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Discussions

# *Interactive comment on* "Hydrograph separation: an impartial parametrization for an imperfect method" *by* Antoine Pelletier and Vazken Andréassian

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We would like to thank Pr. Ian Cartwright for reading our manuscript and for his careful and useful review. Here are our answers to the points raised by his remarks.

### Hydrograph separation and hydrological processes

The separation of streamflow in two components – the slow and the quick one, or more precisely the delayed and the non-delayed one – is artificial: there is generally a wider



range of hydrological processes at stake that have different response times to hydroclimatic events. Having said that, it is still possible to set up an arbitrary barrier between the *not too delayed* components of streamflow and the *delayed enough* components.

But attributing the flow component to an explicit physical process seems to be risky with a conceptual separation method like the one we present in the manuscript. Pr. Cartwright highlights that we define baseflow as the groundwater component of streamflow and quick flow as the surface runoff component. This distinction is improper and partial, we agree that it is an oversimplification of the system. Ideally, we should take into account various intermediate stores of water, for which we do not want to make hypotheses about their water residence time.

Anyhow, process interpretation of a conceptual separation method is hazardous practice – this was highlighted too by the interactive discussion with Pr. Beven. In the revised version of the article, after explaining the various types of water sources and their response behaviour, we will define baseflow as the sum of delayed streamflow components, whatever source they are from. The interest of this component is that it bears inter-annual memory of a catchment.

### Abstract

We believe in short and catchy abstracts that are likely to be read entirely. However, we agree that some crucial elements are missing in the proposed version. We propose this new abstract, which is a little longer.

> This paper presents a new method for hydrograph separation. It is well-known that all hydrological methods aiming at separating streamflow into baseflow – its slow or delayed component – and quickflow – its non-delayed component – present large imperfections, and we do not claim to provide

here a perfect solution. However, the method described here is at least (i) impartial in the determination of its two parameters (a quadratic reservoir capacity and a response time), (ii) coherent in time (as assessed by a split-sample test) and (iii) geologically coherent (an exhaustive validation on 1,664 French catchments shows a good match with what we know of France's hydrogeology). With these characteristics, the method can be used to perform a general assessment of hydroclimatic memory of catchments. Last, an R package is provided to ensure reproducibility of the results presented.

**Introduction and review section**

In the revised version of the article, we will merge the two sections. As underlined by Pr. Cartwright, some recent references are missing in the literature review. We propose to add several citations listed in the references section of this comment.

**Section 3**

Readability of the equations

As suggested by Pr. Cartwright, we will add a table of variables to help the readability. We will also replace the lengthy explanation of the integration scheme through an equation including Dirac functions on page 7 by a plain-text explanation.



Reservoir update

In the presented algorithm, there are two ways the level of the reservoir can be updated: downward, when the computed baseflow is greater than measured streamflow; upward, once a year, at the yearly minimum point of measured streamflow. The first one is understandable – baseflow cannot be greater than total streamflow – and the second one is just practical: as highlighted by Pr. Cartwright, in humid temperate French climate, the hypothesis that streamflow is only composed of baseflow at its yearly minimum is questionable, even though most recent French summers were dry enough to support this assumption. However, we need an upward update mechanism to compensate the downward one, since it allows the algorithm to be constrained to a water balance condition – that can be summed up by $\beta = BFI$. Removing the yearly upward update adds a degree of freedom for the model calibration and it causes significant difficulty to optimize the values of parameters. We will add this discussion in the revised version of the paper.

Recharge as linear fraction of streamflow

This issue was underlined by both referees, Pr. Romanowicz and Pr. Cartwright: the fact that the water inflow of the quadratic reservoir is a linear fraction of daily measured streamflow is a major hypothesis of the algorithm. This is a very crude estimate of aquifer/subsurface recharge, which is a far more complex process including water flow through banks of the river, soil water balance, vegetation, seasonality, etc. Solving the groundwater transmissivity equation in a theoretical framework of a shallow aquifer connected to a river shows that recharge in anything but a linear fraction of streamflow; and real configurations of river-aquifer interactions are even more intricate.

However, as highlighted by the exchange with Pr. Keith Beven, we do not claim to present a physically-based hydrograph separation method. For such a purpose, we would need an explicit recharge model, that would add more hypotheses and parameters: an elaborate production function in such an imperfect, but objective, algorithm would be a disproportionate weapon. Therefore, the inflow function composed of a fixed linear fraction of daily streamflow can be regarded as a basic estimate of the quantity of water that bears the catchment memory.

In the revised version of the article, we will add a clearer explanation about the inflow function of the reservoir.

Tau parameter

The idea of the optimization criterion used to calibrate the parameters is the following: we try to correlate two estimates of the quantity of water available to bear the catchment memory. First, computed baseflow; second, medium-term or long-term cumulative effective rainfall – which we estimated through the Turc-Mezentsev formula. Parameter $\tau$ is the length of the cumulating period for effective rainfall, it is an estimate of the response time of the catchment. Unfortunately, it gave less consistent results than the computed values of baseflow index, due to more calibration difficulty.

**Section 4**

We agree with Pr. Cartwright that using geochemical data would be a less questionable way to calibrate our hydrograph separation process than the hydroclimatic criterion that we use. Unfortunately, we do not have available enough geochemical data in the French catchments of the sample to carry out a reliable study. We will mention this idea as a perspective.



**Section 5**

The technique presented in the manuscript is designed to be used on non-anthropised catchments and perennial streams. As highlighted by Pr. Cartwright, these limitations need to be more explicitly exposed in this section. When the value of streamflow is affected by human activity – pumping, regulation by dams, canals, etc. – the algorithm can be applied only if the anthropised fraction of streamflow is small enough. This is a classical check in rainfall-runoff modelling. The case of groundwater abstraction resulting in disconnection is different: it is still caused by human activity but it indirectly affects streamflow. In such a case, if the aquifer contribution to the river is zero; but in the algorithm, reaching an empty filtering reservoir could result in some artefacts. This is a clear practical limitation of the method.

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