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Understanding the hydrological functioning of headwater streams using periodic observations of river flow state

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Due to their upstream position in river networks, many headwater streams (HS) experience recurrent flow cessation and/or drying events. They have many ecological values since they are located at the interface between terrestrial and aquatic ecosystems and contribute to good status of rivers (sediment flux, input of organic matter...). However, the understanding of HS remains limited because gauging stations are preferentially located along perennial rivers and, consequently, the proportion of intermittent rivers (IR) is highly underestimated.

In France, the observation network ONDE ("Observatoire National Des Etiages", in French) was designed by ONEMA to complement discharge data from the conventional French River Flow Monitoring network (HYDRO) to better understand HS dynamics. ONDE provides visual observations of flow state at 3300 sites along river channels located throughout France since 2012. One observation is made every month between April and October and the frequency of observations may increase during drought period to 4 visits / month. One of the following flow states is assigned at each observation: "flowing", "no flow" or "dry".

The objective of this work is to combine and valorize information from both networks in order to describe the hydrological functioning of headwater streams at a regional scale. A special attention is given to characterize spatial distribution and frequency of flow intermittence and to explore how flow intermittence patterns are related to environmental drivers.

A first analyze of the ONDE network indicated that 35% of sites have shown that at least one zero-flow event between 2012 and 2016 against only 8% with the HYDRO database considering gauging stations as intermittent when the mean number of zero flows $\geq$ 5 days/year. The proportion of zero-flow events for 93 ONDE sites was higher than 50%. Conversely, no drying events were observed for 1680 sites (50 %) during the observation period. These dry events mainly occurs during August and September and the most impacted years were 2012 and 2016 (drying frequency > 20% across France in August and September).

The second step consists in converting the sample of discontinuous observations into continuous time series of river flow states in order to study how flow intermittence develops in both time and space. For this purpose, we matched one ONDE site with one neighboring HYDRO gauging station with respect to distance, drainage area and river flow regime and a relation between discharge and river flow states was investigated. Results show that it is difficult to associate a specific flow range observed at the gauging station with zero-flow conditions because flow could change at very small scale ($\sim$20 meters). Geostatistical methods have been developed to assess the spatial distribution of IRs and to characterize the spatial pattern of zero flows. Finally artificial neural network models were tested as promising tools to account for nonlinear processes involved in the development of flow intermittence.