Dipartimento
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Research activity

The complex functioning of a karstic aquifer: integrated methods for the characterisation of the Gran Sasso aquifer

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Overall objective: In the framework of the European project KARMA, aimed at improving the evaluation of groundwater resources availability in Mediterranean area, an in-depth characterization of flow circulation in paradigmatic karstic aquifers of Central Italy is desirable.

Specific objective: Detailed analysis of the groundwater flow of the Gran Sasso karst aquifer and its hydrogeological complexity through the application of a new multidisciplinary approach. Furthermore, the project aims to analyse how anthropogenic elements and climate change can influence the karst aquifer flowpaths, in terms of resources availability and sustainability.

State of art: Karst process is the result of the dissolution process of carbonate rocks. The karst aquifer is a complex system, characterised by groundwater flow and by a system of pipes network [1]. In the Mediterranean area, where outcrops of carbonate rocks are very common, karst aquifers often provide abundant groundwater reserves that are fundamental for the water supply [2]. The management of karst aquifers and their water resources shows many problems related to heterogeneity and locally high permeability, making karst aquifers much more problematic than any other aquifer types [3].

The Gran Sasso hydrostructure is defined as a single basal calcareous-karstic aquifer of about 700 km^2 of total extension. The hydrogeological complexity is determined by its high permeability for fracturing and karstification and by the highly effective infiltration that feeds important springs, located at the boundary of the hydrostructure. The Gran Sasso aquifer is also characterised by the presence of no-flow hydraulic barriers represented by main tectonic elements [4].

The quantitative hydrogeological analyses of the Gran Sasso karst aquifer are based on direct flow measurements of the main springs, which allow to detect the seasonal and annual flow variations. Moreover, chemical-physical water in-situ characterisation is performed to obtain relevant considerations on meteoric inflows and the variability of the groundwater regime, strongly controlled by fracturing and karstification [5]. Furthermore, specific water analyses have been realised during the construction of two anthropogenic structures, the Gran Sasso motorway tunnels and the underground laboratories of the National Institute of Nuclear Physics [6], which significantly modified groundwater flowpaths. Notably, preliminary tracer test has been performed to evaluate changes in groundwater flow, caused by the human works on the regional water table. In addition, a long record of chemical analysis of the main components and stable isotopes of the water are available. These analyses, performed also in 2001, allows to obtain additional information about groundwater flowpaths and spring recharge areas clarifying the hydrogeological setting at a regional scale [7].

Since the Mediterranean karst aquifers mainly provide water supply for anthropic purposes, the monitoring of karst aquifers becomes strictly relevant. At the same time, classic quantitative hydrogeological studies are not sufficient to shed light on the groundwater hydrodynamics of karst system, since groundwater flows through fractures and karst conduits [8]. Moreover, there is limited knowledge of the groundwater sensitivity to climate change in terms of water availability [9]. The karst water management requires specific investigation methods in spite of capturing their dual groundwater flow regime. It is relevant to characterize the role of the groundwater conduit network, and the tectonic lines acting as hydraulic barriers and locally separating the flowpaths inside the aquifer [10].

The project aims to analyse the aquifers through a wide range of methodologies to better characterise the inherent heterogeneity and anisotropy of karst aquifers and to evaluate the variability of the groundwater regime. This multidisciplinary approach will include hydrological continuous monitoring of the main springs, isotope studies, and tracer techniques [11].

Through the combination of different approaches of investigation, a full and deepen characterisation of karst aquifers will be obtained. It will allow understanding the hydrogeological functioning of the system, from the recognition of groundwater flow paths and velocities to the identification of the recharge areas. Moreover, through this variety of approaches, it will be possible to have a reliable prediction of water availability without over-exploiting the aquifer. To have a better view of the complexity of the karstic system, and especially to accurately assess the impact of climate change on groundwater resources, the semi-distributed lumped model will be used. This simulation will employ to observe the spatial and temporal distribution of flow processes within a karst system and to evaluate the degree of vulnerability of the karst aquifers [12].

Activity: The first part of this study will be conducted to continuously update the data regarding the main features of the Gran Sasso karst aquifer, resuming relevant information from the literature to correctly develop the research project filling the knowledge gaps. The project will take into account the main springs located at the boundary of the hydrogeological system, to estimate a hydrogeological balance of the area examined. In particular, the springs of the Vomano, Tavo, Tirino, and Aterno river basins will be monitored (Fig.1).

