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## Reply on RC2

Maxime Gillet et al.

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Author comment on "Identification of the contributing area to river discharge during low-flow periods" by Maxime Gillet et al., Hydrol. Earth Syst. Sci. Discuss.,  
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**This study estimates the contribution of several groundwater reservoirs, differentiated by geological characteristics, to the low-flow period of a Mediterranean catchment. The authors used various methods to decide on the end-members in an EMMA, and considered correlations between tracers and their variability. I appreciate this thorough analysis and relatively objective decision on end-members, and the work the authors put in here. Additionally, the uncertainty analysis was well performed by using different end-member definitions.**

**However, I must admit I stopped reading the manuscript shortly before the Discussion sections. The manuscript is overflowing with English mistakes, mistakes in units, inconsistencies, strange sentences, etc. It is very difficult to follow and URGENTLY needs a native speaker to polish it up. It borders on unreadable, and it takes too much concentration while reading. Sometimes I was not even sure if I understood a sentence correctly and I had to read it five times; this must not be the case in a scientific publication.**

**Besides this major point, the results section sometimes includes discussion sections...either the authors separate these more clearly, or they combine results and discussions. I have no preference here.**

**Following is a list of inconsistencies and questions I had up to approximately the Discussion section. I hope that in a future version of this manuscript, the readability is strongly increased.**

The article was sent to a native English-speaking translator for correction and improvement of the English.

The results section has been re-read and parts have been moved to the discussion.

- **Title: no caps lock, and change "period" to "periods"**

Periods has been changed.

- **L2: change "trial" to "evaluate"**

The modification was made in the text.

- **L5: delete "the" before "trajectory"**

The modification was made in the text.

- **L16: delete the comma before "and quality" and put it behind "quality"**

The modification was made in the text.

- **L18-19: the sentence closes in on itself: "investigating processes that sustain streamflow are required to understand processes that maintain low-flows" (with sustain and maintain, and streamflow and low-flow having basically the same meaning). The sentence says "investigating A is necessary to understand A", which is logical and does not need to be mentioned.**

« Investigations on the process that sustains streamflow have been identified as a requirement to understanding *the dynamics of the hydrological system* »

- **L27: "maintaining base flow" ... also only in mountain areas? Also, in this line "base flow" changes to "baseflow". Decide on one spelling.**

The change was made in the text and the baseflow was kept.

- **L30: delete first "geological"**

Geological has been deleted.

- **L32: the aim of which study? (of course yours, but needs to be mentioned, especially after discussing a lot of other studies before)**

The modification was made in the text.

"but this has rarely been applied to low-flow. The aim of *this* study was, therefore, to identify and then quantify the contributions of the different geological reservoirs during low water conditions in a watershed showing a variety of geological facies."

- **L42-44: unclear sentence. What is the main interest of EMMA? What are model output probabilities?**

The modification was made in the sentence:

"The main interest of the EMMA analysis *resides* in the ability of *this model* to consider the *whole* dispersion of *the* tracers and thus considering all possible mixing configuration associated with *their* output probabilities *calculated in the runs of the model*."

- **L45-48: what is made possible by differentiating water by season, etc.? The combination of hydrometric data and hydrogeochemical data, of the previous sentence? Or does the EMMA method make differentiating water by season possible?**

The EMMA method make differentiating water by season possible and modification was done in the sentence to clarify it.

*"The use of this model with geochemical and hydrological data permits the decomposition of the discharge in several ways. It is thus possible to quantify the proportion of water coming from different seasonal recharges or to quantify the proportion coming from different units of the discharge."*

- **L50: which assumptions, of which tools? Unclear.**

The modification was made in the sentence:

*'Uncertainties in the contribution estimation obtained with these models can only be minimised if the assumptions made for these tools (use of non-reactive tracer and marked difference in the end member) are followed'*

- **L58: which water table? Groundwater? Why is it limited? Is it artesian groundwater?**

It's the alluvial water table. The modification was made in the sentence:

*"By focusing only on low water period in a watershed where the alluvial water table is limited,"*

- **L60: "this paper search"?? applicability of which methods?**

The EMMA method which the last paragraph refers to. Changes have been made to make the sentence clearer.

*"This paper shows the applicability of the EMMA method for identifying the origin of surface water during low-flow to understand flows dynamics in catchments during scarcity."*

- **L62: "productivity" is a strange word for runoff-generation contribution here.**

Productivity has been replaced by *runoff-generation contribution*.

- **L72: why does focusing on low-flows allow the increase of the sampling rate? Also when sampling the whole hydrograph, the sampling rate can be increased, e.g., with automatic samplers.**

This is indeed possible. However, the analysis made only on the summer low water allows to limit the number of analysis which facilitates a more important frequency. In the case of full hydrological cycle studies the majority of studies adopt a monthly frequency with a focus on flood events. Allow was replaced by *facilitates*.

