THE STUDY OF KARSTIC AQUIFERS BY GEODETIC MEASUREMENTS IN FRIULI VENEZIA GIULIA (NORTH EASTERN ITALY) FOR A WATER SUSTAINABLE MANAGEMENT

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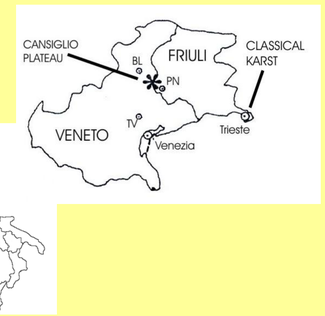
Introduction

The Department of Geosciences, University of Trieste has a network of underground geodetic stations in Friuli Venezia Giulia (North Eastern Italy) composed of: Grotta Nuova di Villanova in Tarcento (UD), the Giant Cave station near Trieste and the Genziana Cave station, which are all set in karstic areas (Braitenberg and Zadro, 1999; Braitenberg *et al*. 2005 (a)(b)). In the area of Cansiglio a unique permanent GPS station (CANV) has been installed by the National Institute of Oceanography and Experimental Geophysics (OGS-CRS) in 2004 and is part of the monitoring GPS network Zuliani (2003) of the Friuli area (FREDNET). The GPS station is situated at about 800 m height in the Friulian external segment of the Cansiglio-Cavallo Plateau and at a distance of about 8 km from the Genziana Cave. There are over 7200 caves in Friuli Venezia Giulia and a lot of karstic landscapes. Cansiglio Plateau and Classical Karst are two interesting karst areas of the Region and they have different hydrogeological characteristics. The geodetic underground stations give hydrodynamic informations. The Livenza River rises from the southeastern slope of the carbonatic Massif of Cansiglio – Cavallo and the principal springs are in Polcenigo. The Timavo River rises from Mt. Nevoso in Slovenia and disappears following the Škocjan Caves (San Canziano), in Slovenia; in Italy the Timavo River is intercepted by some caves and the springs are in San Giovanni di Duino (Monfalcone) at the Adriatic Sea. The Department of Geosciences, University of Trieste, several years ago set up a monitoring network to study Classical Karst aquifer hydrodynamics. Several water points are monitored by multiparametric probes which collect water level, temperature and conductivity. Trebiciano Abyss is one of these, 300 m deep, near the border with Slovenia.



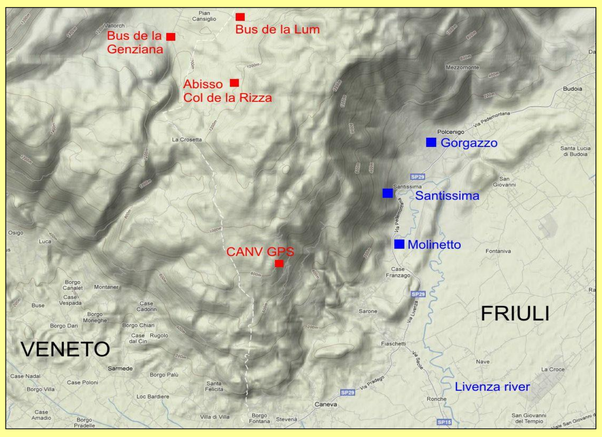


Fig. 1 A, B. Location of Cansiglio – Cavallo Plateau and Classical Karst; B: red squares represent the positions of the main caves and GPS station, blue squares the principal springs

Cansiglio Karst area and Genziana Cave tiltmeters

The Cansiglio-Cavallo Plateau is a karstic massif situated in the Prealps of Carnia, which stretches forward as a mountainous block on the Venetian and Friulian plains and is divided between two Regions: Veneto on the west and Friuli-Venezia-Giulia on the east. Its maximum height above mean sea level is 2200 m and it has two plateaus of medium height of 1000 m, the Cansiglio and the Piancavallo Plateau. The River Livenza rises from the southeastern slope of the carbonatic Massif of Cansiglio – Cavallo. It is supplied by three main springs: the Gorgazzo, the Santissima and the Molinetto. All three have an average flow from 5 to 10 cubic meters per second and derive from the thrust along the Caneva – Maniago Fault. The Massif is characterized by a marked deep karst, having about 200 caves and variegated surface morphology. Though the annual mean precipitation is about 1800 mm, the Cansiglio Plateau is without superficial hydrography, but is acting like an endorheic basin with an articulated system of underground canalization.

