Geophysical Research Abstracts
Vol. 16, EGU2014-10977, 2014
EGU General Assembly 2014

Application of a baseflow separation method in ten minutes hydrological records in Navarre (Spain)

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A baseflow separation method separates streamflow into its partitions of baseflow and surface runoff. Runoff is measured in hours to days from its rainfall source while baseflow takes days to years to appear as part of the streamflow. As a consequence, surface runoff has a very fast response; it is followed by the more moderate and slightly delayed response of the interflow, and finally comes subsurface flow or baseflow, defined as the dry-weather flow of streams, that is further delayed, softer, and continual, lasting longer in the hydrograph.
Conventional baseflow separation methods were originally designed to be applied to individual event hydrographs. These manual graphical methods are subjective procedures on which visual approximations and the ability of each person is key to get a proper baseflow separation.
Eckhardt (2005) proposed the general form of a recursive digital filter considering a digital filter parameter, a, and BFImax (maximum value of long term ratio of baseflow to total streamflow). This equation can be rearranged to solve for the baseflow at the current day, given the substitution of direct runoff plus baseflow for the total streamflow.
It is a conceptual method where the 3 hydrograph components: runoff, interflow and baseflow, are associated to high, medium and low frequency signals, respectively, waves from higher to lower velocity. This technique allows its application to long periods (several years), that is why they are also called continuous separation techniques, achieved by detecting non-linear changes on the streamflow. These mathematical methods are lacking any hydrological basis, but their goal is to generate the low frequency curve that can be related to the baseflow of a watershed in an easy to automate way.
This technique has been applied to the ten minutes hydrological record from La Tejería experimental watershed in Navarre, Spain, and gives us a baseflow as a curvilinear and deferred in time response, similar in shape to a normal curve, as proposed by Horton (1933).
The index BFImax controls the area below the curve, whereas, a, the recession parameter, delays and attenuates the curve, moving forward the baseflow curve center of gravity. Increasing a, the baseflow curve is delayed with respect to the total stream flow hydrograph. In this application three digital filter passes were chosen as the most suitable to describe properly the baseflow for a wide range of hydrographs. The main advantage of applying several filters is to obtain softer baseflow hydrographs, which adapt better to complex, multi-peak, hydrograph shapes of different magnitudes.
The filter parameter, a, will always be between zero (0) and one (1) and will limit the average annual baseflow between the long-term baseflow and the average annual streamflow. The adjusted values in this application have been very high, 0 999$\leq$ a$\leq$ 0.9999, and on the other hand 0.25 $\leq$ BFImax $\leq$ 0.65. The higher filter parameter, a, are combined with lower BFImax corresponding to the more attenuated and delayed passes within the baseflow curve. The preferred option is characterized by the three passes (a- BFImax): 0.9999-0.65+0.9995-0.4+0.999-0.25; the average and standard deviation baseflow to streamflow ratio of the 9 hydrological years analyzed is 0.65$\pm$0.07. This value is half way between values of 0.80 for perennial streams with porous aquifers and 0.50 for ephemeral streams with porous aquifers proposed by Eckhardt.
The comparison of conventional baseflow separation methods, with the Eckhardt digital filter method shows how Eckhardt can be applied to the continuous hydrograph, always in the same way, being consistent and diminishing the subjectivity of conventional methods. Moreover, pollutants that infiltrate down through the root & vadose zone feeding groundwater, are re-appearing in the baseflow. Water quality models will have to include contaminants from baseflow if their contribution is relevant, another reason why baseflow separation methods should be chosen carefully, and Eckhardt recursive digital filter stands as a good option.