- **L73-77: delete. This is just a summary of the basic layout of every research paper, and therefor unnecessary.**

This paragraph was deleted.

- **L88: Figure 1 1? Figure 1 l (L)?**

The modification was made in the text.

- **L91: 1,110 mm. Adapt everywhere and avoid the space between digits.**

The modification was made in the text.

- **L93: 50 mm in which months exactly? Jul-Sep? And autumn from Oct to Dec?**

Though total rainfall is high, summer rainfall is very low, less than 50 mm (*July to September*), and almost half of the total annual rainfall falls in autumn (*October to December*) during high-intensity rainfall events.

- **L94: modulus = ? also mean monthly annual discharge without capital letters, and the term is very confusing. Is this the monthly or annual discharge? Is this the mean minimum discharge of all months for all years?**

The sentence has been changed:

"The Gardon de Sainte-Croix river has a *mean annual discharge* of 960 l/s, and its *mean monthly annual minimum discharge* is equal to 0.135 l/s at the hydrometric station located at approximately one-third of the basin length ..."

- **L98: "mica schists 1"? what is the meaning of the "1"?**

The sentence has been corrected:

"mica schists (*Figure 1*)"

- **L105: "and suitable to trial our approach carry out our research" English needs correction**

The sentence has been corrected:

"Hence the basin can be considered as little affected by human activity and *suitable to trial our approach*."

- **L111: I would either choose l/s or m<sup>3</sup>/s to make it easily comparable with line 94.**

The flow rate has been harmonized in l/s.

- **L117-118: The first sentence says that rainfall has a low impact on runoff, while the next sentence starts with the information that runoff variations are due to rainfall events.**

The whole paragraph has been changed.

"*The importance of the volumetric discharge rate at the beginning of the monitoring period is linked to the amount of rainfall during winter and spring. But during the summer period the rainy events have a low impact on the stream's volumetric discharge rate which shows small and brief peaks following these events. The flow in fact returned to a level lower than that of the flow measured before the event in 1 to 3 days. This implies that the*

*recharge brought by these rains to the subsurface reservoirs is negligible and hence it is possible to disregard their impact on those reservoirs in our future modelling."*

- **L128: call hydrogen potential by the more commonly known pH. Like in L130, but not PH but pH.**

pH has been corrected in the whole document.

- **L132: collected in tubes? Not in sample bottles? If tubes, how were the closed?**

They were collected in plastic closed tubes to be analysed the same evening and to limit the loss of nitrates and simplify handling in the field. A spare sample bottle of sample was also collected to be preserved and analysed in case of suspected errors in the analysis.

"Samples for the analysis of major ions were collected in *closed* polyethene tubes *suitable for analyses on the IC* (one for the cation and one for the anion)."

- **L137: which reservoirs? It is unclear how the sub-catchments were chosen, since what is meant with reservoir is not clear and Table 1 is not helpful in this regard.**

The mention "*identified as potential end members*" has been added to clarify the sentence.

"*To facilitate the monitoring during the low-flow period, the observations were downsized to two representative sites for each geological reservoir identified as potential end members*"

- **L147: what is the difference of river and surface water? Tributaries? Lakes? And what was the sampling frequency for surface waters?**

The sentence has been changed:

"The 2018 campaign focus on the characterisation of the groundwater contribution during the drying up period of the river with a *high* frequency, *weekly sampling* for surface water and bi-monthly for groundwater."

The term "river" is used for the main river (Gardon de Sainte Croix) and the term "tributaries" is used for the tributaries of this river. There are no lakes mentioned in the publication.

- **L148: does the 4 in brackets mean that four sections were sampled? Why not directly write this then?**

Yes and modifications has been done to clarify it:

"The 2019 monitoring period was complemented to include a spatial analysis where the stream was sampled on *four* sections (*shown as: I, II, III and IV on Figure 1*) ..."

- **L149: what is a "large panel of groundwater"? Also, why does the sampling campaign in 2019 last until December when in line 145 it stops in October? Is this a different sampling campaign and "completed" in Line 148 should be "complemented"?**

The mention "at least" has been added to clarify the text. And larger panel

"Two monitoring campaigns were carried out during the summer of 2018 and 2019. Both spanned *at least* from June to October;"

"... and campaigns including a larger panel of groundwater *sampling site (8 spring or boreholes sites)* were carried out every month

And larger panel has been further detailed and campaigns, with a larger panel of groundwater *sampling site (8 spring or boreholes sites)*, were carried"

Completed was also changed by complemented

- **L151: the wastewater treatment plant was not mentioned in the study description where "minimal anthropogenic influence" was discussed, only tourism and a cheese factory. It must be mentioned there, especially if samples were taken from it...for which I assume it can not simply be ignored.**

Anthropic activities that can impact the stream water quality include tourism, with only two campsites, *one waste water treatment plant* and a cheese factory, all located in the downstream section of the basin.

