Study of two hydrograph separation methods for the best resolution of the concentration -flow relationship mixing equation.(Obs. ORACLE)

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José Manuel Tunqui Neira[1,2*], Gaëlle Tallec[1], Vazken Andréassian[1], Jean-Marie Mouchel[2]

[1]UR Hydrosystèmes et Bioprocédés, Irstea, Antony, UMR Metis 7619 UPMC * jose.tunqui@irstea.fr

www.irstea.fr

1. Introduction

1.1. Mixing equation

$$C(t) = C_{1j} + (C_{2j} - C_{1j})\frac{Q_e(t)}{Q(t)}$$

with :
- $C(t)$: Total concentration for the time step t (mg/L)
- $Q_e(t)$: Quick response runoff for the time step t (m^3/s)
- $Q(t)$: Total flow for the time step t (m^3/s)
- C_{1j} : Representative daily parameter of the concentration from the baseflow (mg/L)
- C_{2j} : Representative daily parameter of the concentration from the quick response runoff (mg/L)
- $Q_b(t)$: Baseflow for the time step t (m^3/s)

$$Q_e(t) = Q(t) - Q_b(t)$$

Hydrograph separation

✓ It is vital to determine the value of this component because it will determine the effectiveness of our equation:.

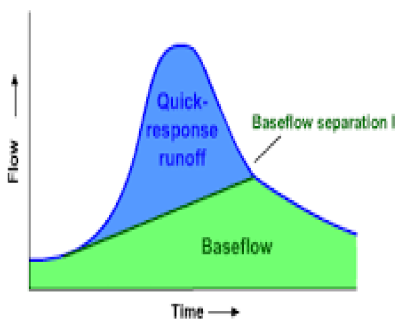

Figure 1: Classical hydrograph separation

Two Methods

✓ Smoothed Minima Technique [1]

✓ Recursive digital filter [2,3]

2. Material and method

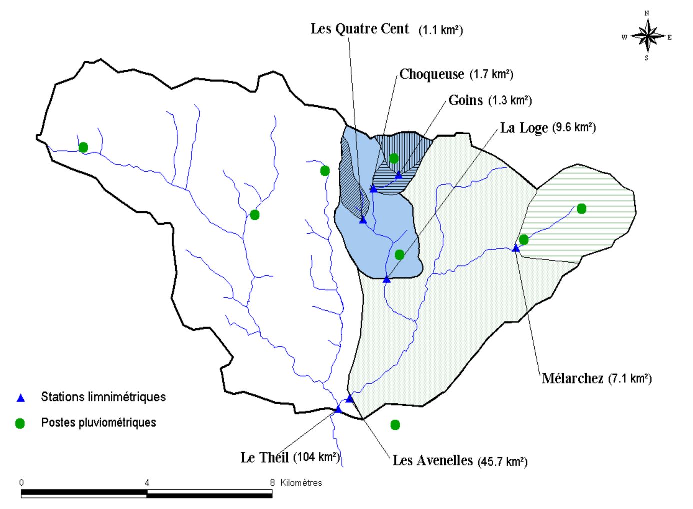

Figure 2: Orgeval catchment with its corresponding subs-catchments (source: Irstea-Antony)

✓ Study Zone: Catchment of Avenelles (45,7 km^2)

✓ High-frequency measurements from River Lab [4] (approximately every 30 minutes) from June 2015 to August 2016.

✓ Ten chemical elements studied (Table 1)

Table 1: Summary of the mean values, min and max of the chemical elements studied from the high frequency measurements

item	Unit	Avenelles Catchment		
		Mean	Min	Max
magnesium	mg/L	8,58	2.98	11,46
potassium	mg/L	3,53	1.57	8,65
calcium	mg/L	118,55	56.51	168,04
sodium	mg/L	13,10	2.79	26,53
strontium	mg/L	0,35	0.17	0,57
fluoride	mg/L	0,15	0.03	2,88
sulfate	S mg/L	19,06	4.06	25,69
nitrates	Nmg/L	11,85	3.08	18,36
chloride	mg/L	31,48	3.63	51,05
phosphate	P mg/L	0,13	0,00	0,22
rainfall	mm/30min	0,05	0,00	10,10
flow	m^3/s	0,33	0,05	12,20

✓ We present here only the calculations and results related to the nitrates ions

3. Description of methods of hydrograph separation

3.1. Smoothed Minima Technique [1]

✓ Divide the mean daily flow data into non-overlapping blocks of five days and calculate the minima for each of these blocks, and let them be called Q_1, Q_2, Q_3...Q_n.

