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Hydrogeological drought characterization in semi-arid zones

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The study of the hydrogeological drought implies to investigate its drives and to understand its dynamics. Droughts can be triggered by both natural and anthropic causes (i.e. the propagation of the meteorological drought throws the hydrological system and the water resources overexploitation, respectively). The hydrogeological drought dynamics strongly depends on the the system inertia, controlling the propagation of the meteorological drought in the groundwater system. Drought means a water deficit respect to normal conditions or reference to supply demand, and is characterized by its intensity, duration, frequency and the affected areal extension. The most widely applied techniques for characterizing droughts include the Standardized Precipitation Index (meteorological droughts), the Palmer Drought Severity Index (meteorological and hydrological drought), and the threshold level method. These techniques have been traditionally applied in meteorological and hydrological drought studies but this is not the case in hydrogeological drought characterization studies.

We have concentrated in the application of the threshold level method applied to the hydrogeological drought characterization. To apply this methodology it is necessary to define the threshold level value. This value is obtained as a percentile from the “low duration curve” (i.e. the empirical cumulative frequency curve of the state variable on study). This percentile value is named as the “non excedence frequency”(NEF). Unfortunately the NEF value is different for every focused variable and application site. Even more, there is not an objective way to define the most appropriate NEF value by taking into account important site characteristics such as the climate, geology, etc.

The objective of this study is to investigate how the meteorological drought is transformed into hydrogeological drought, by focusing on: (1) the selected state variable to apply the threshold level method (piezometric level, aquifer-river exchange, recharge, etc); (2) the selected NEF value; and (3) the minimum drought area (i.e. the minimum affected area necessary to considered as a regional drought event).

The study zone is the Upper Guadiana basin in Spain. This area present a semi-arid climate (average precipitation is 400 mm/year and evapotranspiration exceeds 1100 mm/yr). The surface basin presents a dense river net, and is underlying by a groundwater aquifer system with these main characteristics: (1) conformed by five interconnected aquifers with a high transmissivity; (2) regional discharges with wetlands associated; (3) a strong aquifer-river interaction; (4) two of the aquifers (Campos de Montiel y La Mancha Occidental) have been officially declared overexploited in 1980.

The meteorological drought analysis is performed by applying the threshold level method to the observed rain time series. The hydrogeological drought analysis is performed by applying the threshold level method to (1) the spatial groundwater recharge, (2) the aquifer system storage variation, and (3) the aquifer-river exchange. These time series are obtained by numerical simulation of the aquifer system in the period compressed 1958-2001.

The comparison between the meteorological and the hydrogeological droughts shows how the hydrological and hydrogeological systems can modulate the meteorological drought signal. As a result the hydrogeological drought shows lower frequency and larger persistency than the meteorological drought. The drought characteristics (i.e. intensity, duration and frequency) strongly depend on both the NEF value and the minimal drought area.

The aquifer-river exchange volume has reveled as a good state variable to characterize hydrogeological droughts. This variable works well in the hydrogeological drought assessment at the basin scale because it provides the temporal evolution of the spatial integration of the exchange for the whole basin.