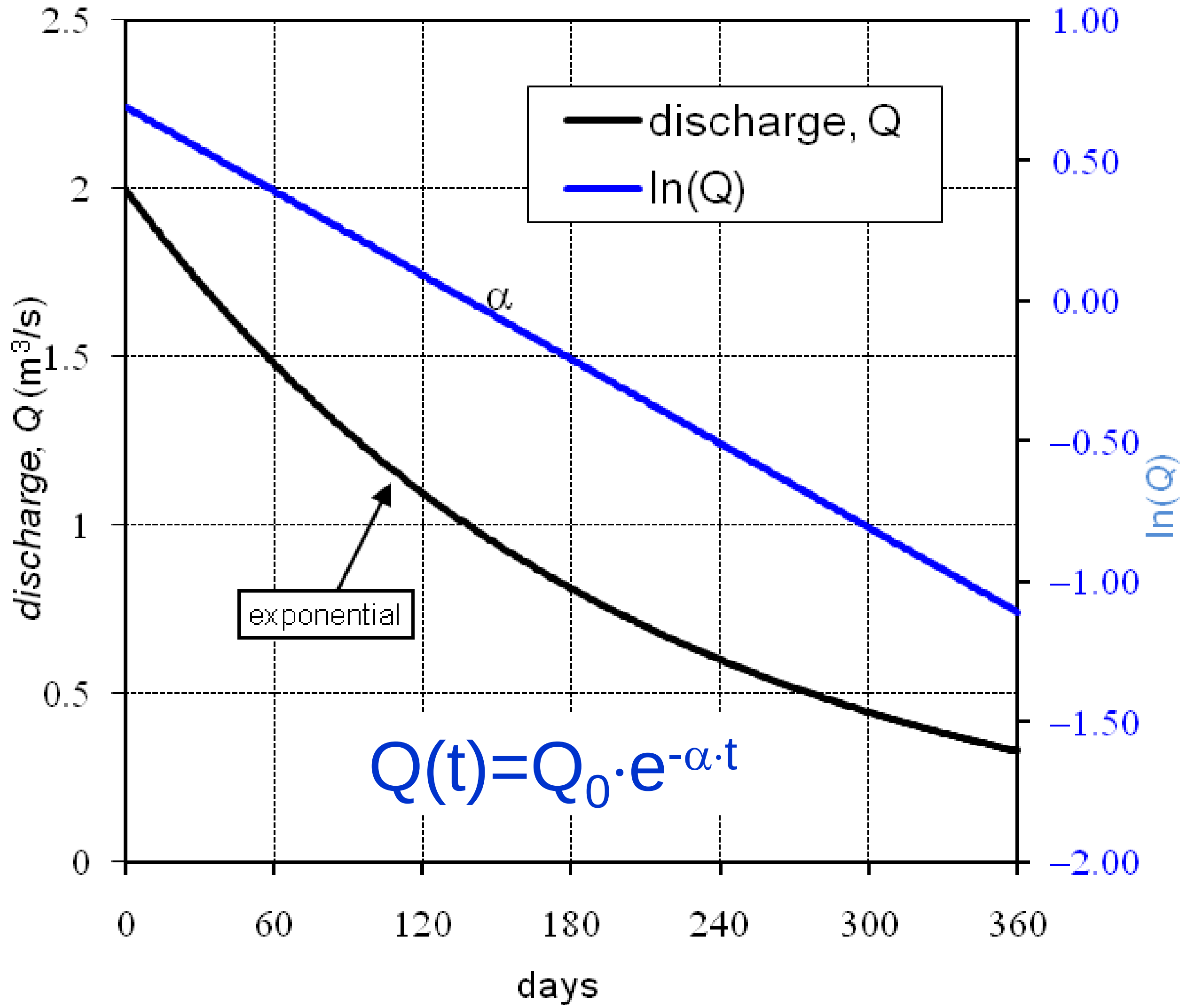
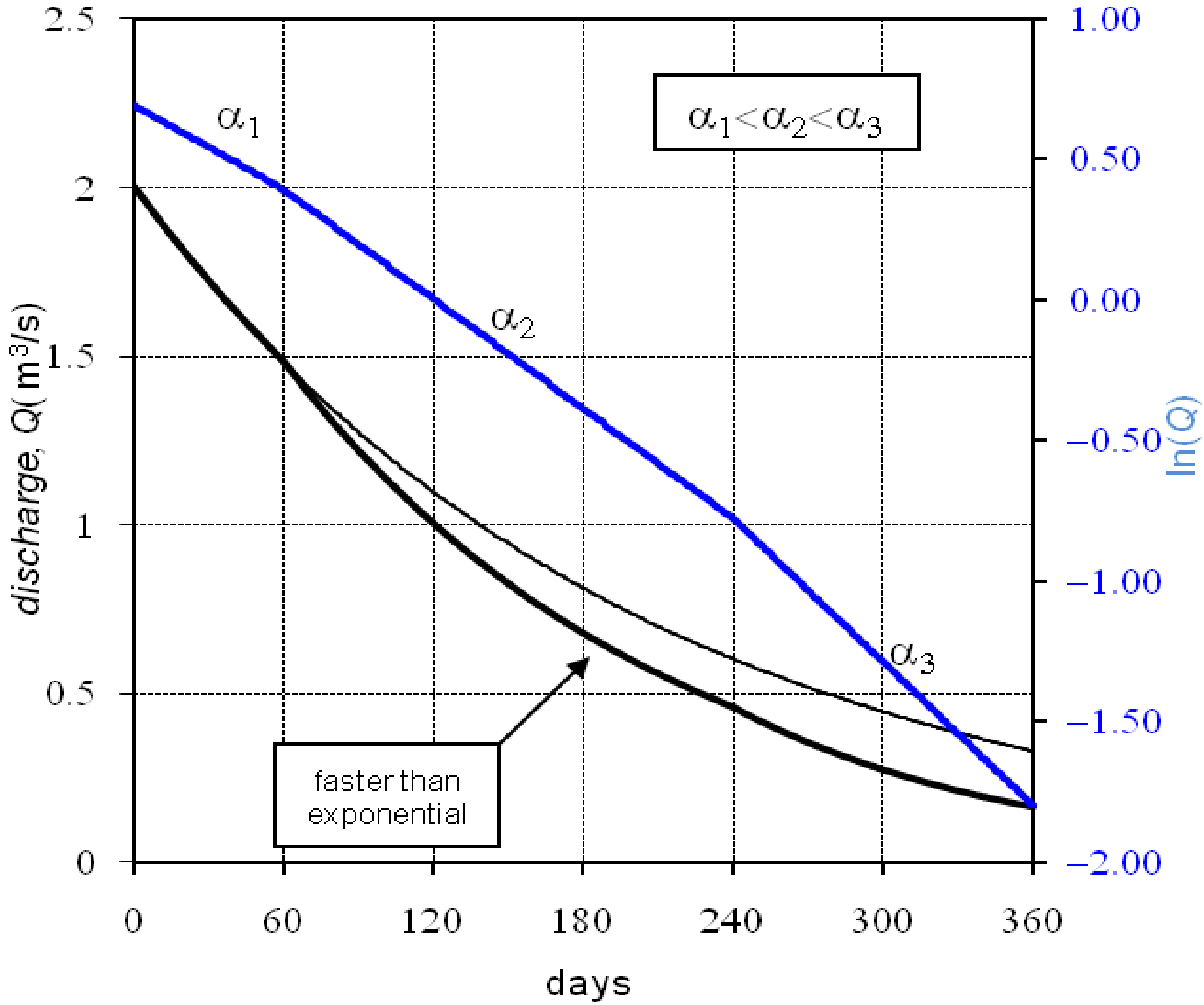
Aquifer behavior during dry periods (recession)