✓ Consider in turn (Q_1, Q_2, Q_3), (Q_2, Q_3, Q_4),...(Q_{i-1}, Q_i, Q_{i+1}) etc. In each case, if 0.9 x central value < outer values, then the central value is an ordinate for the base flow line. Continue this procedure until all the data have been analyzed to provide a derived set of base flow ordinates Qb_1, Qb_2, Qb_3,...Qb_n which will have different time periods between them..

✓ By linear interpolation between each Qb_i value, estimate each daily value of Qb_1...Qb_n:

✓ If $QB_i > Qi$ then set $QB_i = Q_i$

3.2. Recursive digital filter[2,3]

✓ We use the following equation:

$$f_k = \alpha f_{k-1} + \frac{(1+\alpha)}{2}(y_k - y_{k-1})$$

Where :

f_k : filtered quick response at the kth sampling instant.

α : parameter of the filter, in our case 0.90

y_k : Total flow

✓ Finally the base flow is $f_k - y_k$

✓ The filter was passed 3 times over the data: forward, backward et forward again.

✓ Also if $QB_i > Qi$ then set $QB_i = Q_i$

3.3. Results

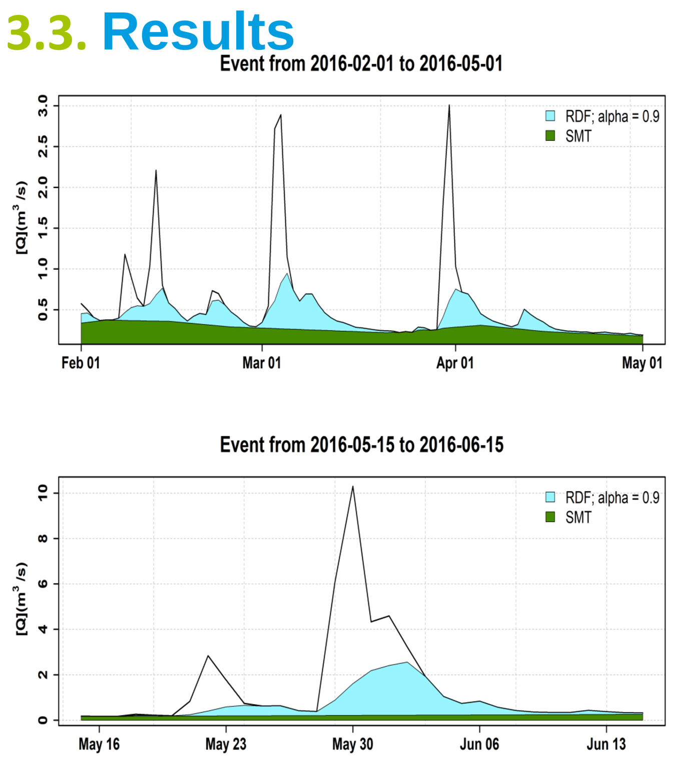

Figure 3: Graphical comparison of the two methods used in different climatic events (floods). In light blue, the Recursive Digital Filter method (RDF), in green the Smoothed Minima Technique (SMT) method

4. Application of the two methods of separation of hydrographs in our mixing equation

4.1. Solution of the mixing equation

✓ Resolution of the mixture equation with two unknowns C_1 and C_2, using the linear regression method.

✓ Thanks to the high frequency we can calculate values of C_1 and C_2 for each day.

✓ For solve the equation $C(t) = C_{obs}$ from High-frequency data.

