X Convegno dei Giovani Ricercatori di Geologia Applicata 2016
18 – 19 febbraio 2016, Bologna

Climate changes and piezometric level fluctuations in the Soča/Isonzo River Plain (NE Italy)

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ABSTRACT
It is always more evident that something in the climate is changing, everybody can see it on their own, but evaluating the numbers supporting the change it is not always so simple. In an area where the water quantity is actually not a problem, the global warming identified through the meteorological data analysis of the historical time series seems to have consequences on the phreatic aquifer of the Isonzo /Soča River Plain (NE Italy). The analysis of the piezometric levels in facts show a decreasing trend actually still sustainable but not sustainable any more if compared to the climate models at 100 y showing a temperature increase and a decreasing in the precipitation amount.

INTRODUCTION
The increasing temperatures pose uncertainties on the supply and management of the groundwater resources (Arbisala et al., 2015; IPCC, 2014) being freshwaters the first requirement for life (Batelaan et al., 2007). The definition of the freshwaters reserves is already of vital importance in certain part of the planet, but also in areas where waters are abundant, the necessity to monitor them is always a more urgent issue. It is in fact of primarily importance not to waste this precious good.
The studied area, located in the north eastern side of Italy, within the Friuli Venezia Giulia Region, is an area where the abundance of water is well known by the inhabitants as only few episodes of drought have been observed (Radman et al., 2015). It is characterized by the presence of the transboundary Soča/Isonzo River shared between Slovenia and Italy. In order to define which is the state of the art of the phreatic groundwaters in the Isonzo/Soča plain area comparing their behavior to the climate change conditions, an investigation was realized. Three meteorological time series data (1961-1990) and historical piezometric level data (1985-2012) were analyzed. From a human point of view, this area is very important because here the groundwaters are exploited for drinking purposes by two aqueducts (Fig.1): IRIS aqueduct and AcegasApsAmga aqueduct. IRIS is providing waters for Gorizia town and the province, while AcegasApsAmga supplies Trieste town as well as its province (Cucchi et al., 2015). In the whole more than 350,000 inhabitants drink waters coming from the Isonzo/Soča plain.

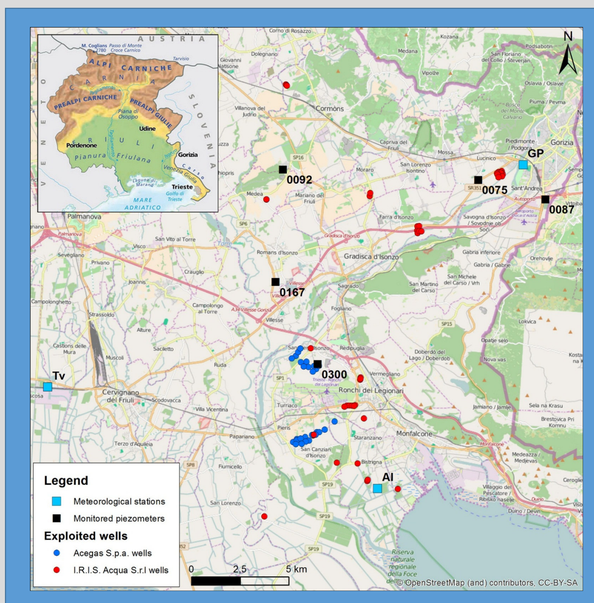
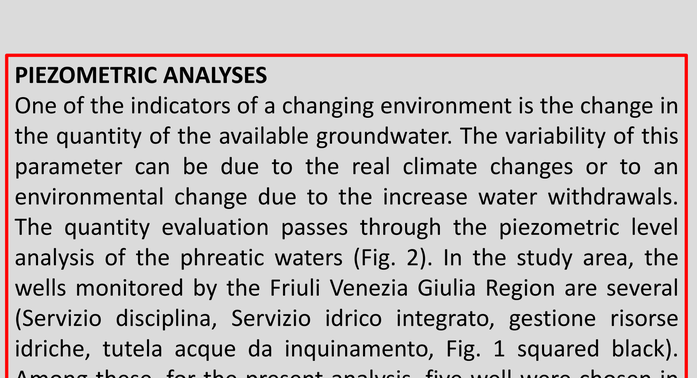