Fiorillo F., Revellino P., Ventafridda G. (2012) - *Karst aquifer drainage during dry periods*. J. of Cave and Karst Studies

Aquifer behavior during dry periods (recession)

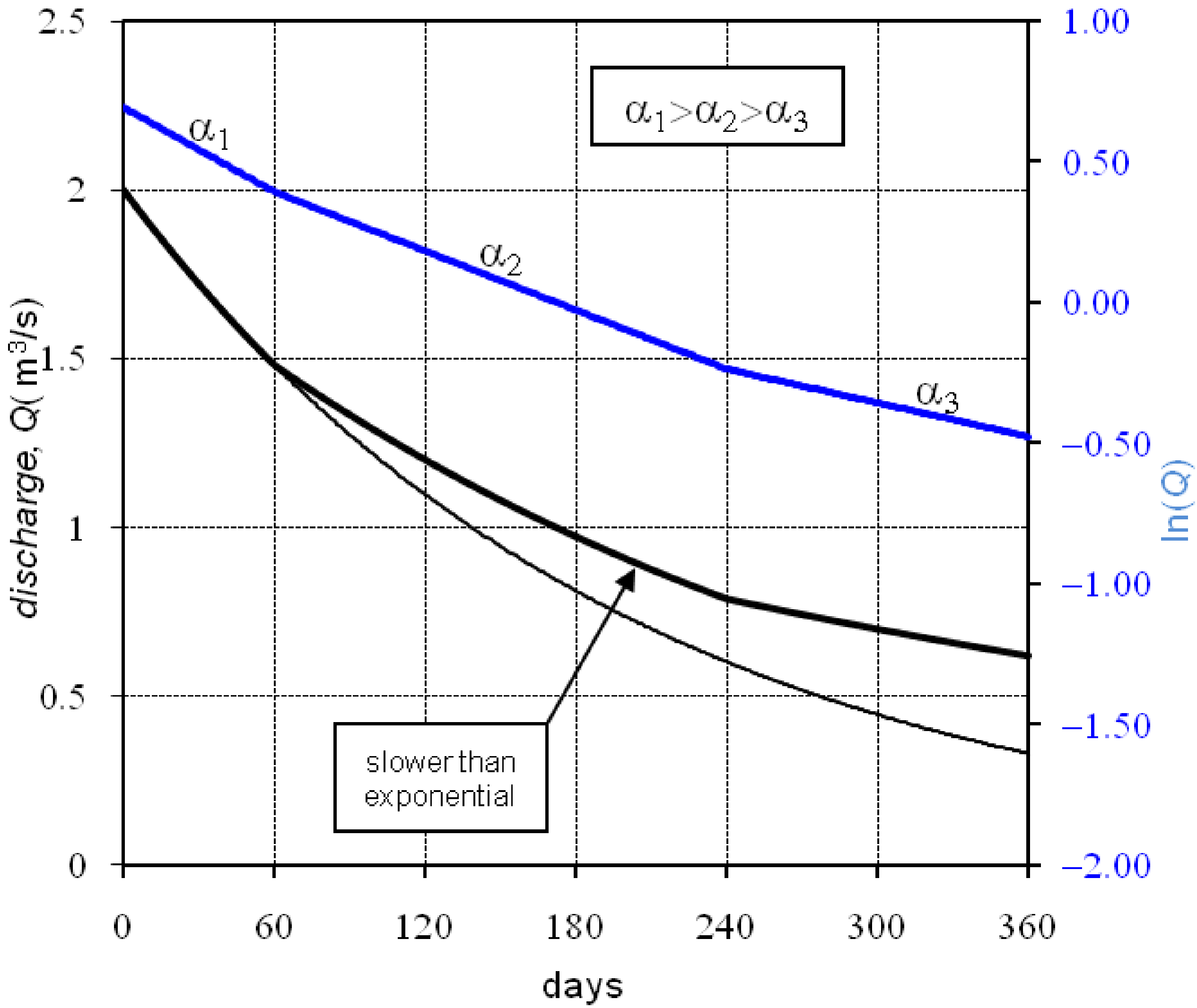
drought-vulnerable



Fiorillo F., Revellino P., Ventafridda G. (2012) - *Karst aquifer drainage during dry periods*. J. of Cave and Karst Studies

Aquifer behavior during dry periods (recession)

