



Identifying distributions of response times in karst aquifers

Fulvio BOANO, Alberto VIGLIONE, Bartolomeo VIGNA

Politecnico di Torino

DIATI - Department of Environment, Land and Infrastructure Engineering, Torino, Italy



Aim & motivation



- Structure of karst aquifer \rightarrow pattern of water flow \rightarrow response time distribution f(t)
- The response time distribution *f(t)* summarizes the time(s) after which a recharge input induce a discharge output
- Monitoring <u>spring discharge (Q)</u> & <u>recharge (I)</u> can provide <u>f(t)</u> ... but robust methods are needed





Geostatistical approach





• The integral is discretized in matrix form as:

$$Q_i = H_{ij} \, \mathbf{f}_j + \varepsilon_i$$

- where: Q_i = observed discharge at time t_i (known)
 - f_j = value of <u>response time pdf</u> for response time τ_j (unknown \rightarrow <u>this is what we find using the method</u>!)
 - ε_i = random measurement error at time t_i (assumed to be normally distributed)

 $H_{ij} = \varphi A h(t_i - \tau_j)$ depends on known quantities: $h(t_i - \tau_j)$ is rainfall height at time $t_i - \tau_j$

- arphi is the runoff coefficient
- A is the catchment recharge area



Geostatistical approach (2)

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 $Q_i = H_{ij} \, \frac{f_j}{f_j} + \varepsilon_i$

- ASSUMPTION: the family of possible solutions for *f*(*t*) is given by random functions with the following statistical structure:
 - > At each instant, values of f(t) follow a random (Gaussian) distribution
 - > For different instants, values of f(t) are statistically correlated $\rightarrow cov(t_i, t_j) = \sigma^2 \cdot e^{-\left(\frac{t_i t_j}{l}\right)^2}$
- CONSEQUENCE: possible values of Q(t) are also random functions (with known statistical structure)
- SOLUTION: the random functions are conditioned to the observations to estimate:
 - 1. the expected values of f(t)
 - 2. the 95% confidence interval





Results: different among catchments



• Comparison among karst systems (Northwestern Italy):

VENE system

(highly karstified, mainly large fissures)







BOSSEA system

(less karstified, more complex environment)



Results: differences among seasons

• Comparison **among different seasons** for the Bossea system:



Faglie verticali Succes carbor	ssione latica
vulcaniti	quarziti
	Ingresso Grotta di
vulcaniti	Bossea
1 180 G	Sau R

	Peak time (days)	Amplitude (days)
Spring	4 (range: 1-8)	11 (range: 5-25)
Summer	1.3 (range: 0-2)	5 (range: 3-7)

Wet season \rightarrow higher aquifer saturation

 \rightarrow activation of slower flowpaths