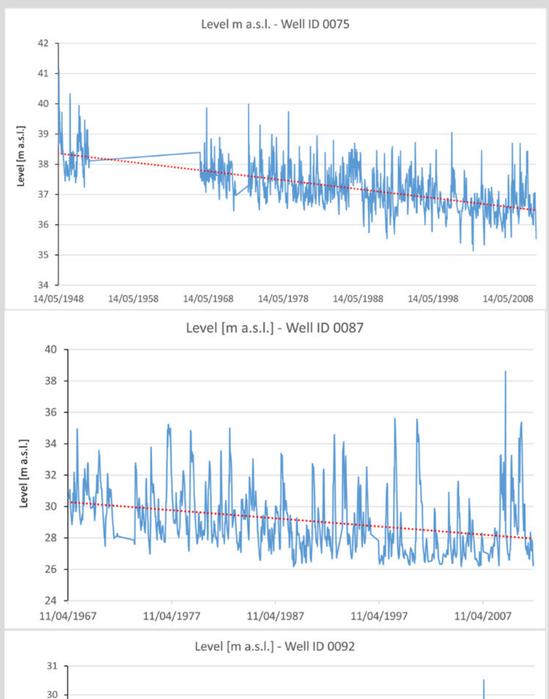
Fig. 1 – The study area. Red (IRIS) and royal blue (AcegasApsAmga) circles represent the exploited wells for drinking purposes. Black squared are the monitored piezometers of the FVG monitoring network. In light blue the meteorological stations used for the analyses.

GEOLOGICAL SETTINGS
The studied area, located in the north eastern side of Italy, belongs to the hydrogeological basin of the Friuli Plain. It is located in the eastern side of the Friuli Venezia Giulia Region at the border with Slovenia (Fig. 1). The Region extends from the Alps to N, to the Adriatic sea to the S, bounded by the Livenza River to the W and the Soča/Isonzo River to the E, in correspondence of the karst hydrostructure. The mountain part presents very complex characteristics from the lithological and structural point of view (Bisaglia et al., 2014; Carulli, 2006; Zini et al., 2011; Zini et al., 2013). To North, along the border with Austria, the Palaeozoic units outcrop, hereclastic lithotipes (claystones, marls, sandstones often in facies of Flysch) prevail on the platform carbonate lithotipes. Mesozoic sediments made up by calcareous and dolomitic rocks characterize the central part. The piedmont belt connects the mountains to the plains.
Quaternary deposits are widely present in the Plain reaching thickness, near the south west part of the Region, of more than 600 m (Zini et al., 2011). The Plain can be divided in two parts: the High Plain and the Low Plain separated by the Resurgence Belt. In this area, groundwater emerges through a myriad of springs giving rise to a series of rivers. In the High Plain, characterized by the high permeability of the loose coarse deposits, a phreatic continuous aquifer is recognized. In the Low Plain, the phreatic aquifer joins in a complex layered aquifer systems. In almost all the Low Plain at shallow depth, is present a discontinuous phreatic aquifer. Under it eleven confined aquifer systems were recognized of which the deepest aquifer show a geothermal character (Zini et al., 2013).