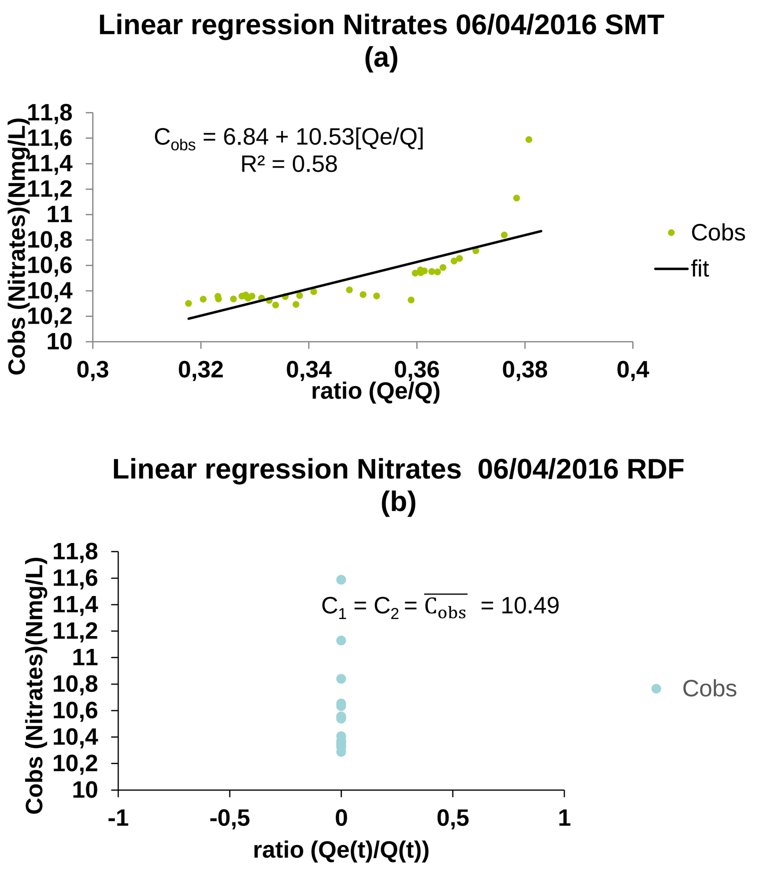

Figure 4: Example of calculation of C_1 and C_2 Nitrates, from C_{obs}, Q_e and Q using the linear regression method for : a) Smoothed Minima Technique (SMT) and b) Recursive Digital Filter (RDF), date of 06/04/2016.

