Hydrodynamics of karst aquifers in metamorphic carbonate rocks: results from spring monitoring in the Apuan Alps (Tuscany, Italy)

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Storm hydrographs and lags measurements

The components of the storm hydrographs of the two springs were analysed. The storm hydrograph represents the spring response to an impulsive infiltration event. Several infiltration events were examined for each spring. Two types of storm hydrograph can be broadly distinguished: simple and complex (multiple) ones. The former ones consist of single peaks whereas the latter ones are composed by consecutive peaks because of multiple precipitation events. The storm hydrograph parameters considered in this study are listed below (Fig. S1; Kresic & Stevanovic, 2009):

- The rising limb (from point A to C) – the time elapsed from the beginning of flow increase (A) and the maximum discharge (B) is called the concentration time (Δt_C). The difference between Q_C and Q_A gives the magnitude of the discharge increase.
- The starting time (Δt_S) – the time elapsed between the onset of precipitation (t_{P0}) and the beginning of the rising limb (t_A).
- The falling time (Δt_f) – the time interval from the maximum discharge (point C) and the end of the storm hydrograph (E). The time interval from A to E gives the storm hydrograph duration (Δt_b).

- The lag time (Δt_{lag}) between the centroid of precipitation (C_P) and the maximum discharge (C).

The simple and the complex storm hydrographs were analysed with the same method, although the information carried by the latter is more complicated to unravel. The parameters of the multiple storm hydrographs were measured for each individual peak and the falling time was measured only for the last peak. If the last peak was too irregular, the parameters were extracted for the first peak only. Rainfall rate and the duration of dry conditions (i.e., without significative precipitation, Δt_p) previous to each infiltration event were considered. The thermograph and chemograph corresponding to each storm hydrograph were also considered and the lag time between Q_C and T/EC peaks were measured ($\Delta t_{lag(Tp1\text{-}Qc)}$, $\Delta t_{lag(ECp1\text{-}Qc)}$, respectively).

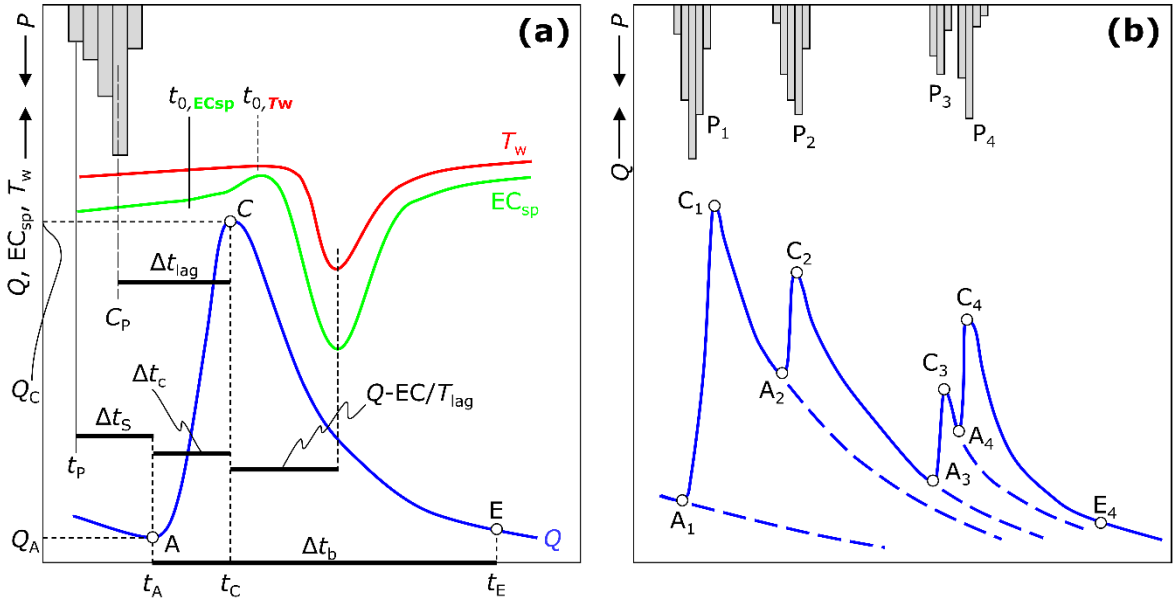

Fig. S1a Simple storm hydrograph and its components; thermograph and chemograph components are showed; **b** Complex storm hydrograph. Redrawn after Kresic & Stevanovic (2009).

ESM Reference

Kresic N, Stevanovic Z (2009) Groundwater hydrology of springs: engineering, theory, management and sustainability. Butterworth-Heinemann.