drought-resistant



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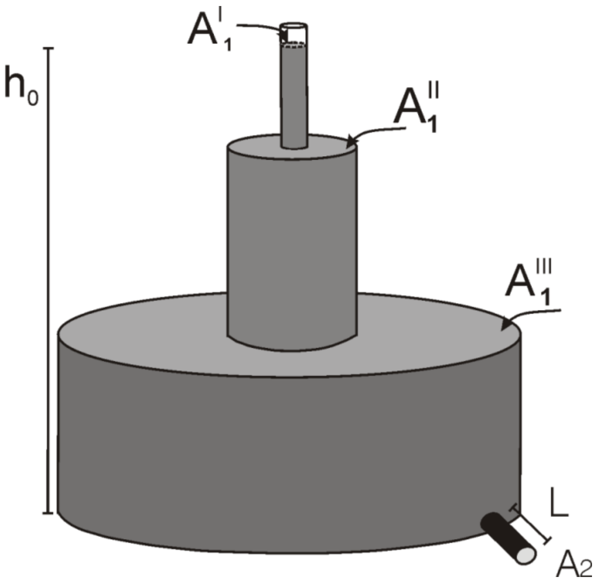
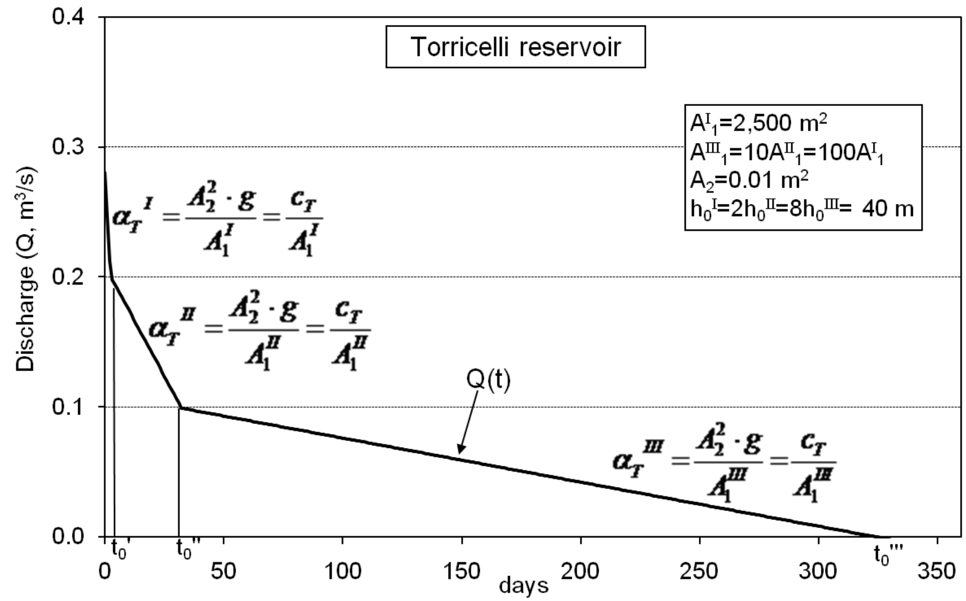
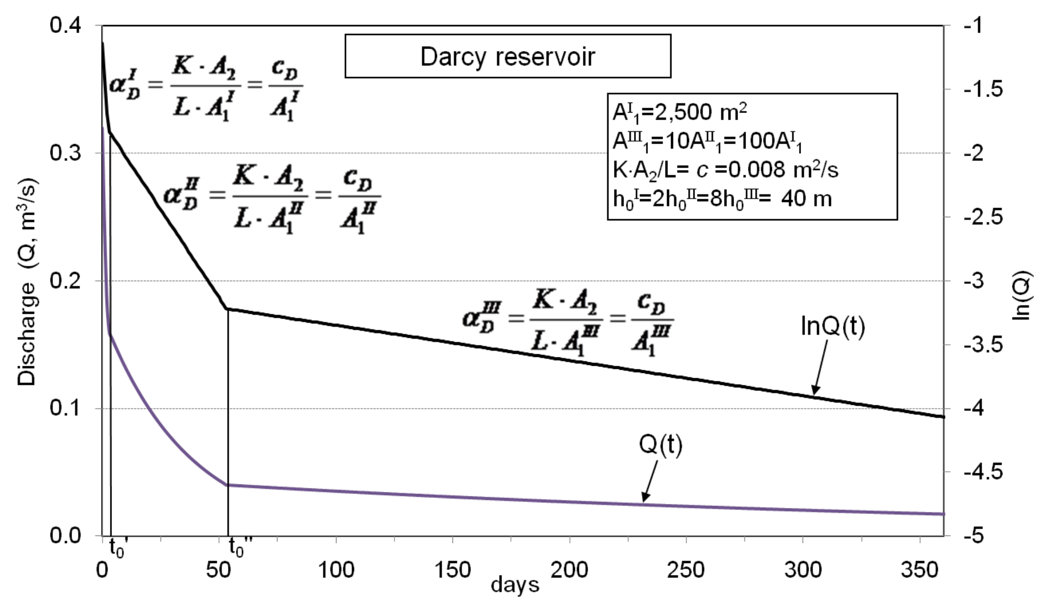
Drainage of a composite cylindrical tank-reservoir







Independent of the model used, the following relationship can be deduced:

$$\frac{\alpha^I}{\alpha^{II}} = \frac{A_1^{II}}{A_1^I} \qquad \frac{\alpha^{II}}{\alpha^{III}} = \frac{A_1^{III}}{A_1^{II}}$$

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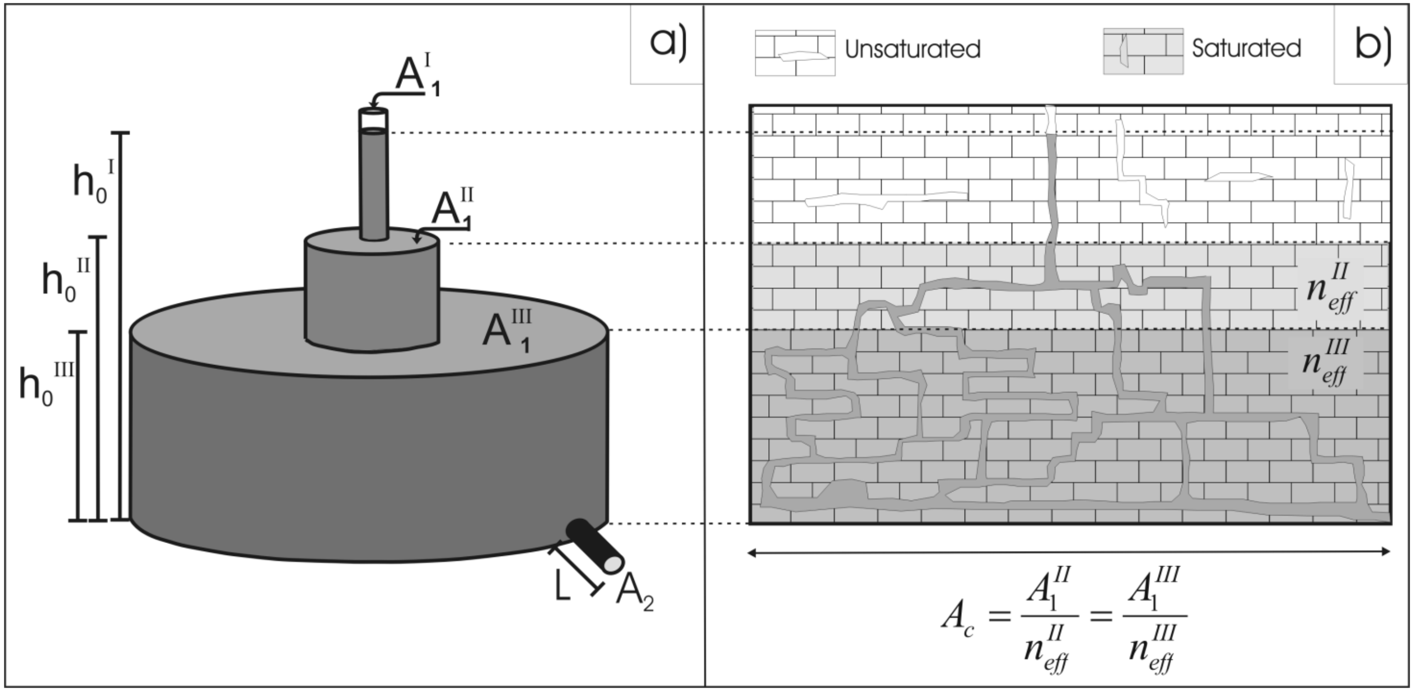
From the composite tank-reservoir to karst aquifers



composite tank-reservoir

karst aquifer

$$\frac{\alpha^{II}}{\alpha^{III}} = \frac{A_1^{III}}{A_1^{II}}$$

Torricelli law

$$\frac{\alpha^{II}}{\alpha^{III}} = \frac{A_c \cdot n_{eff}^{III}}{A_c \cdot n_{eff}^{II}} = \frac{n_{eff}^{III}}{n_{eff}^{II}}$$