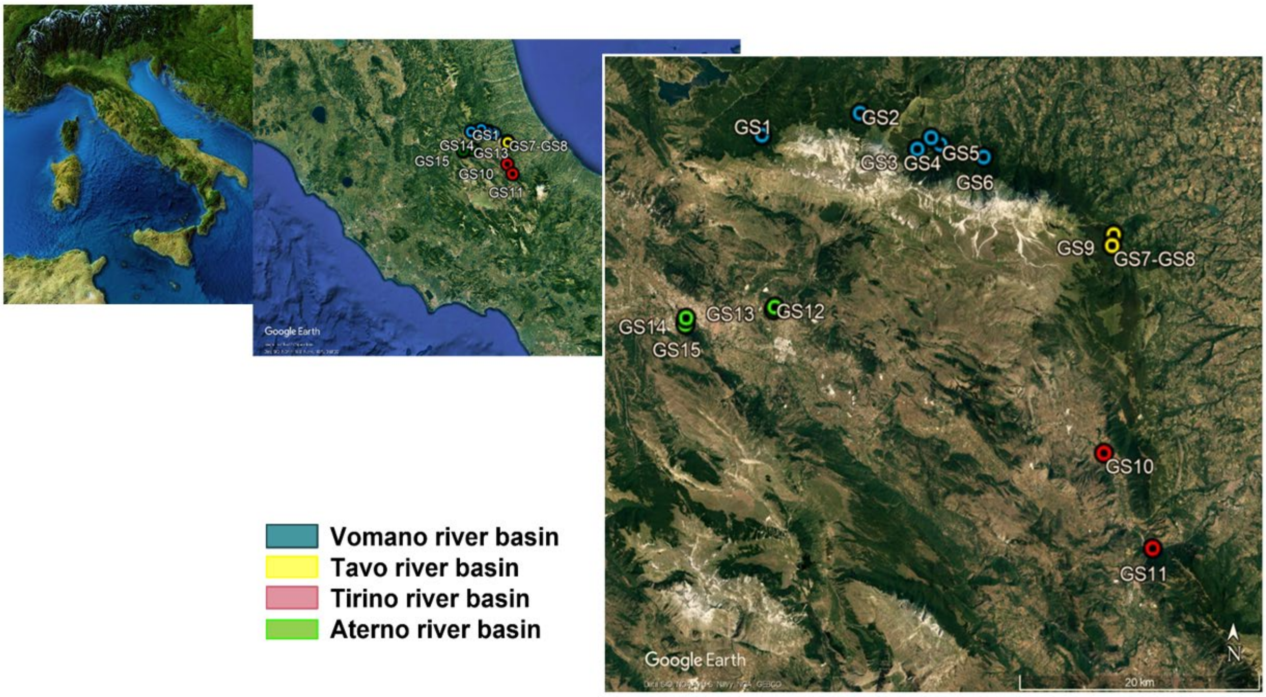

Fig.1: The main springs taken into account

To have useful information on the groundwater flow of the Gran Sasso karst aquifer system, the quantitative and continuous monitoring of the water resources will be carried out, using multiparametric probes. In particular, the variation of hydrometric/piezometric level, temperature and electrical conductivity will be continuously investigated.

Monitoring the trend of the main hydrogeological parameters allows to improve the knowledge of the system and to detect any changes over time, related to possible interference due to natural or anthropogenic causes.

In addition, classic flow measurements will be carried out to provide useful information on seasonal variations in the recharge of the aquifer and on the flow rate. Moreover, a detailed analysis of climatic parameters will be used to quantify the recharge of aquifers and analyse the regime of annual variability.

In order to obtain information on karst water availability, tracer techniques will be realised to determine groundwater recharge and to achieve further information regarding the groundwater flowpaths [13]. This type of technique is particularly useful in karst areas and can provide direct information on the hydraulic connection and hydrogeological parameters with the aim to separate the contribution of flow with different velocities [14]. Tracer tests, combined with geological and hydrological observations, are the best way to delineate the karstic system even in complex geological areas. Among the various types of tracers, fluorescent dyes are the most powerful tool to investigate groundwater connections, to quantify flow velocities and to obtain the direction of transport of contaminants.