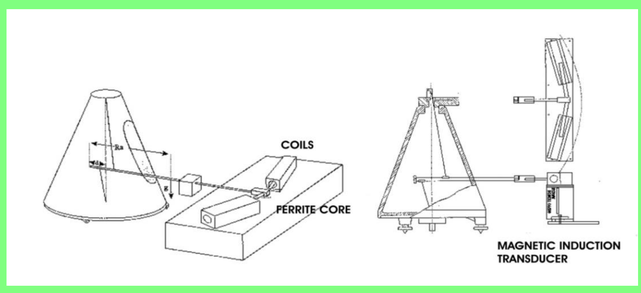
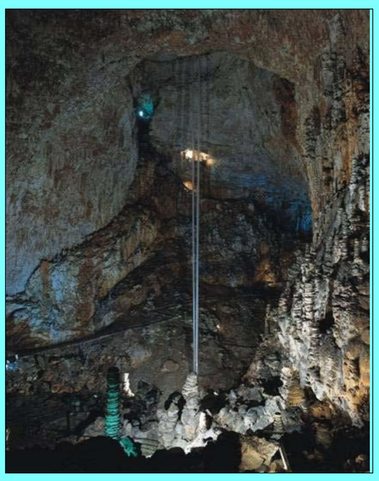


Fig. 2. Schematic design of the Marussi tiltmeter. Since December 2005 the Cansiglio Plateau hosts a tiltmeter station 25 m deep in Bus de la Genziana, a Natural Hypogean Reserve managed by the Foresters Department of State (Braitenberg *et al.* 2007) with a maximum depth of 587 m and a development of 8 km. The Marussi tiltmeters are 0.5 m tall inside a cast iron bell resting on three small flat platforms of compact rock. The data acquisition is digital and based on an inductive transducer. These are horizontal pendulums with Zöllner type suspension (Zadro and Braitenberg, 1999): the bar of the pendulum with the mass is suspended by two wires, an upper and a lower one, in such a way that the bar rotates in the horizontal plane. The inclinations are measured along two directions, NS and EW, recorded respectively by the two pendulums

Classical Karst area and Giant Cave pendulums



Classical Karst is a large area located between the North-Eastern part of Italy and the South-Western part of Slovenia; it is 40 km long and 15 km wide in the SE-NW direction, the area is bounded NW by the Isonzo River valley, N and NE by the Vipava valley, E by the Pivka River basin, S and SE by the Cicarija structure while on W it is bounded by the Gulf of Trieste (Adriatic Sea). The plateau, slightly inclined towards NW, consists of carbonate lithotypes widely involved by karst landforms. The rainfall water and the one that comes in the form of rivers are immediately channelled in the underground where they create an underground network: there are over 3000 caves. The main water contribution to the Classical Karst aquifer is well identified in the area where Reka River (Timavo) sinks in Škocjan Caves, in Slovenia. The windows on to the path of underground Timavo River are extremely rare; in Italy Timavo River is intercepted by Trebiciano Abyss and Lazzaro Jerko Cave.