4.2. Results

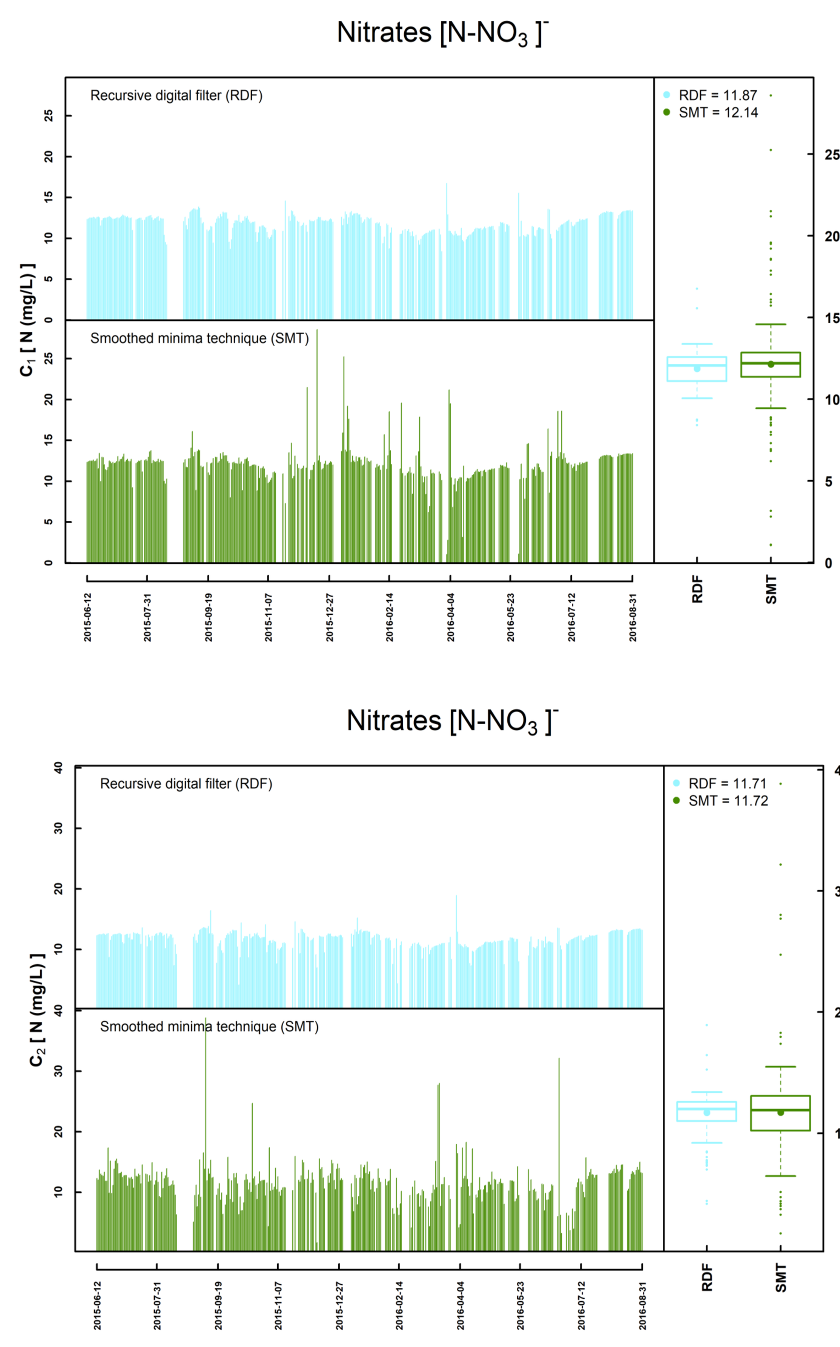

Figure 5: Values of C_1 (up) and C_2 (down) for each day for the whole study period (from 06/12/2015 to 31/08/2016) for Nitrates: in light blue the Recursive Digital filter method (RDF), in green, Smoothed minima criteria (SMT)

✓ For each chemical element, the daily values of C_1 and C_2 were calculated from June 2015 to August 2016.

✓ For the majority of chemical elements, The Recursive digital filter (RDF) method with α = 0.9, has better results than The smoothed minima technique (SMT) method, since the values found for C_1 and C_2 are more stable.

✓ From these results it is envisaged:

✓ To find a single parameter of C_1 and C_2 that efficiently encompasses interactions between flows and concentrations.

✓ To apply this method to medium and low-frequency measurements

5. Conclusions

✓ It is possible to identify two components to explain the variations in the concentration of the ten chemical elements studied.

✓ The separation of hydrographs, is a very useful and simple method for calculating baseflow.

✓ For the moment, the linear regression method works very well for the resolution of our two components C_1 and C_2 of our mixing equation.

✓ The method that works best with our mixing equation is the Recursive Digital Filter method, so for the next stage of our work, we will use only this method

6. Perspectives

✓ Sensitivity analysis of parametersC_1 and C_2 to better understand how they vary.

✓ Make seasonal study of C_1 and C_2 parameters.

✓ Link C_1, C_2 and flow descriptors.

✓ If the optimization of $C_1$and/or C_2 does not work, it may be necessary to introduce a third component C_3, which represents the subsurface flow, as shown in the following figure:

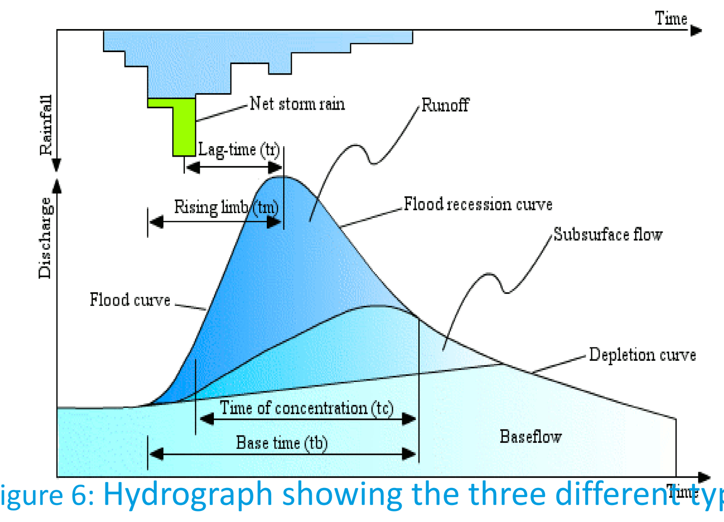

Figure 6: Hydrograph showing the three different types of flow [5]

7. References

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