Darcy/Poiseuille law

$$\frac{\alpha^{II}}{\alpha^{III}} \approx \frac{n_{eff}^{III}}{n_{eff}^{II}}$$

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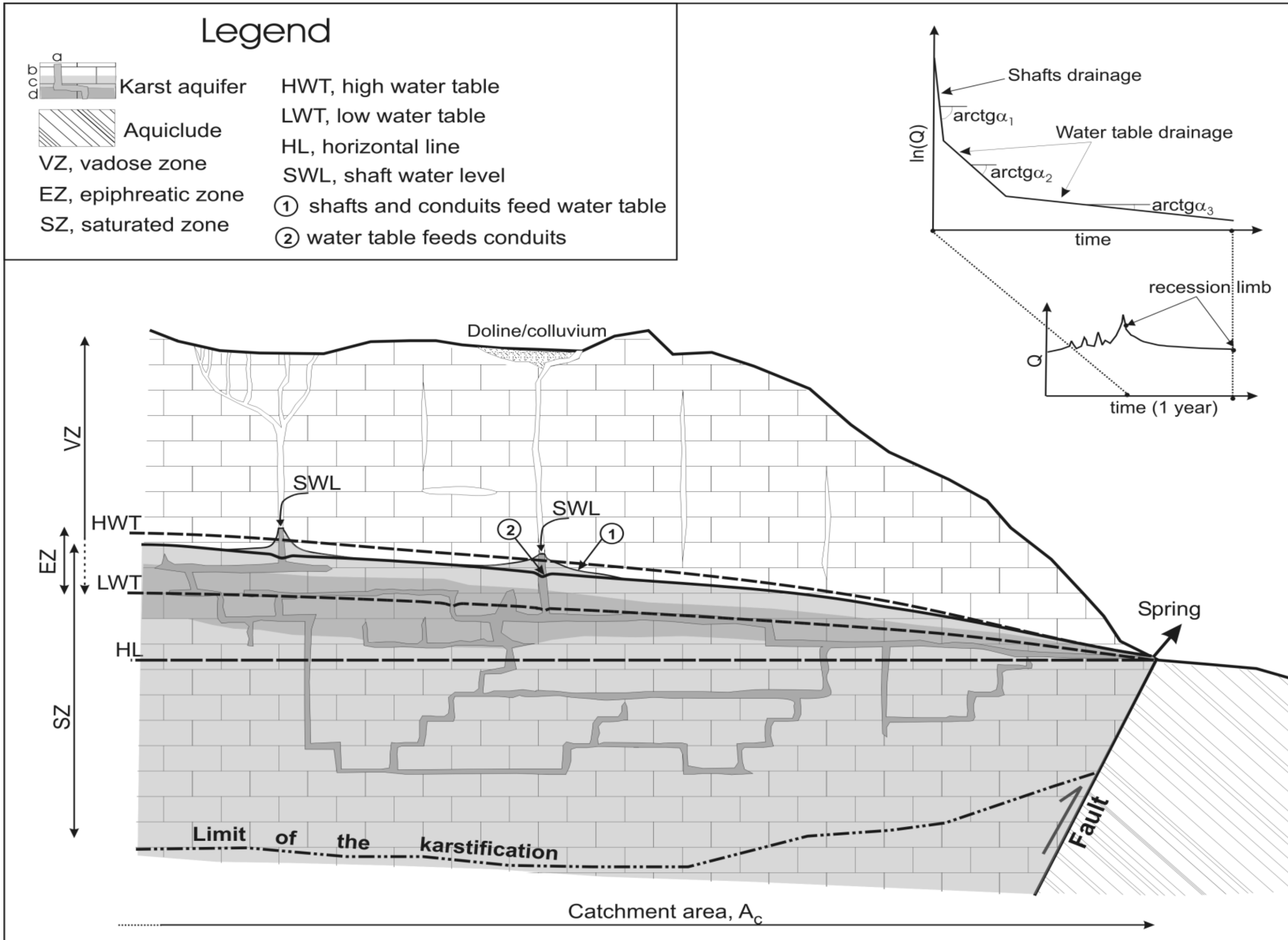
Example of a karst aquifer, tectonically bounded by impervious terrains

Conduits, shafts, vadose zone and saturated zone with different effective porosity are shown