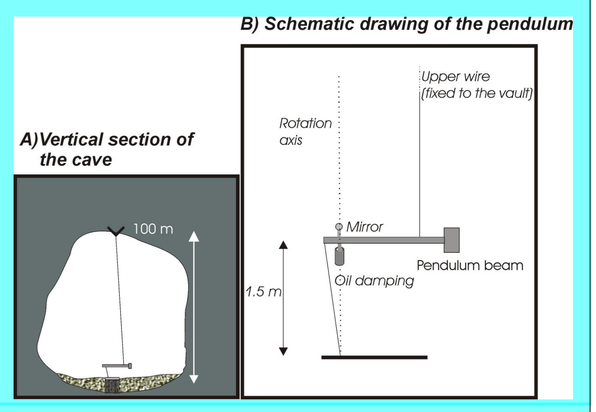
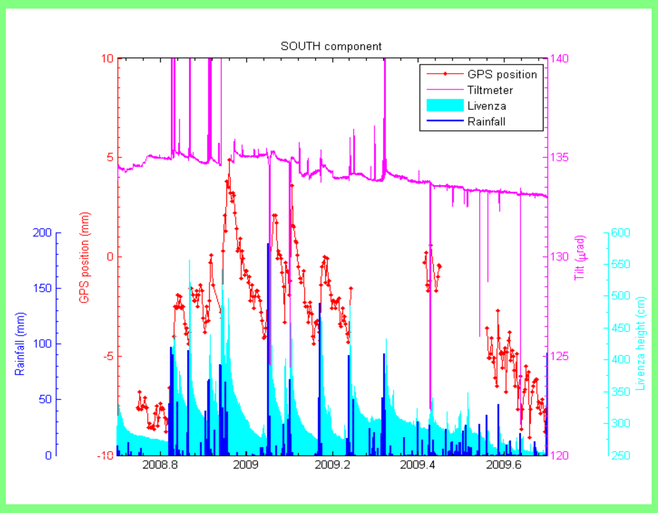


Fig. 4 A, B. Above: plastic protection of the couple of horizontal pendulums. Right: instrument design. Giant Cave is an important Italian touristic cave, consisting of a large room 165 meters long, 65 meters wide and 107 meters high (for a total volume which is over 600000 cubic meters). Its morphology, its central location within the Classical Karst and the easy access have suggested over the years to position a lot of monitoring stations that make it as a reference point for geosciences studies. In the center of the large room there are two long base horizontal pendulums, installed in 1960 by prof. Marussi, University of Trieste to measure the tilt of the cave in NS and EW direction respectively; they are 100 m long; the observed signals go from secular slow crustal movements through Earth tides and free oscillations to earthquakes.



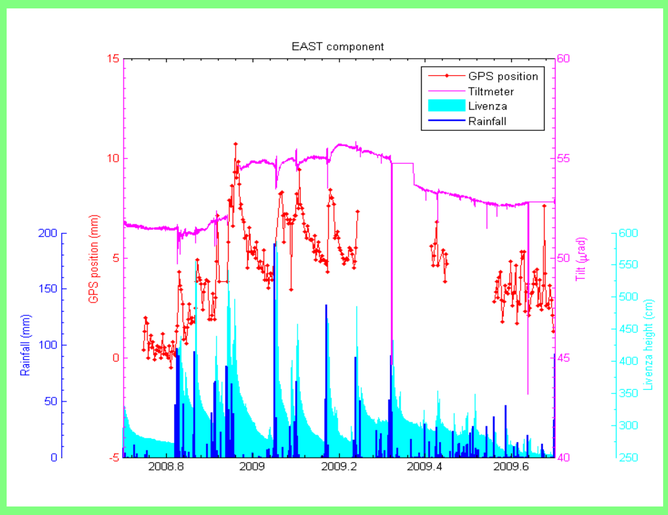


Fig. 3 A, B. Comparison between the horizontal components NS (a) and EW (b) of the GPS station Caneva, the tilting signal of station Genziana, pluviometrical recordings of Cansiglio and hydrometric signal of River Livenza from 19 October 2008 to 2 April 2009. The tilting signal is violet. The satellite signal is red. Both of them register simultaneously strong rainfalls. The scale on the ordinate permits to quantify the displacement induced by hydraulic loading. The hydrologic signal is evident at the spikes and "loops" in correspondence with rainy events, which sometimes appears like a slow drift equal to runoff curves of the karstic aquifers. For example, when the rainfall is 100 mm/hour, the EW impulsive signal is about 1,65 μrad, the NS tiltmeter signal is 10,66 μrad. Both geodetic stations record the hydraulic loading at the same times, reflecting the fluid flow in the underground conduits during the phase of full load. The slow (weeks) long term response is a deformation which could be the runoff of water from the rock matrix towards the conduits in the phase of normal water flow. The variation in direction of the tilt impulses could be derived from the non homogeneous hydrology of the karstic system and from the presence of at least two areas, one situated west and one east of the station, with different hydrogeologic characteristics.

