November 2022

POLICY BRIEF - Reservoir modeling

The KARMA Project

Reservoir modeling

Key findings

Reservoir models are widely used to assess both changes in groundwater resources and discharges at main outlets of karst aquifers, as they are relatively easy to use and several software tools are freely available.

Such models were applied over the whole Mediterranean area to simulate karst spring discharge at various test sites with different hydrological properties, data availability and environmental conditions.

These models are particularly suitable to simulate the response of spring discharge to precipitations, and can be used, even with very few hydrological data, given an accurate conceptual model of the karst system.

They allow gaining insights into the hydrological functioning of a system and therefore are especially suited for research purposes.

They can also be used to predict climate change impacts on water resources with the assumption that system processes and properties do not undergo major changes over long periods of time.

Around 9% of the world's population and up to 90% in some parts of the Mediterranean area such as Montenegro, is dependent on karst water resources for drinking water (Stevanović, 2019). Understanding the functioning of karst systems is therefore a major challenge for water resource management. Among many tools used in karst hydrology, modelling is a key approach that helps, for instance, managing the exploitation of karst auifers or forecasting floods. Numerous approaches such as reservoir models, artificial neural networks, and physical-based models are used to support the sustainable water resource management of karst aquifers (Hartmann et al., 2014; Jeannin et al., 2021). Reservoir models are a conceptual representation of a hydrosystem, which involves the association of several reservoirs (Figure 1). They are connected to each other through flow equations that turn an input signal (precipitation and evapotranspiration) into an output signal (discharge at spring). Each reservoir is described by a variable, its water height, and several parameters related to the flow equation that translates the water height into a discharge.

The structure and parameters of reservoir models can help identifying the main processes and factors that condition the hydrological functioning of a karst system but also developing knowledge of internal flow and storage processes.

At catchment scale, such models can also be used to estimate groundwater recharge and the dimennsions of the catchment. Reservoir modelling has been performed on the 8 KARMA test sites (Figure 2) using the KarstMod platform. This adjustable platform is dedicated to rainfall–discharge modelling and hydrodynamic analysis of karst aquifers (Mazzilli et al., 2019). It provides a modular, user-friendly modelling environment for educational, research and operational purposes. The objectives were to study the characteristics of each karst system and to identify the strengths and weaknesses of the reservoir modelling approach.

The consideration of different test sites allowed different hydrological conditions, system characeristics and input-data to be studied (Table 1). The results of the models were contrasted either due to (i) difficulties to reproduce

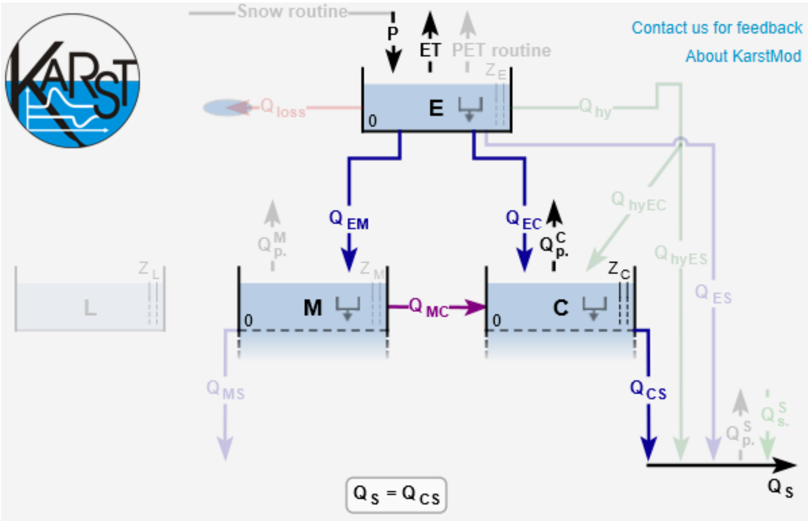

Figure 1: Structure of a reservoir model within the KarstMod modular platform. The conceptual representation of the hydrosystem includes 3 reservoirs (E, M and C) connected to each other through flows QEM, QEC and QMC. P and ET stand for Precipitation and Evaporation over the catchment. Groundwater pumping is simulated with flow QCp. in reservoir C, which water level corresponds to ZC. Reservoir C outflow (QCS) corresponds to the simulated spring discharge QS.

specific hydrological functioning or (ii) uncertainties on the input data. Overall, the simulations range from satisfying to vervy good and give relevant insights into thre systems in terms of aquifer properties. internal flwo dynamics and overall functioning with regards to meteorological regime and catchemnt charateristics.