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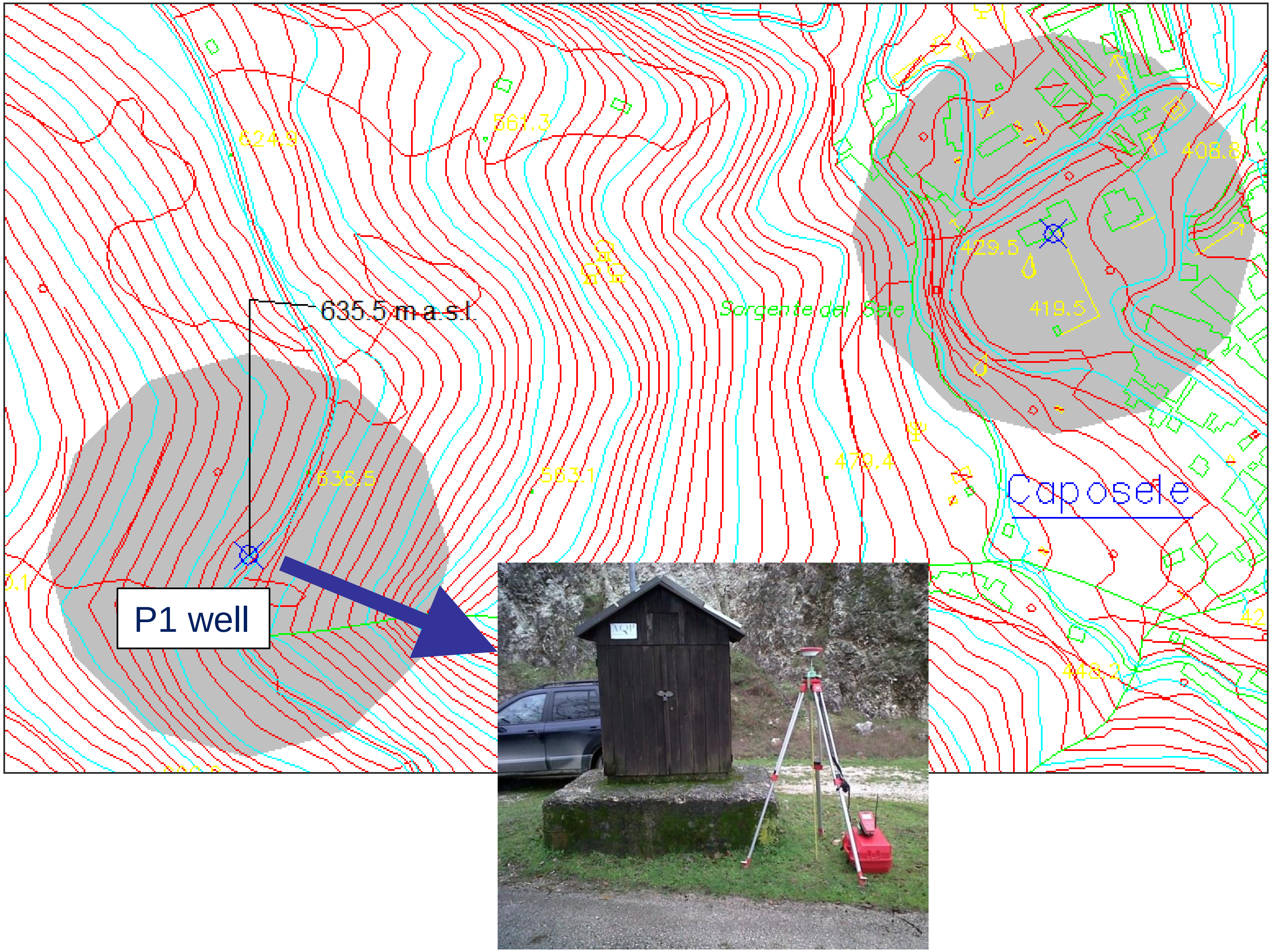
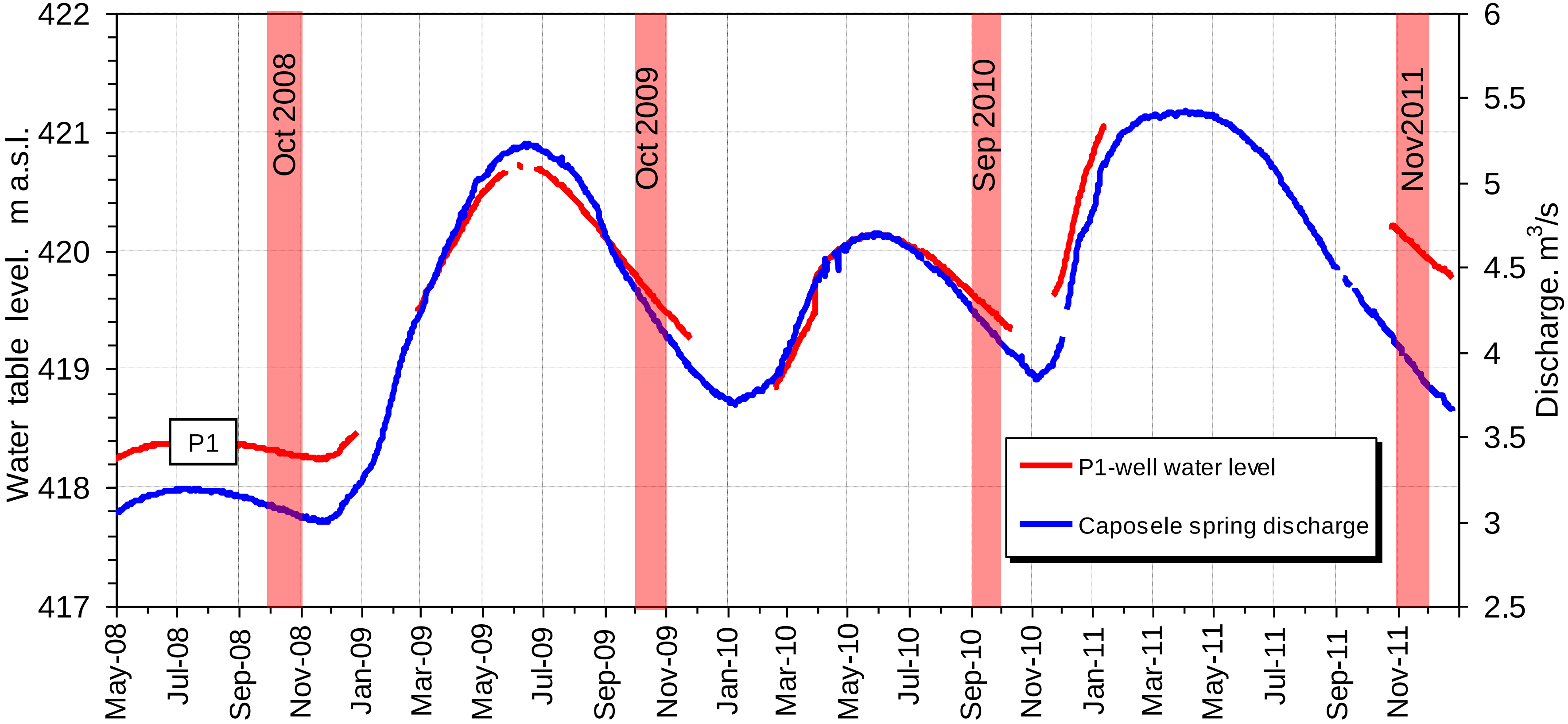
Caposele spring discharge and water level monitored in well P1



Caposele spring discharge and water level monitored in well P1



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Caposele spring discharge and water level monitored in well P1

Recession period	Discharged water volume at spring D_w ($m^3 \times 10^6$)	Water level decrease in P1 ΔL (cm)	Discharged volume for unit of water level decrease $V_w = D_w/\Delta L$ ($m^3/cm \times 10^6$)
October 2008	8,2	6	1,37
October 2009	11,3	31	0,36
September 2010	10,8	24	0,45
November 2011	9,8	23	0,43

Caposele spring discharge and water level monitored in well P1

Check the formula $$\frac{\alpha^{II}}{\alpha^{III}} \approx \frac{n_{eff}^{III}}{n_{eff}^{II}}$$

2008 and 2009 years

$$\frac{n_{eff\,(2008)}}{n_{eff\,(2009)}} \approx \frac{V_{w(2008)}}{V_{w(2009)}} = \frac{1.37 \times 10^6}{0.35 \times 10^6} = 3.91 \qquad \frac{n_{eff(2008)}}{n_{eff(2009)}} \approx \frac{\alpha_{(2009)}}{\alpha_{(2008)}} = \frac{0.00230}{0.00060} = 3.83$$