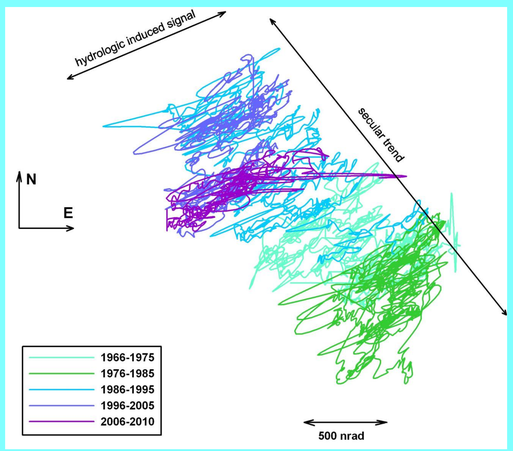


Fig. 5. Long term movement recorded by the horizontal pendulums in Giant Cave. During periods of high flow of the Timavo River a characteristic signal has been observed of the Giant Cave tilting: it consist in a strong inclination toward SW and in a subsequent recovery of the inclination. Analyzing trails by pendulums a number of additional considerations were made regarding the response time of deformation compared to the rise of water level.

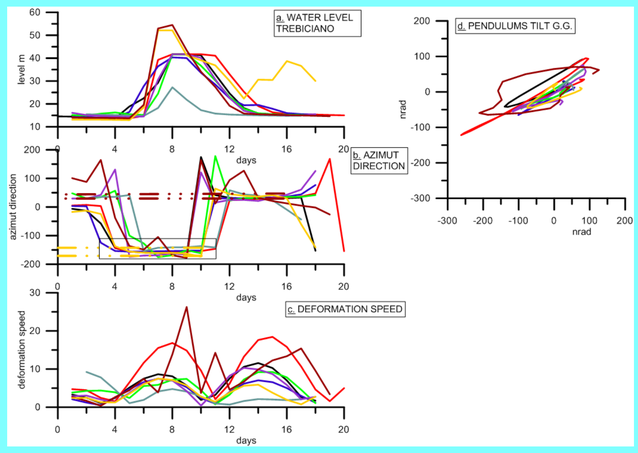


Fig. 6. Comparing the pendulums time series with the hydrometric data of high flow in Trebiciano Abyss, 10 km far from Giant Cave, we noted a linear relationship between the tilting and the runoff of underground rainwaters. There is a minimum value of 23,24 m (referenced to m.sl.) level of the water in Trebiciano Abyss to be sensed by the pendulums in Giant Cave. The linear coefficient equivals to 100 nrad tilting for a 9,7 m variation of the river Timavo level.

Conclusions

We propose to study the karstic aquifers using underground tiltmeters and GPS observations in Friuli Venezia Giulia (North East Italy), in particular in the area of the Cansiglio Plateau and the Classical Karst. The tiltmeters are set in natural caves (Genziana Cave and Giant Cave) making part of two interesting karstic areas of particular hydro – geologic importance. These areas have high vulnerability. From the Friuli slopes of the karstic massif the Livenza River is born. The Classical Karst hosts the Timavo River aquifer. In the specific case of Cansiglio by means of comparison of the tilt- signal registered at the Genziana station with the pluviometrical series of Cansiglio and the hydrometric series of Livenza, local hydrologic effects have been observed and interpretations have been proposed. Putting in correlation also the GPS data of Caneva, a clear correspondence has been ascertained among the clinometric, satellite geodetic and hydro – pluviometrical signals. The slow deformations recorded match the curves of run-off of the karstic aquifer, meanwhile one can observe also brief deformations correlable to conspicuous rain precipitations. We record hydrodynamic signals also by an analysis in the Classical Karst between Giant Cave pendulums and the River Timavo discharge. The purpose of research is to open a new multidisciplinary frontier between geodetic studies and studies of the karstic systems to obtain a better indirect knowledge of the underground hydric circulation and thus a more complete geologic description for a water sustainable management.

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