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Effects of the 2017 drought on isotopic and geochemical gradients in the Adige catchment, Italy

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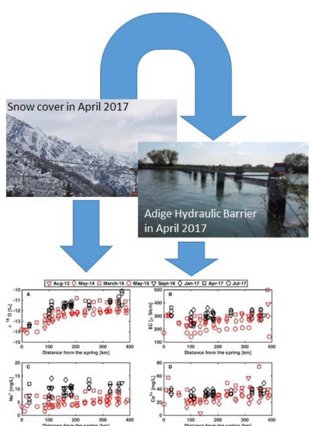
HIGHLIGHTS

- Isotopic and geochemical dataset for the Adige catchment during drought conditions
- Analysis of spatial and temporal variability in isotopic and geochemical composition.
- Source of the 2017 drought was lack in winter precipitation.
- Isotopic water composition highly sensitive to the drought
- Water geochemical composition generally not affected by the drought

GRAPHICAL ABSTRACT



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ABSTRACT

Drought events can significantly influence the isotopic and geochemical composition of surface water even in large (>1000 km^2) catchments. Monitoring this variability is challenging, due to the practical difficulty in carrying on adequately resolved (both in time and space) sampling campaigns. This study presents a dataset collected during the drought occurred in 2017 in the Adige catchment. The low flow conditions were caused by a remarkable lack of fall and winter precipitations throughout the entire catchment. This led to higher δ^{18}O and δD values during spring and summer than in samples collected for the period 2013–2016. The low discharge was generally not associated with an isotope fractionation effect due to evaporation and the river water signature was still in agreement with the local meteoric water line. The drought had an important impact on the geochemical composition of the water close to the river mouth, evidencing the occurrence of saltwater intrusion up to the hydraulic barrier (4.2 km far from the river mouth) constructed with the purpose of limiting this negative effect. The Alpone subbasin was the most impacted one by the drought showing anomalously high values in ionic content, EC (up to 647 μS/cm) and isotopic composition (up to −7.58‰ and −51.4‰ for δ^{18}O and δD, respectively). The Adige catchment overall showed a good resilience towards this extreme event thanks to the contribution of baseflow, highlighting the importance of groundwater resources management in the catchment.

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1. Introduction

The analysis of isotopic and geochemical parameters provides important information about the hydrological functioning of a catchment (Chiogna et al., 2014; Leibundgut et al., 2009; Penna et al., 2017a; Tetzlaff et al., 2017). Studies using tracer time series with a high temporal resolution are getting more and more common (e.g., Birkel et al., 2010; Penna et al., 2017b; Engel et al., 2018; Volkmann and Weiler, 2014) and facilitate the understanding of local scale hydrological processes in medium to small size catchments (i.e., smaller than 10–100 km^2). The investigation of hydrological processes in large catchments (i.e., >1000 km^2) are still challenging due to the large number of sampling locations needed to get a comprehensive overview of the ongoing processes and the inherent costs and technical as well as organizational difficulties related to a highly resolved sampling campaign over a large area (Marchina et al., 2016; Nasrabadi et al., 2016; Halder et al., 2015; Reckerth et al., 2017). Moreover, large-scale event-based sampling campaigns have often the limitation of representing only a snapshot of the existing conditions in the catchment and the representativeness of the outcomes could be questionable.

Water stable isotopes and water geochemical composition have been used in large catchments to identify the hydrological behaviour under stress conditions (e.g., Lambs et al., 2005; Petelet-Giraud et al., 2017), such as drought events. Among others, Wu et al. (2018) observed that the isotopic composition along the Yangtze River in drought years changes depending on the regulation of the Three Gorge Dams and they were able to identify the major role played by lakes and artificial reservoirs in the catchment. Vanplantinga et al. (2017) identified that, in the highly regulated Brazos River catchment, drought events enhance reservoir discharge dominance while under undammed conditions a run-off and baseflow dominance would be expected. Martínez et al. (2017) applied hydrochemical and stable isotope data to differentiate between baseflow and direct runoff in the Quequén Grande River and were able to identify the characteristic water signature occurring during La Niña phase of the ENSO (El Niño Southern Oscillation). Marchina et al. (2017) showed the impact of the 2015 drought event on the water composition of the Po river delta and observed a high sensitivity of the isotopic signature to drought events.

This work aims at identifying the effects of the 2017 drought on the isotopic and geochemical composition of the Adige river water. The comparison of our results with those presented in Natali et al. (2016) for the same catchment allows us describing the temporal dynamics of the isotopic and geochemical signature of the Adige catchment over 4 years. Therefore, in our study, we do not limit our investigation to the spatial and seasonal variability of water composition, but we can provide a more comprehensive temporal analysis comparing data collected in different hydrological years (2013–2017). Moreover, we present novel results about the isotopic and geochemical composition of important tributaries of the Adige river, i.e., Passirio, Talvera, Isarco, Noce, Avisio, Fersina, Leno and Alpone, to investigate the effect of the drought on different parts of the catchment.