The use of an external snow module, now implemented in the KarstMod modelling platform, has been required to correctly simulate karst spring discharge on five sites influenced by snow accumulation and melting. Results show that reservoir models do not need long calibration period to provide accurate and relevant simulations, whereas short time series can be detrimental for other modelling approaches. The conceptual model allows for the integration of elements that e.g. artificial neural networks models do not have time to learn (e.g. double porosity behaviour, matrix-conduit exchanges, fast conduit transfer in wet periods). Reservoir models seem also suitable for research purposes, as they provide a model structure and parameters that can be used to better understand the hydrological functioning of a system. The modelling of these 8 karst systems with different characteristics (catchment area, mean discharge and mean annual precipitation) shows the broad applicability of the reservoir modelling approach, whatever the climatic context or the hydrogeological behaviour of the karst system. These models were further used to assess the effect of climate change on some of the KARMA test sites.

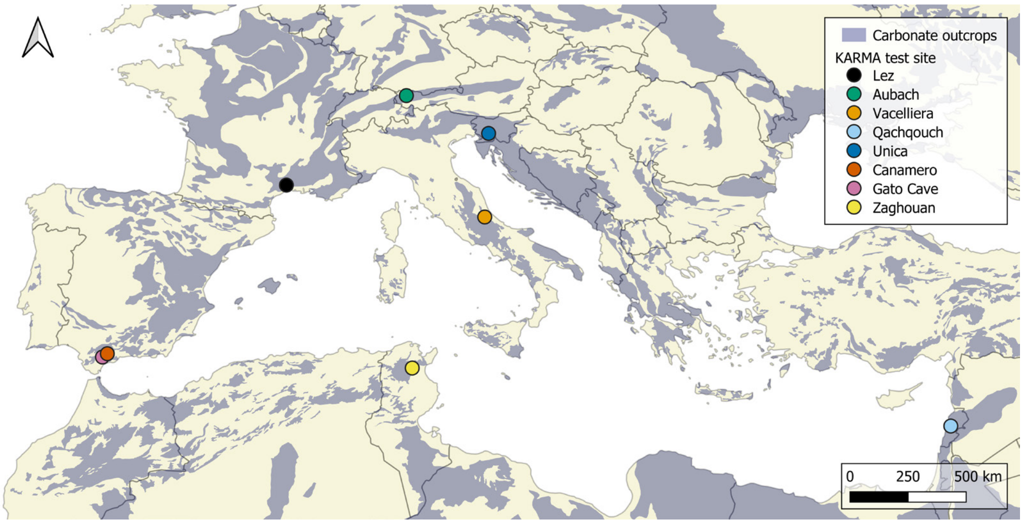

Figure 2: Localisation of the 8 KARMA test sites (delimitation of carbonate outcrops after Goldscheider et al. (2020)).

Table 1: Summary of the main hydroclimatic characterstics of the studied karst systems.

Spring	Country	Climate	Catchment area [km^2]	Mean discharge [m^3 s^{-1}]	Mean annual precipitation [mm]	Calibration period	Simulation period
Aubach	Austria	Cooltemperate and humid	9	0.91	2113	2014-2019	2014-2020
Canamero	Spain	Mediterranean	20-40	0.92	900	2008-2009	2008-2010
Gato Cave	Spain	Mediterranean	69-79	1.50	1872	1963-2011	1963-2015
Lez	France	Mediterranean	130	0.91	933	2008-2016	2008-2018
Qachqouch	Lebanon	Mediterranean	56	2.01	1293	2015-2019	2015-2020
Unica	Slovenia	Moderate continental	820	21.97	1605	1961-2016	1961-2018
Vacelliera	Italy	Moderate continental	1.3	0.06	1491	2018-2020	2018-2020
Zaghouan	Tunisia	Mediterranean	19	0.10	500	1915-1917	1915-1918

References and further Reading

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KARMA policy briefs present relevant scientific results of projects concerning a better karst groundwater management across the scale of the Mediterranean area, single catchments and selected springs.

Authors: Guillaume Cinkus, Naomi Mazzili, Hervé Jourde

Contact:
Guillaume Cinkus
University of Montpellier, HydroSciences
guillaume.cinkus@umontpellier.fr

Naomi Mazzilli
Avignon University, Department Hydrogeology
naomi.mazzilli@univ-avignon.fr