Groundwater floods: linking the hydrodynamic characterization of the karst aquifer to the karst structure using statistical analysis of temperature: Case study on the Cadarache CEA center (South of France)

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Autors

Manon Erguy[1,2]
Sébastien Morilhat[2]
Guillaume Artigue[1]
Julien Trincal[2]
Anne Johannet[1]
Séverin Pistre[3]

(1) HydroSciences Montpellier (Univ. Montpellier, IMT Mines Alès, IRD, CNRS), 6 av. de Clavières, 30100 Alès, France
(2) CEA, Centre de Cadarache, 13108 Saint Paul Lez Durance cedex, France
(3) HydroSciences Montpellier (Univ. Montpellier, IMT Mines Alès, IRD, CNRS), Place Eugène Bataillon, 34095, France

References

Mangin, A., 1975. Contribution à l'étude hydrodynamique des aquifères karstiques (Thèse de doctorat, Sciences de la Terre). Université de Dijon.

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You can find the poster here:

QR CODE

Introduction – Study site

Objective: Improving the understanding of the Cretaceous karst aquifer by coupling statistical analyses of piezometry and temperature data

Study site: the *Cadarache* center of the French Alternative Energies & Atomic Energy Commission

- **Geological context**: outcropping Cretaceous limestone or covered by Miocene and Quaternary deposits
- **Structural context**: subvertical faults N045-060, N120-150 locally karstified
- **Hydrological context**: 3 aquifers Quaternary, Miocene, Cretaceous
- **Monitoring network**: 8 rain gauges, around 400 piezometers
- **Focus on the southern sector**: the most sensitive area to groundwater flooding → water level increase of 40 m

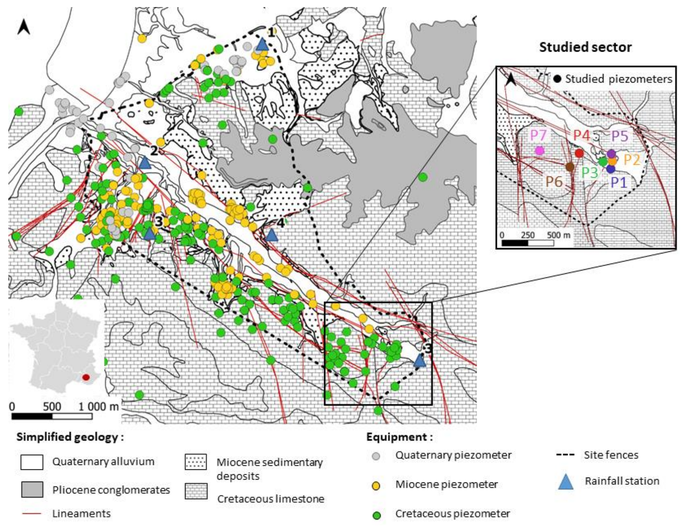


Fig. 1. Simplified geology of the *Cadarache* site and hydrological monitoring network

Material & methods

Statistical analyses:
Simple & cross-correlation

$$r_k = \frac{C_k}{\sigma_x \sigma_y} \quad \text{with :} \quad C_k = \frac{1}{n-k}\sum_{i=1}^{n-k}(x_i - \bar{x}).(y_{i+1} - \bar{y})$$

Where r_k: correlation coefficient; x,y: time series of the studied variable; $\bar{x}$ their mean; σ_x their standard deviation; n the number of samples; k is the discrete-time delay

Simple correlation: memory effect → r_k = 0.2, system inertia (Mangin, 1975)

Cross-correlation: memory effect & response times (1st peak on the correlogram) (Mangin, 1975)

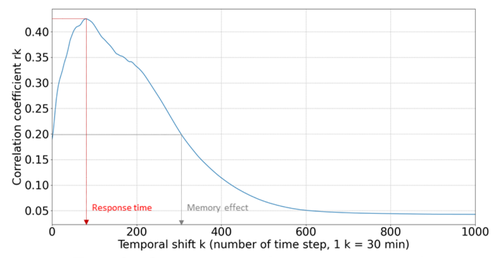


Fig. 2. Cross-correlogram example

Results & interpretations

Data visualization

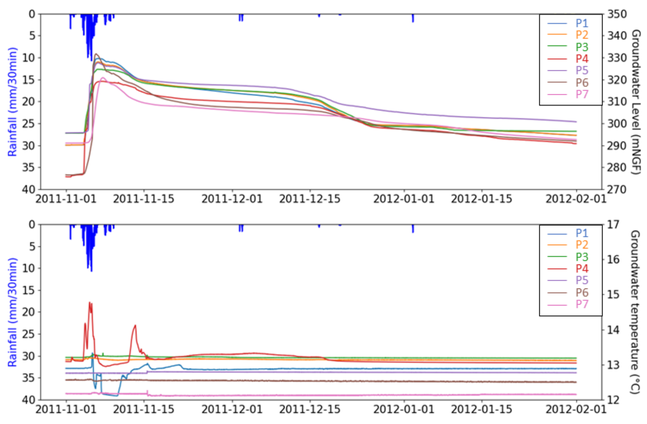


Fig. 3. Piezometric and temperature variations in the Cretaceous aquifer during the 2011 groundwater flooding