- **L154: the description of the additional sampling campaign does not make sense. Five sites were monitored with six tributaries, with 3 per site.  $3 \times 5 = 15$ , and not 6. Or is it "side", as in left and right side of the river? That would explain the 6, but why then five locations?**

The sentence has been changed to be clearer:

"Gauging and sampling were performed on five sites distributed along the main river, and *also on six tributaries (3 on each side of the river)* using the same sampling and laboratory analysis method presented above."

- **L156: description of the salt tracer method applied to the tributaries needs to be rephrased, as it is almost incomprehensible. At least I assume the salt tracer method was used, since dilution gauging was mentioned, but then a current meter is used which is a sensor that measures the flow of water and not electrical conductivity...which was used in the main river and not the tributaries where actually dilution gauging was applied (?)...this section is like many before very, very confusing.**

"The discharge *measurements were* carried out by *salt dilution method* on the tributaries and *by exploring the velocity field* using a current meter for the main watercourse."

- **L182: use "18.2 MΩ" instead of "18.2 M". "Rock water" should just be "rock", since it's the mixture of rock powder with the ultrapure type 1 water?**

Modifications has been done.

"Rock powder was mixed with ultrapure water (18.2 M $\Omega$ ) in a 50 mL bottle, in ratio of 1/10 (3g rock water to 30g water)"

- **L187: delete "presented in 2.2"**

"Presented in 2.2" has been deleted.

- **L208: the name of GLUE is wrong, it's likelihood and not probability. The explanation of GLUE in the next two sentences is lacking.**

Modifications has been done.

- **L214: the uncertainty is associated with 5% of the devices used to analyze the data? The sentence seems to say this. And how is the uncertainty due to the chosen tracer in any way related to the measurement precision? This is measurement uncertainty and not the model conceptualization uncertainty.**

There is a difference between analytics errors and natural variability, the sentence just says that the variability allowed for tracers for surface water is set at 5% which is the uncertainty associated with the measurements. For surface water, only 1 point was measured in each campaign and does not show natural variability in a single time point. The only uncertainties that can be attributed to surface water are the uncertainty of the analytical means

"The variability accorded to the tracers chosen for the surface water is defined by the uncertainty associated with the devices used in the measurement (5%)"

- **L214-215: "A temporal variation treats uncertainties associated with the choice of geochemical poles." I have no idea what this means. Temporal variation of what? Treats uncertainties?**

Modifications has been done.

"A temporal variation of ionic concentration is included in the uncertainties associated with the choice of geochemical poles".

- **L215: linking measurement uncertainty to the variation in the tracer signal makes absolutely no sense. Of course the tracer signal will vary in time, otherwise it's not a good tracer. The measurement uncertainty must be linked to the uncertainty of the measurement device, or sampling uncertainty due to spatial heterogeneity.**

The sentences has been corrected

« This measurement uncertainties are defined by the variation *in the measurements of the control samples.* »

The explanation of the « *control sample* » has been added in the methodology :

« *The mobile phase was prepared in 1 L of deionized water (18.2 MOhms-cm at 25 °C) with 50 ml of Na<sub>2</sub>CO<sub>3</sub> /NaHCO<sub>3</sub> at 64mM/20mM for the anions, and 25 ml of 2.6-Pyridinedicarboxylic acid at 0.02 M and 2 ml of HNO<sub>3</sub> 3N for the cations. The chromatographs obtained were calibrated according to a series of standards ranging from 0.01 to 100 mg/L for the target ions. Two control samples, one with low concentrations close to water found in metamorphic waters (EC of 50 μS/cm) and the other with high concentrations close to water from sedimentary reservoirs (EC of 600 μS/cm), water, were analysed at the beginning of each series of analysis as well in order to ensure the absence of instrumental contamination or drift. A verification step was carried out on the integration of the chromatographs obtained.*»

This section presents only the variability associated with surface water tracers. The variability of groundwater is presented in the following section, which presents the different approaches used to try to take it into account (temporal monitoring, seasonal mean, geological mean) which integrate the spatial heterogeneity . It is therefore not relevant to address these issues of heterogeneity or spatial variability here

- **L224: the digits in brackets behind each method that follows are unnecessary**

The digits are been deleted.

- **L229: why does the seasonal mean (2), which considers seasonal mean values, then use annual mean values?**

The calculation has been done on the average of the groundwater sites previously defined as representative of the formation and not on the annual average. The average is therefore seasonal because it takes into account only the values during the summer low water period and not an annual average.