PIEZOMETRIC ANALYSES
One of the indicators of a changing environment is the change in the quantity of the available groundwater. The variability of this parameter can be due to the real climate changes or to an environmental change due to the increase water withdrawals. The quantity evaluation passes through the piezometric level analysis of the phreatic waters (Fig. 2). In the study area, the wells monitored by the Friuli Venezia Giulia Region are several (Servizio disciplina, Servizio idrico integrato, gestione risorse idriche, tutela acque da inquinamento, Fig. 1 squared black). Among these, for the present analysis, five well were chosen in the Isonzo/Soča River Plain in accordance with the available longer time series: 0075, 0087, 0092, 0177 and 0300. The historical series of these wells were analyzed in order to define their trend. Data series, for some wells, cover a period from 1948 to 2012.
As defined also by Gerdol (2013), the data analysishighlights different but always decreasing trends for the considered wells. Well 0092 shows the minimum lowering trend with a value of -1.5 cm/y. The well 0075 has a lowering of -3.4 cm/y, followed by the 0300 well with a value of -3.9 cm/y. The 0087 well has almost a double lowering if compared to the others with a value of -6.3 cm/y. The worst value is the one related to 0167 well with a drop of -6.9 cm/y.

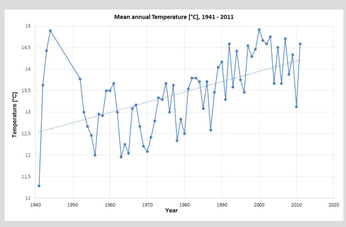


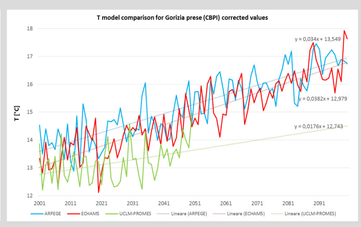
Images of the Soča/Isonzo Plain and some ancient wells monitored within different Interreg Projects as ASTIS and GEP.

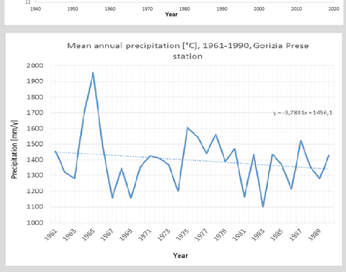


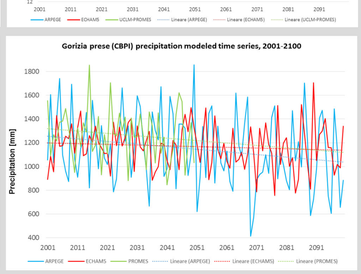
Data (in blue) and trends (in red) of 5 piezometers present in the study area and used for the analyses.

CLIMATE CHANGE ANALYSIS
In the whole world climate is changing with always increasing temperatures and episodes of short but intense precipitation events (Bates et al., 2008; Micheletti and Cicogna, 2014). The pattern plays a fundamental role in shaping the natural ecosystem, the economies and, in general, the culture (Aribisala et al., 2015). It is possible to consider the climate change from different point of views: as global warming or/and as change in weather pattern. Even if the changing pattern is important, for the present research, the authors focused their attention on the global warming analyzing the available data present in the area (Desiato et al., 2012). In the Friuli Venezia Giulia Region, OSMER (Osservatorio Meteorologico Regionale) has a good quality meteorological network with data available, for same stations, since the beginning of the 1900 (Micheletti and Cicogna, 2014). Within the study area 3 meteorological stations were chosen for the analysis chosen for their location and for the good quality and length of the time-series: Gorizia Prese (GP), Torviscosa (Tv) and Alberoni (Al). All of them had daily data available in the range 1961-2012.
Temperatures in the catchment area of the Isonzo/Soča River vary greatly. For all the three stations, the annual cycle of air temperatures is well defined, with a maximum of 36°-39°C and a minimum of -10.6 – -12°C indicating a passage by a temperate marine climate to a continental alpine ones. Temperature trends, calculated using the Kendall's tau method (Sen, 1968), are similar for the analyzed stations. For Gorizia Prese (Figure 2) the Trend is of 0.2°C/10y, with a mean temperature value in the analyze period (1941-2011) of 13.4°C; for Tv the trend is of 0.6°C/10y, with a mean temperature value in the analyze period (1941-2011) of 13.5°C. For Al station the trend is of 0.4°C/10y, with a mean temperature value in the analyze period (1972-2011) of 14.4°C.
The average annual rainfall was computed for the period of 1961-1990. At Gorizia Prese, the yearly average rainfall value is 1397.5 mm. At Tv the highest precipitations are recorded in autumn with average values of 118.9 mm and maximum values up to 317 mm. The yearly average rainfall value is 1205.9 mm. The same trend is visible for the Al station where the higher mean values belong to autumn with 112.8 mm. Here the max recorded values are of 422.8 mm and the min values are of 12 mm. The yearly average rainfall value is 1108.2 mm.









