

Master's Internship Project

Analysis of Long-Term Trends in Groundwater Quantity and Quality in French Karst Aquifers Using SNO Karst Data

Background

Karst aquifers are a strategic freshwater resource, supplying drinking water to approximately 9.2% of the world's population (Stevanović, 2019). These hydrosystems are increasingly affected by global changes, including hydroclimatic drivers (changes in precipitation regimes and temperature) and anthropogenic pressures (land-use change and groundwater abstraction). Compared with other types of aquifers, karst aquifers are more sensitive to climate change because of their rapid flow pathways, which respond strongly to variations in groundwater recharge. Improving our understanding of their long-term evolution is therefore essential to assess their vulnerability and support sustainable groundwater management.

Long-term observations at karst springs provide a robust empirical basis for analysing quantitative and qualitative changes in groundwater resources (Jeannin et al., 2016; Giese et al., 2025). In France, the SNO Karst (French National Karst Observatory) monitors karst springs distributed across contrasting geological, physiographic, hydroclimatic and land-use settings (Jourde et al., 2018). The discharge and physico-chemical time series collected within this network have recently been harmonized and published as a data paper (Cinkus et al., 2026), providing a reference database for nationwide trend analyses.

Objectives and Methodology

The objective of this internship is to analyse the hydrodynamic, physico-chemical and hydrochemical time series collected at the SNO Karst monitoring sites in order to identify the impacts of hydroclimatic changes and human activities on groundwater resources in karst aquifers.

To achieve this objective, the work will be organized into the following steps:

- 1) *Literature review*: review of studies investigating long-term trends in hydrodynamic, physico-chemical and hydrochemical parameters in karst aquifers.
- 2) *Data compilation*: construction of the study database using the SNO Karst hydrodynamic and physico-chemical time series (already harmonized as part of the data paper), meteorological data, and hydrochemical datasets available for the monitored sites.
- 3) *Data analysis*: analysis of trends in spring discharge, high-frequency physico-chemical parameters (water temperature, electrical conductivity, dissolved organic carbon, etc.), hydrochemical parameters (major ions, stable water isotopes, etc.), and meteorological variables (precipitation and air temperature). Analyses will be performed for different hydrological conditions (low-flow periods, flood events, recharge and recession periods, etc.).
- 4) *Karst hydrosystem characterization*: calculation of indicators describing aquifer hydrodynamic behaviour (storage capacity, inertia, flow variability) and compilation of information describing the spring catchments (geology, land use, groundwater abstraction, etc.).
- 5) *Results interpretation*: interpretation of the observed trends in relation to hydroclimatic and anthropogenic changes and the characteristics of the karst hydrosystems in order to identify the main factors controlling long-term changes in groundwater quantity and quality.

Required Background and Skills

- Master's level (M1) education in hydrogeology, hydrology, geosciences, environmental sciences, or a related discipline.

- General knowledge of hydrogeology, with an interest in karst aquifer systems.
- Basic knowledge of statistics and time-series analysis.
- Basic programming skills in R or Python for data analysis.
- Autonomy, scientific rigor, analytical skills, and ability to work in a team.

Skills Developed During the Internship

- Management and processing of environmental time-series datasets.
- Statistical trend analysis.
- Scientific programming in R or Python applied to hydrological data.
- Characterization of karst aquifer functioning using hydrodynamic and hydrochemical indicators.
- Assessment of the impacts of hydroclimatic change and anthropogenic pressures on groundwater resources.
- Scientific communication and dissemination of research results.

Internship Details

Supervisors:

Raphaël Bondu, HSM - raphael.bondu@umontpellier.fr

Vianney Sivelles, HSM - vianney.sivelles@umontpellier.fr

Yohann Cousquer, HSM - yohann.cousquer@umontpellier.fr

Location: laboratoire HydroSciences Montpellier

References

Cinkus, G., Bondu, R., Aliouache, M., Jourde, H., Mazzilli, N., Arfib, B., ... & Zappelli, A. (2026).

Comprehensive dataset of continuously monitored hydrodynamic and physico-chemical parameters in various karst systems, France. *Scientific Data*.

Giese, M., Caballero, Y., Hartmann, A., & Charlier, J. B. (2025). Trends in long-term hydrological data from European karst areas: insights for groundwater recharge evaluation. *Hydrology and Earth System Sciences*, 29(14), 3037-3054.

Jeannin, P. Y., Hessenauer, M., Malard, A., & Chapuis, V. (2016). Impact of global change on karst groundwater mineralization in the Jura Mountains. *Science of the Total Environment*, 541, 1208-1221.

Jourde, H., Massei, N., Mazzilli, N., Binet, S., Batiot-Guilhe, C., Labat, D., ... & Wang, X. (2018). SNO KARST: A French network of observatories for the multidisciplinary study of critical zone processes in karst watersheds and aquifers. *Vadose Zone Journal*, 17(1), 1-18.

Stevanović, Z. (2019). Karst waters in potable water supply: a global scale overview. *Environmental Earth Sciences*, 78(23), 662.