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Combining concentration-discharge hysteresis and reach-scale lateral flow modelling to characterize flood water origin and processes: application to karst catchments

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We propose a data-driven approach of concentration-discharge (C-Q) relationship analysis, including a new classification of C-Q hysteresis loop at the catchment scale, combined to a simulation of lateral Q and C at the reach scale. We analyse high-frequency, multiple-site records of Q and electrical conductivity (EC) in karst catchment outlets, in which EC informs on water residence time. At the catchment scale, contributions of pre-event water (PEW) and event water (EW) during storm events are investigated through hysteresis loops analysis, which allows inferring hydrological processes. Our new classification of hysteresis loops is based on loop mean slope and hysteresis index. At the reach scale, lateral Q and EC are simulated using a diffusive wave equation model, providing a more spatialized picture of PEW and EW contributions to streamflow during storm events. The methodology is applied to two catchments (Loue river and Cèze river) in France, including 8 gauging stations with hourly Q and EC time series covering 66 storm events.

For both catchments, a conceptual model of water origin and hydrological-processes seasonal and spatial variability is drawn. Regarding Loue catchment, summer and fall storm-events are characterized by contribution of PEW through piston-type flows, whereas decreasing EC values in winter and spring storm-events indicate the major contribution of EW through surface runoff and following fast infiltration in karst. EW contribution is increasing towards downstream. Regarding Cèze catchment, higher contributions of EW are observed, indicating that fast infiltration and surface runoff are the dominant processes, associated to a PEW signature in summer and fall. PEW contribution also increases in karstified areas. Intra-site water origin seasonality is mostly related to karst aquifer saturation state, whereas inter-site variability is linked to karst areas extension. These results are encouraging to extend this approach to a variety of sites, notably influenced by important surface water/groundwater interactions, and groundwater flooding.