2010 and 2011 years

$$\frac{n_{eff(2010)}}{n_{eff(2011)}} \approx \frac{V_{w(2010)}}{V_{w(2011)}} = \frac{0.45 \times 10^6}{0.43 \times 10^6} = 1.05 \qquad \frac{n_{eff(2010)}}{n_{eff(2011)}} \approx \frac{\alpha_{(2011)}}{\alpha_{(2010)}} = \frac{0.00170}{0.00160} = 1.06$$

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Recharge processes in the spring catchment (Cervialto massif)

Estimation of the long-term recharge (ratio between discharge volume and rainfall on the catchment)

Then, a daily recharge model, calibrated on the previous annual scale estimation, allows to simulate the recharge and the runoff at daily scale

The model have to distinguish the *endorheic areas* (closed morphological zones, where runoff cannot escape from the spring catchment) from the rest of the catchment (*open areas*)

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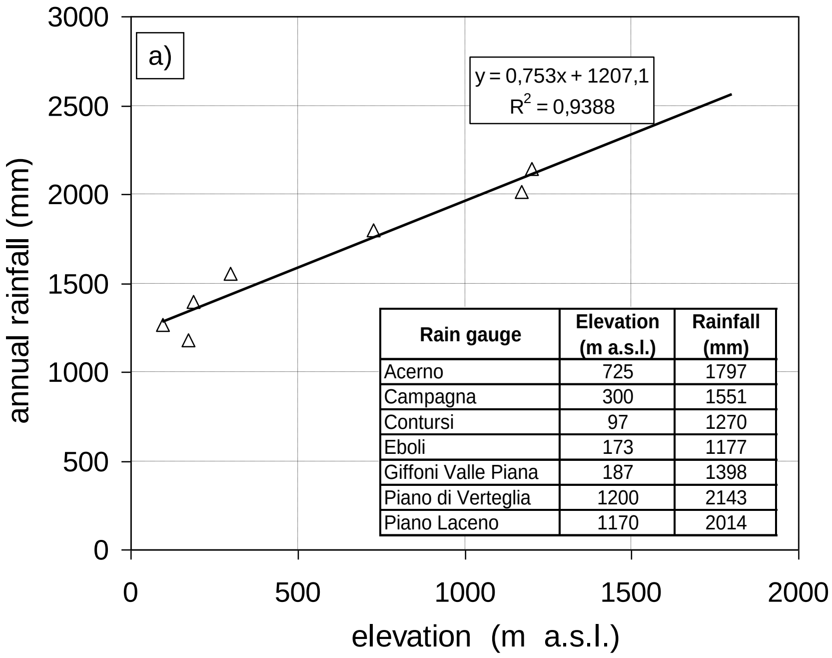
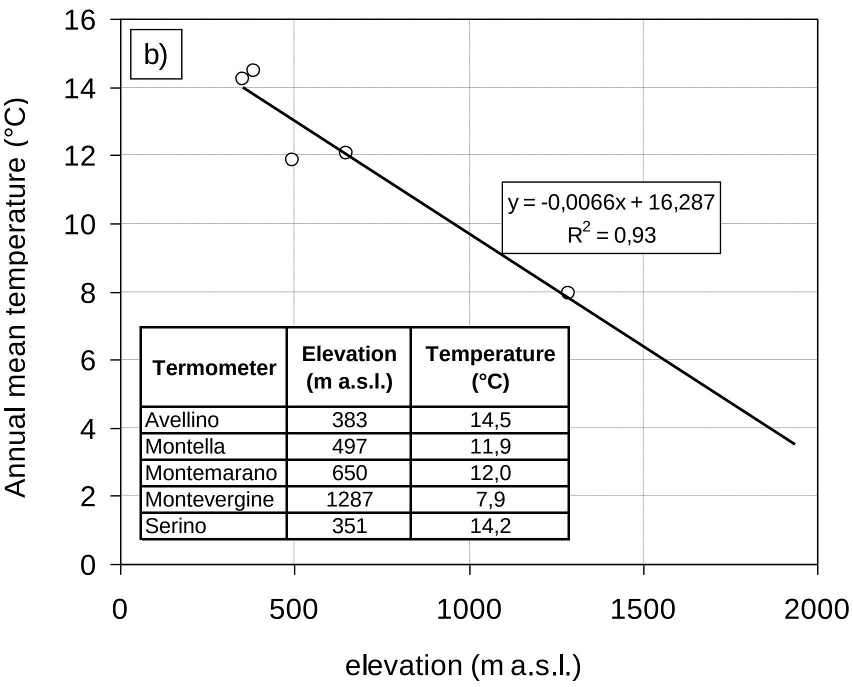
Annual mean rainfall and annual mean temperature in relation to ground-elevation

period 1970 - 1999



Rain gauge	Elevation (m a.s.l.)	Rainfall (mm)
Acerno	725	1797
Campagna	300	1551
Contursi	97	1270
Eboli	173	1177
Giffoni Valle Piana	187	1398
Piano di Verteglia	1200	2143
Piano Laceno	1170	2014