- Similar piezometric variations in the sector
- Very heterogeneous temperature variations: P5, P6, P7 do not react

Simple correlation

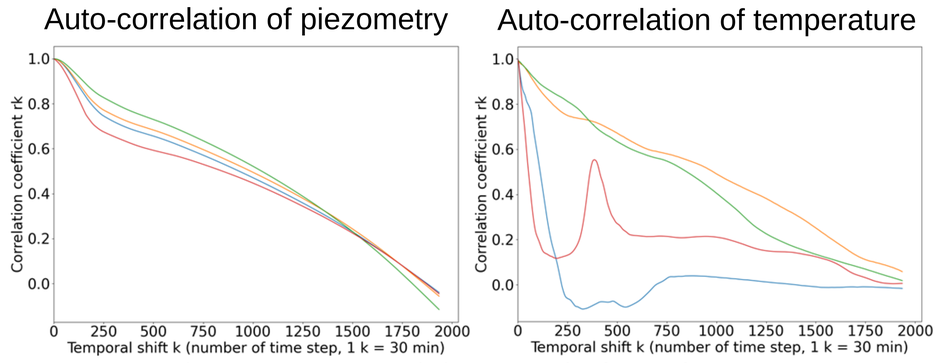


Fig. 4. Temperature and piezometry simple correlograms

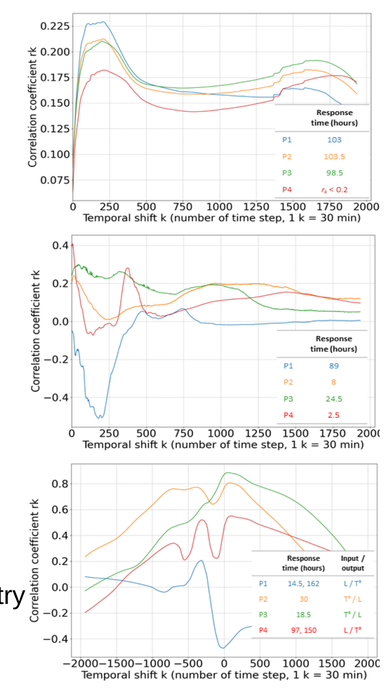
- Piezometry memory effect (around 33 days), temperature memory effect (between 2 and 30 days → heterogeneous)
- P1 and P4 show a complex evolution

Cross-correlation

Cross-correlation: rainfall / piezometry

Cross-correlation: rainfall / temperature

Cross-correlation: temperature / piezometry



Observations

For some piezometers: temperature data reacts before the piezometry (P2 response time of 30 h and of 18.5 h for P3)

For all the piezometers except P3 : complex phenomena in several stages are highlighted

Hypothesis

Mass transfer faster than the pressure one: lateral transfer comes first

Different delays regarding the inputs of the different continuum, piston effect…

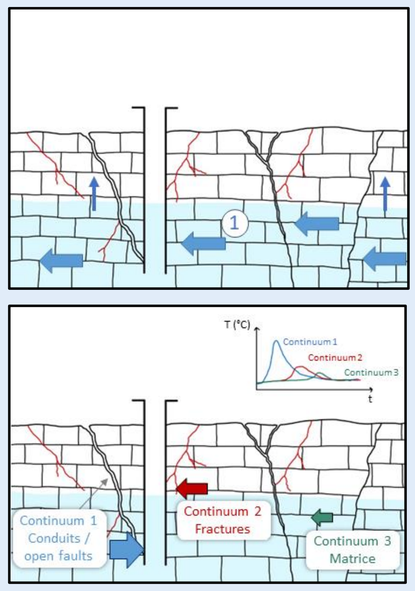


Fig. 5. Cross-correlations and hypothesis on the aquifer behavior

Conclusion

- Statistical analyses of aquifer temperature coupled with piezometer data can provide information on the dynamics of the system and the role of geological structures, as here, faults and fractures, constituting time-shifted inflows. The **multi-continuum** aspect of the system has been highlighted.
- Study is being extended to other rain events. The first results on the October-November 2019 and June 2015 episodes do not necessarily show a faster temperature response but always a temperature peak appearing before the piezometry peak. The temperature signal could be integrated into a model as a precursor of groundwater flooding.

Perspectives

For some piezometers, no temperature variations are observed: sensor problem, rainfall/aquifer temperature delta too low, or bad position of the sensor in a non transmissive zone

→ A study is currently underway with the installation of several sensors at different depths within several piezometers for:

- Verify the impact of censor depth on temperature data
- Identify potential water inflows and link them to karst structures.

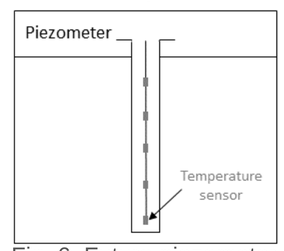


Fig. 6. Future piezometer equipment diagram

Contacts: manon.erguy@cea.fr, sebastien.morilhat@cea.fr, guillaume.artigue@mines-ales.fr, julien.trincal@cea.fr, anne.johannet@mines-ales.fr, severin.pistre@umontpellier.fr

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