The best time to apply this type of technique in the Gran Sasso karst aquifer is between April and June, months in which it is possible to have a maximum water level due to snow melting.

In addition, to shed light on the groundwater hydrodynamics of the complex karst system, it is important to simultaneously evaluate isotopic parameters. The monitored changes in stable isotopes over time and space can give a better understanding of aquifer recharge and spring discharge. Notably, in the Gran Sasso fissured carbonate aquifer, a long-term ^{222}Rn tracing survey will be performed to investigate the mechanisms that influence the groundwater flow and the water-rock interaction [15]. Moreover, ^{222}Rn is a useful tracer for karst analysis because its half-life (3.8 days) corresponds to the time scale of rapid flow components in karst systems aquifers, which is often of particular interest to assess the vulnerability of karst systems [16]. Furthermore, the combined measurement of ^{222}Rn and CO_2, with common hydro-chemical parameters, makes it possible to get a detailed picture of the flow paths and to provide information about the dynamics of solute transfer across the unsaturated zone [17].

To simulate the spatial and temporal distribution of flow processes within a karst system, this project will use the Lumped model approach [9]. This method is an interesting and efficient alternative to simulate karst spring hydrographs and is particularly suitable for the management of groundwater resources in karst.

The combination of process-based modelling and GIS data analysis allows to reduce the problem of insufficient data set that karst models are frequently facing. The conceptual model realistically elaborates the impact of possible climate changes on the Mediterranean karst system.

The expected results will allow to significantly deepen hydrogeological knowledge of the Gran Sasso karst aquifer, considered as paradigmatic area. Therefore, the transfer of the performed methodologies in similar aquifer contexts, in Italy and abroad will be promoted. In detail, the integrated methods will supply an overview of the complexity of one of the most representative karst aquifer in Italy. This will contribute to improve the hydrogeological knowledge of Mediterranean karst aquifers in order to manage the water resources, as provided by the European project KARMA. The KIT University in Germany coordinates the European project, and I am involved by international mobility to go deeper into the subject of my PhD. In particular, I will learn details on the themes of tracing techniques, groundwater quality, and groundwater protection.

Timetable

PhD activity	First year		Second year		Third year	
	I semester	II semester	I semester	II semester	I semester	II semester
Bibliographic study	x	x	x	x	x	
Installation of multiparametric probes	x					
Water flow measurements		x		x		x
chemical-physical sampling analysis		x		x		x
Site selection and installation of the Albillia probe		x				
Tracer test		x		x	x	
Data interpretations		x		x		x
Isotopes investigation	x	x	x	x	x	
Mobility abroad		x				
Publications		x		x		x
Seminars and courses	x		x		x	
Thesis						x

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Research products

Manuscript

- Valeria Lorenzi, Chiara Sbarbati, Francesca Banzato, Alessandro Lacchini, Marco Petitta (2022). *Recharge assessment of the Gran Sasso aquifer (Central Italy): Time-variable infiltration and influence of snow cover extension (Under review)*
- Giovanni Luca Cardello, Laura Tomassetti, Irene Cornacchia, Alessandro Mancini, Marco Mancini, Ilaria Mazzini, Giovanni Rusciadelli, Enrico Capezzuoli, Valeria Lorenzi, Marco Petitta, Marco Brandano (2021) - *The Tethysian and Tyrrhenian margin record of the Central Apennines: a guide with insights from stratigraphy, tectonics and hydrogeology - Geological Field Trips and Maps (in preparation)*
- Marco Petitta, Francesca Banzato, Valeria Lorenzi, Edoardo Matani, Chiara Sbarbati (2021) - *Isotopic findings on recharge distribution in fractured carbonate aquifers in Central Italy: addiction to snowpack cover as alert for future availability of groundwater resources- Hydrogeology Journal (Under review)*

Abstract

- Valeria Lorenzi, Chiara Sbarbati, Francesca Banzato, Mauro Manetta, Marco Petitta (2022). *Updating the water budget of the Gran Sasso carbonate fractured/karstified aquifer (Central Italy) for a sustainable management of groundwater resources.*