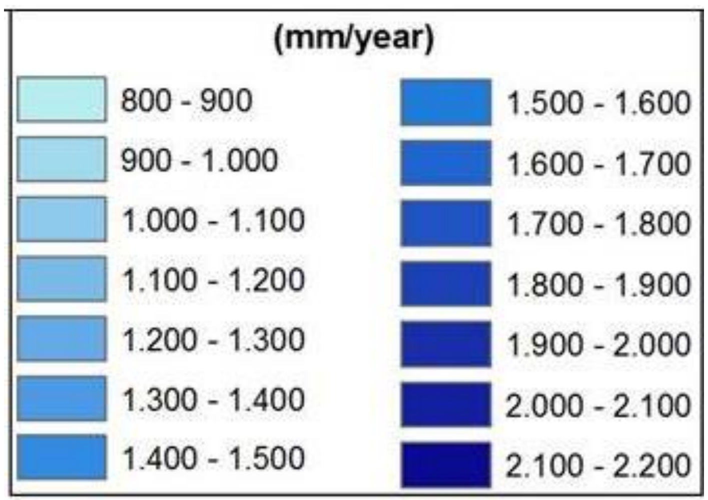


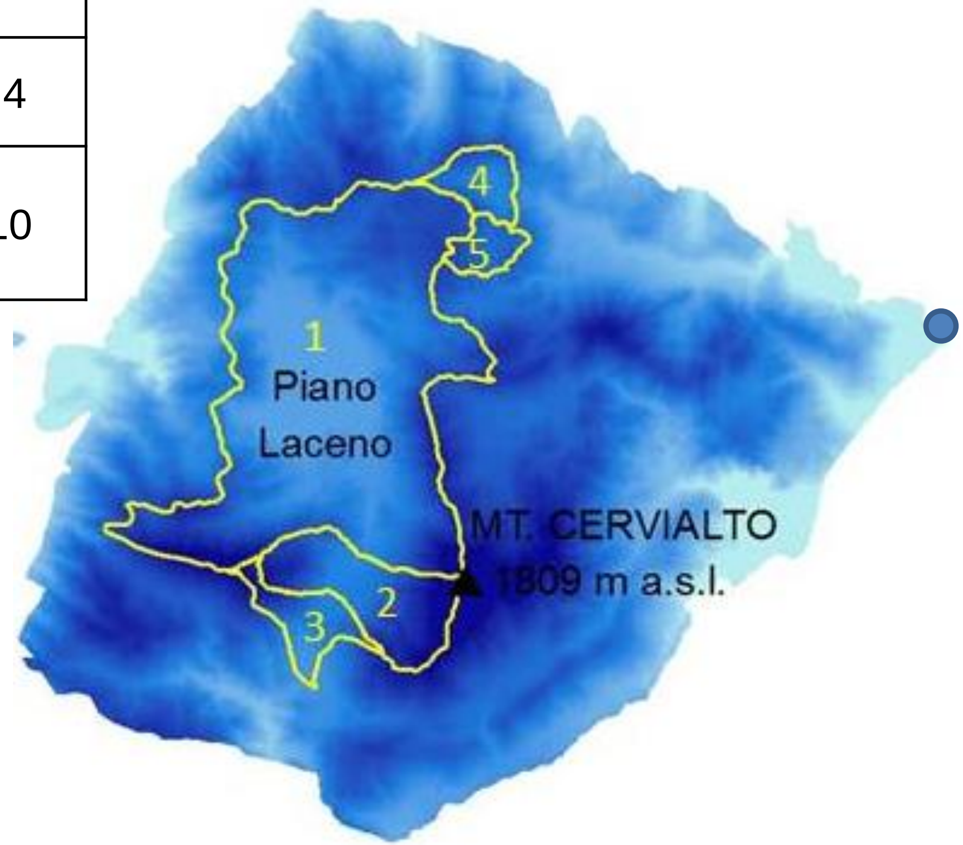
Termometer	Elevation (m a.s.l.)	Temperature (°C)
Avellino	383	14,5
Montella	497	11,9
Montemarano	650	12,0
Montevergine	1287	7,9
Serino	351	14,2

Main hydrological features of the Cervialto massif

long-term annual values

		Mean	Max	Min
Mt. CERVIALTO (spring catchment)	Elevation *m (a.s.l.)*	1179	1809	417
	Afflux *mm/year*	2109	2621	1529
	Temperature *°C*	8,5	13,5	4,4
	Actual evapotr. *mm*	529	688	410





Main hydrological parameters estimation (*long-term annual scale*)

effective afflux, F_{eff}, in a specific area, *A*

$$\left(F_{eff}\right)_A = \frac{\sum_1^n P_{eff}}{n} \times A$$

recharge amount, *R*, in endorheic area, A_E

$$\left(R\right)_{A_E} = \left(F_{eff}\right)_{A_E}$$

recharge in the open areas, $(R)_{Ao}$,

$$\left(R\right)_{Ao} = Q_s - \left(F_{eff}\right)_{A_E}$$

<u>effective recharge coefficient</u>, C_R

$$(C_R)_{A_O} = \frac{\left(R\right)_{A_O}}{(F_{eff})_{A_O}}$$

$$(C_R)_{A_E} = 1$$

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Main hydrological parameters of Cervialto catchment

Springs			Massif	Area	Item	Elevation (minimum) m a.s.l.	km^2	F $m^3 \times 10^6$	F_{eff} $m^3 \times 10^6$	RO $m^3 * 10^6$	Q_p $m^3 \times 10^6$	R $m^3 \times 10^6$	C_R
Group	m^3/s	$m^3 \times 10^6$											
Caposele	3,96	128,5	Cervialto	Piano Laceno	1	1047	20,5	43,8	32,9	0,0	0,0	32,9	1
				Piano Acernese	2	1168	3,3	7,4	5,8	0,0	0,0	5,8	1
				Piano dei Vaccari	3	1164	1,4	3,0	2,3	0,0	0,0	2,3	1
Bagnoli Irpino	0,07			Valle Rotonda	4	1156	1,1	2,3	1,8	0,0	0,0	1,8	1
				Raia dell'Acera	5	1246	0,7	1,5	1,2	0,0	0,0	1,2	1
				Closed areas, A_E	-	-	27,0	58,0	44	0,0	0,0	44,0	1
Others	0,10			Open areas, A_O	-	-	83	172,4	128,3	43,8	0,0	84,5	**0,66**
				Springs catch., A_C	-	-	110	230,4	172,3	43,8	0,0	128,5	0,75

F, afflux
F_{eff}, effective afflux
RO, run off;

Q_P, groundwater abstracted
R, recharge
C_R, effective recharge coefficient

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Daily scale model of the recharge

$$P_i = AET + \Delta\theta + Pexc$$

- excess rainfall, P_{exc}=daily recharge + daily runoff
- daily runoff occurs if P_{exc} exceeds a specific threshold values at daily scale
- the threshold is deducted from the long term annual scale : $(C_R)_{Ao} = \Sigma(R)_{Ao} / \Sigma P_{exc}$

The model generally needs:
- the thickness of the soil which is undergoing evapotranspiration processes, H;
- the (volumetric) water content at field capacity, Θ_{max};
- the minimum water content reached at the end of dry season (summer), Θ_{min};
- the total and effective porosity of the soil.

