



## **Processes behind multi-year droughts in catchments with seasonal climate and storage**

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Multi-year droughts in groundwater and streamflow occur in catchments with an arid or polar climate with low seasonality (B/E-climates). In addition, multi-year droughts are found in catchments with seasonal climate (C/D-climates) and considerable storage (e.g. in lakes and groundwater). The causes of these long-lasting droughts are not easy to determine because a combination of mechanisms plays a role. In this research, we studied droughts in two headwater catchments in the Czech Republic, i.e. Upper-Metuje and Upper-Sázava. As a common model we used the semi-distributed rainfall-runoff model HBV. Droughts in precipitation, soil moisture, groundwater, and discharge were evaluated using the threshold level method with a smoothed monthly 80th percentile of the duration curves as threshold. The processes behind the most extreme multi-year droughts in the two catchments have been analysed. In Upper-Metuje we used: i) the 1983-1984 groundwater drought (duration 14 months) caused by two successive summer droughts in 1982 and 1983, and ii) the 1999-2001 groundwater drought (duration 20 months, with short interruptions), caused by two summer and autumn droughts in 1999 and a spring drought in 2000. In Upper-Sázava we studied: the 1989-1992 groundwater drought (duration 25 months) caused by two successive winter droughts in 1989-1990 and 1990-1991.

Based on the study of these long-lasting groundwater droughts we found the following mechanisms underlying the development of these multi-year droughts:

- more than one precipitation drought period is needed over several years: an isolated precipitation drought is attenuated in the stores,
- a considerable lag occurs: the first precipitation drought leads to lower groundwater levels, but only after a second or third precipitation drought a groundwater drought develops,
- quickflow by snow melt does not recharge the groundwater system, but is discharged to the stream as surface runoff or shallow subsurface runoff: groundwater droughts continue, whereas droughts in discharge are interrupted, but they return to their drought state afterwards,
- at the end of the multi-year drought, groundwater levels are still low and the system is vulnerable to another drought if recharge is not above average for a longer period.

This analysis shows the mechanisms related to multi-year droughts in catchments with a seasonal climate and considerable storage in lakes or groundwater. It shows that although droughts are unique, having different causes and different timing, they share common characteristics.