The selected 50-year period (2001-2050) within which the impacts of potential climate change on water resources are analyzed shows characteristics of the rainfall regime that differ to the reference 30-year period 1961-1990. The behavior of the three stations is different. GP observed data are indicating a decrease in the precipitations of the 7.4%, Al instead is showing a very small increase, only 0.7%. A higher increase is instead shown by the Tv station that has a 15.7% of increase in the precipitations in the period 1961-1990.

DISCUSSION AND CONCLUSIONS
The Isonzo/Soča River, has its source in Slovenia and flows into the Adriatic Sea. The basin has a pronounced mountainous character with an average elevation of about 599 m a.s.l.. Isonzo/Soča is a river shared between two countries that are trying to benefit most from its waters. In both countries dams are present along its river course. Three are situated in Slovenia, one in Italy. Salcano dam (in Slovenia at the border with Italy) is used for regulation of flow and floods; the reservoir operations have a direct influence on the downstream discharge. Water from the river is withdrawn for hydroelectric, industrial and agricultural purposes, creating pressure especially during drought period. Pressures arise from both anthropogenic and natural sources keeping the equilibrium in an unstable steady state. Dumped mining residues of the mercury mine in Slovenia cause quicksilver contamination in fluvial and marine sediments. Wastewater discharges are flushed into a tributary causing organic contamination in the Italian side of the Isonzo basin. In general organic matter from wastewater discharges and heavy metals cause a transboundary impact affecting the water quality.
All the problems summarized above have a common international character, being directly related to quantitative and qualitative pressures requiring the definition of immediate corrective cross-border measures using the cooperation between Italy and Slovenia already started following the Osimo Agreement implemented in the far 1975.
To the general frame is necessary to add the climate changes occurring on the whole planet. In the framework of the Drinkadria IPA Adriatic Project, through the use of different climate models as ALADIN, ICTP-REGCM and UCLM-PROMES were identified for the Isonzo/Soča area an increase of the temperature together with a decreasing trend in the precipitation on a period of 100y (Radman et al., 2015). In particular, if one looks at the future projection using the three model time series (CNRM-RM5.1 (or ALADIN) forced by ARPEGE, ICTP-REGCM forced by ECHAM5 and UCLM-PROMES forced by HadCM3Q0) for the period 2001-2100, notices that the three models are showing a huge temperature increase in the range of 0.13°C/10y (Al station) to a maximum of 0.5°C/10y in correspondence of the Tv station (Promes). For the precipitations all the models evidence a slight decrease in the annual precipitation amount. GP is in the range -1.2 mm/y to -2.8 mm/y; Tv from -1,1 mm/y to -3.0 mm/y and Al from 0.6 mm/y to -1.9 mm/y according to the used model.
If we look at the groundwaters, in the last 30 years, there is a general lowering in the phreatic waters with values going from -1.5 cm/y (well 0092, 1978-2012) to -6.9 cm/y calculated for the well 0167 (1979-2012).
It is not easy to evaluate the pressure of the climate changes on the groundwaters also because during the last 50 years the groundwater exploitations increased influencing the water table behavior. Actually, the exploitation in the High Plain only for drinking purposes are estimated to be 1.9 m3/s (Zini et al., 2011) still actually sustainable for the system, but not in view of future. In the long run in fact, these new conditions will compromise the recharge of the aquifers taking to an escalation the facing problems.

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ACKNOWLEDGMENTS
The present research is part of the international EU IPA Adriatic DRINKADRIA Project that view the Isonzo/Soča plain as pilot area. The Authors would like to thank the anonymous reviewer who helped in the improvement of the manuscript.