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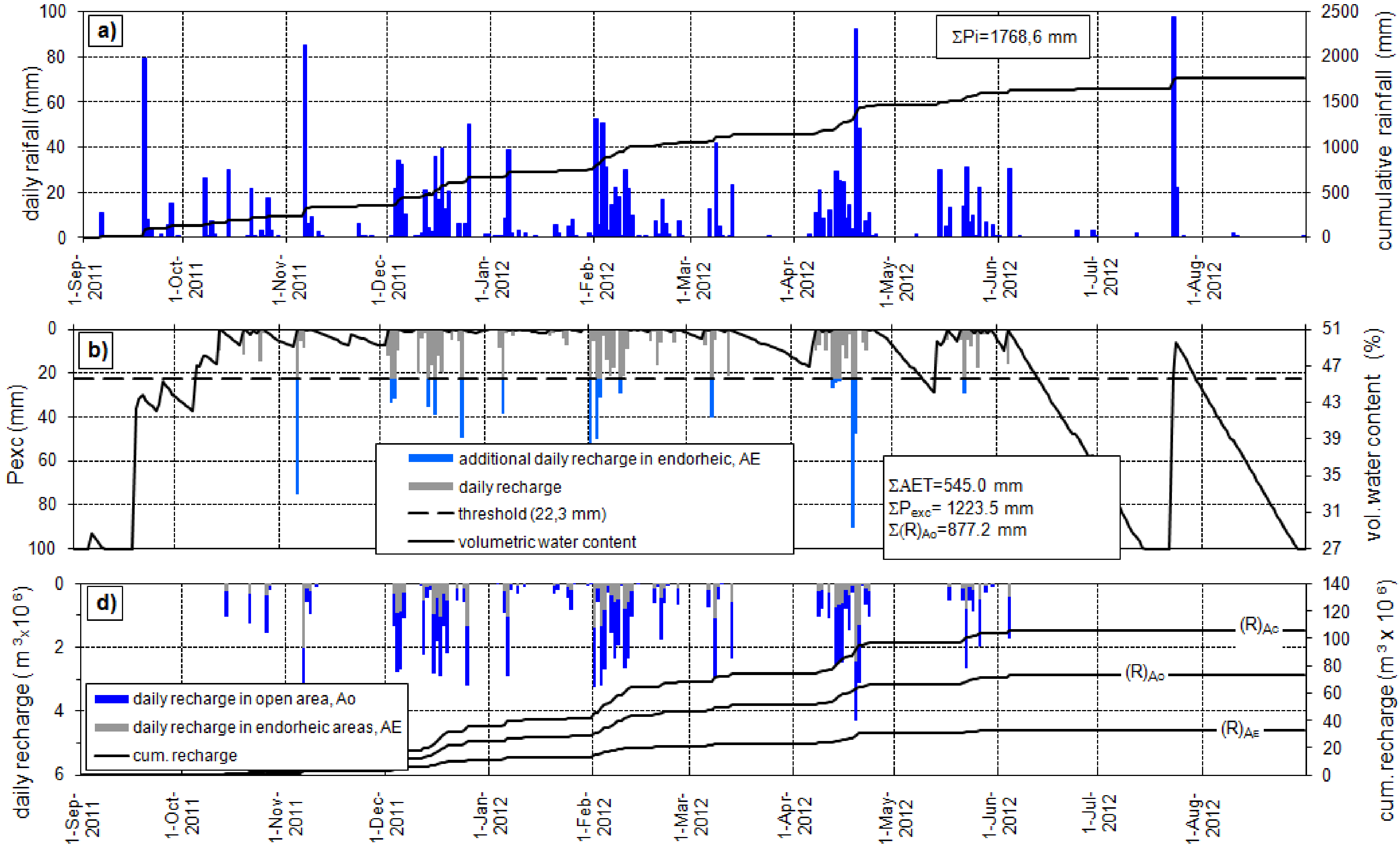
Daily scale recharge model, Mt. Cervialto catchment



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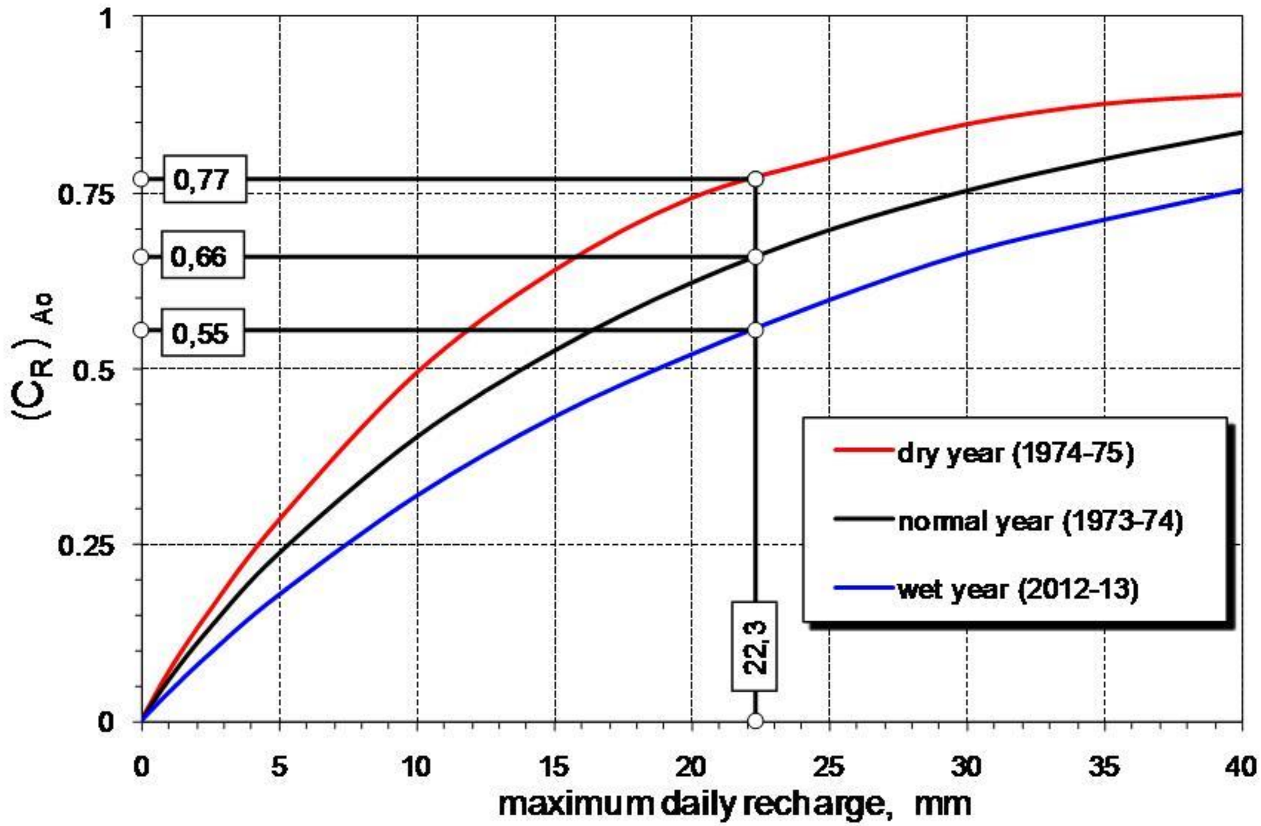
Recharge coefficient for open areas, $(C_R)_{Ao}$

function of threshold of daily recharge, for different hydrological years



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Conclusions

- Caposele spring is a fundamental water resource in southern Italy
- two hydrogeological aspects enhance its usability: absence of peaks (as a typical porous medium) and the regime almost opposite to that of precipitation
- drought reduces the discharge of following years as well, highlighting a memory effect of the aquifer
- the spring is *drough-resistant*, as the (exponential) recession coefficient decreases when initial discharge(Q_0) also decreases
- as the spring catchment is not interested by pumping (groundwater abstraction) and its environment is almost unchanged during the last century, spring discharge is a powerful indicator of climate

Aspetti idrologici ed idrogeologici della sorgente Sanità di Caposele, alimentante l'Acquedotto Pugliese

Hydrological and hydrogeological features of the Sanità spring of Caposele, Southern Italy, which feeds the Pugliese aqueduct

Grazie!

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Caposele spring, tapping zone