"Annual" has been removed in the sentence:

"The second method, so-called hereafter "Seasonal Mean", consider the mean seasonal value of the groundwaters selected as representative of the reservoir."

- **L254: mark the discussed end-members also clearly in Figure 4.**

Ellipse has been added to Figure 4.

- **L256: "3 groundwater"???**

"This end-member is composed exclusively of water from sedimentary rock reservoirs, mainly limestones and dolomites, hence consistent with the composition of groundwater *issue from limestone aquifers* found in the literature."

- **L258: correct unit is  $\mu\text{S}/\text{cm}$ , not  $\mu\text{s}/\text{cm}$  which looks like seconds.**

The modification was done.

- **L260: correct to assume the authors mean MEGAequivalent per liter with MEQ/l ( $10^6$ ), instead of milliequivalents per liter mEq/l ( $10^{-3}$ )?**

The modification was done.

- **L264: the sulphate contents remain low for other elements?**

Sentence has been changed:

"Indeed, sulphate contents vary from 0.3 to 1 mEq/l and remain relatively low for all other *end-members*."

- **L265: specify the schist alterations at least in the Discussion if not here directly**

There is no specific information on schist alteration on this watershed that can be added her. But the discussion includes a section on schist alteration."

- **L277: it was not mentioned in the site description that black mica schist is directly under the limestone plateau. In which depth does the limestone end and black mica schist start?**

Only one source of information (a drilling) carried out on the limestone plateau was found

and it gives a thickness of 20 meters for the limestones laid on the black micaschists.

- **L279: it is mentioned that Figure 5 shows a seasonal evolution of ion concentrations, but Figure 5 has no temporal information, at least not clearly discernible.**

The seasonal variation is discerned by the drift seen on the waters of the different reservoirs. A sentence has been added to better explain the observed variation.

"The definition of the correct geochemical signature of the different poles is complicated by the seasonal variation of the concentration in groundwater. *This increase of different ion concentration  $Ca^{2+}$ ,  $Mg^{2+}$ ,  $SO_4^{2-}$ ,  $HCO_3^{2-}$  during summer* observed in groundwater ... "

It is true that this variation is not very discernible on graphs that do not treat the information in a temporal manner, but the document already contains a lot of figures and the addition of a new figure does not seem judicious to me.

- **L287: "lixiviation" -> "leaching"**

Modifications has been done.

- **L322: There are more than one outlier visible in Figure 8, I count at least 3, e.g. borehole cluster 1 in black mica schist, two cluster three elements in black mica schist.**

Only two outlier are visible. The first corresponds to the point presents in the granite formation and previously identified as a mixture of limestone and black mica schist. The second correspond to the black mica schist spring identified by the classification as being from the quartz micaschist pole. Conversely, the K-means method attributes this point to the sedimentary rock clusters' in coherence with the mixing hypothesis of groundwater issue from limestone and black mica schists.

The drilling in the black micaschists is badly placed (his location has been corrected in the figure), the point is located on the fountain but the drilling is located in the limestone cause.

- **L346-347: identical measurements of dissolved oxygen in springs and surface water to those of streams and springs? Two times surface water/stream and springs are compared, of course they are the same.**

The sentence has been modified by delating some term

"The measurement of dissolved oxygen in the springs confirms this by revealing identical oxygen concentrations to those found in the streams"

- **L361: contribution of -10%?**

Minus has been changed *in under 10%*.

- **Figure 1: in the caption "a water mine is a horizontal well dug a slope"??? what does this mean? Why is the station PR marked in the figure and not also the main outlet?**

It is the definition of this term quite specific to the Cevennes. The main output has been noted C4 and PR corresponds to the measuring station presented in the text and located on this figure

- **Figure 2 does not seem to transport important information that is not also described in the text and could be deleted.**

The figure is used in the document and is used as a reference in the results section to show the differences in flow rates between years

- **Figure 4: the legend is too small.**

The legend was made bigger.

- **Figure 5:  $\mu\text{S}/\text{cm}$  is written as  $\text{uS}/\text{cm}$ . Are all axis logarithmic? Must be mentioned somewhere.**

The modifications has been made.

- **Figure 9: change colors from black mica schist and limestone, they are very difficult to differentiate**

The size of the symbols have been increased to make the difference between water from black micaschists and limestones more discernible

- **Table 1: more confusing than helpful. Is it important if collection was outsourced? Outsourced to whom? Can be deleted in my opinion. What do the numbers in the rows "Sampling in 2018" and "Sampling in 2019" mean? What does bold mean? The text is not helpful due to the lack in English.**

Modification has been done Sampling in 2018– Number of sampling in 2018

For bold row it was explain in the caption: "The bold row in the table correspond at main groundwater sites, sample weekly."

- **Table 3: the caption mentions red values, there are no red values**

Red has been changed in bold.