The collection of isotopic and geochemical information at the river basin scale is beneficial to manage the effects of multiple stressors on aquatic ecosystems with water scarcity. This is the final goal of the FP7 European project Globaqua (Navarro-Ortega et al., 2015) and the Adige catchment is one of the Globaqua river basins under investigation. A review about the hydrological and chemical studies available for this river basin was provided by Chiogna et al. (2016). The authors highlighted the lack of an integrated and comprehensive characterization of the Adige river at the basin scale. In the framework of the Globaqua project, new studies focusing on water quality (Diamantini et al., 2018; Lutz et al., 2016; Mandaric et al., 2017), eco-hydrology (Vigiak et al., 2018), climate change (Gampe et al., 2016; Marcolini et al., 2017) and hydrology (Chiogna et al., 2018; Laiti et al., 2018; Tuo et al., 2018a; Tuo et al., 2018b; Tuo et al., 2016) have partially filled this gap of knowledge. Complementary to these existing studies we additionally focus on the consequences of hydrological variably in the lower part of the river basin (i.e., the part of the river located in the Veneto Region, about 210 km downstream the spring of the river) and we investigate the behaviour of the entire catchment under the drought occurred in 2017. The Adige catchment allows us to investigate the behaviour during a drought of a river basin entailing both Alpine as well as Mediterranean hydrological conditions, in the upper and lower part, respectively, and highly affected by anthropic activities (e.g., damming).

The goals of this work are therefore i) to complement the available dataset presented by Natali et al. (2016), including an analysis of the main tributaries of the Adige catchment, ii) to explore the seasonal dynamics in the isotopic and geochemical composition of the water in the Adige catchment and iii) to investigate how the drought occurred in 2017 differently affected the geochemical and isotopic water composition of different parts of the Adige river basin.

2. Material and methods

2.1. Catchment description

The Adige river basin (Fig. 1) has a catchment area of about 12,100 km^2 and the discharge shows the typical behaviour of Alpine catchments, with peaks usually registered during the melting period from June to September. More details about hydrological and chemical stressors of the catchment as well as its ecological status are given in Chiogna et al. (2016). Precipitation is not evenly distributed in the catchment and varies between 500 mm/y in Val Venosta (north-west part of the catchment) and 1600 mm/y in the southern part of the basin (Duan et al., 2016; Laiti et al., 2018). Temperature is also highly variable in the catchment due the high elevation gradient. Mean monthly temperatures range between 14 °C in July and −4 °C in January and December (Laiti et al., 2018). The mean water discharge is about 202 m^3/s at the Boara Pisani gauging station. The catchment in its northern part is characterized by the presence of large artificial reservoirs mainly used for hydropower production, which significantly alter the flow regime and influence water availability (Zolezzi et al., 2009; Chiogna et al., 2018). The Adige river is affected by salt water intrusion, particularly during low flow conditions, potentially up to a distance of 20 km from the river mouth (Bogoni, 2013). In order to prevent a deterioration of the river fresh water quality a hydraulic barrier is present to prevent the intrusion of saline water in the river channel. Fig. 1 shows the catchment area, the sampling locations and the boundaries of the sub-catchments covering the main tributaries, i.e., Isarco, Talvera, Passirio, Noce, Avisio, Leno, Fersina and Alpone.

2.2. Sampling campaigns and analytical methods

Four sampling campaigns were performed between September 2016 and July 2017: sampling campaign 1 in September 2016 (23–24.9.2016), sampling campaign 2 in January 2017 (13–15.01.2017), sampling campaign 3 in April 2017 (03.–06.04.2017) and sampling campaign 4 in July 2017 (17.–18.07.2017). The sampling campaigns were performed after a period of at least 4 days where no significant precipitation events interested large parts of the catchment (though in the sampling campaign of July local storm events occurred) and in days free of precipitation events to avoid isotopic signatures influenced by rainfall and direct runoff or diluted ionic composition. However, in sampling campaign 4, the point 03 (Campo di Trens) was sampled during a heavy precipitation event. During sampling campaign 4, the point 16 (Alpone), was almost dried out. Flow was discontinuous and the water sampling was conducted in a remaining pond in a shadowed place.

The samples were taken using a rope and bucket if taken from bridges or a telescope bar in order to sample the water from the main part of the stream. The sampling locations were chosen considering the locations for which discharge and water level data were publically available