# RESPONSE TO REVIEWERS
# of “Changes in discharge and solute dynamics between a hillslope and a valley-bottom intermittent streams”
## by S. Bernal and F. Sabater
## 19th of January of 2012

We would like to thank the reviewers for their thoughtful review of the manuscript. They raise important issues and their inputs are very helpful for improving the manuscript. We agree with almost all their comments and we have revised our manuscript accordingly.

We are already crafting a revised version of the paper that it states the hypothesis and the implications of our work more clearly than before. Moreover, we are including all reviewers’ suggestions and clarifying the text when needed. We are confident that the new version of the manuscript will be greatly improved.

We respond below in detail to each of the reviewer’s comments. In addition, we include how we have revised things, or if we have slightly disagreed with something, we stated why. We hope that the reviewers will find our responses to their comments satisfactory, and we are willing to finish the revised version of the manuscript including any further suggestion that the reviewers may have.

Please, find below the referees’ comments repeated in italics and our responses inserted after each comment. To facilitate the work of the reviewers, in some instances we refer to the former manuscript indicating the page and the line (page-line).

Looking forward hearing from you soon.

Sincerely,

Susana Bernal and Francesc Sabater

## *Response to comments from Anonymous Referee #1*

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### General comments

1) *The authors refer a lot to previous work, of which most comes from studies in humid, often boreal, catchments, without clearly discussing differences between the geographical setting. This needs to be clarified.*

We agree with the reviewer that we need to emphasize the differences between temperate and arid/semiarid systems and we thank him/her for highlighting this important point. In fact, climate is a key factor controlling the interaction between surface and subsurface water bodies at the stream-riparian interface. In humid regions, the flux of water in the stream-riparian interface is usually from the aquifer to the stream and losing stream reaches are not as common as in arid and semiarid regions. By contrast, losing streams are common in arid and semiarid catchments where a large volume of stream water can be retained in the alluvial zone (high hydrological retention). This phenomenon has been widely described in many arid and semiarid systems (e.g., Valett et al., 1996; Morrice et al., 1997; Martí et al., 1997, 2000; Butturini et al., 2003).

In addition, climatic conditions can strongly affect the frequency as well as the duration of the hydrological connectivity between hillslope, riparian and stream zones (and thus, the timing and magnitude of solute transport). In temperate catchments, hydrological connectivity between hillslope and riparian zones can last for weeks or even months (Jencso et al., 2010), whereas in semiarid catchments the hydrological connection between hillslope and riparian zones may only eventually occur during some large storm events (Meixner and Fenn, 2004; Meixner et al., 2007). We agree with the reviewer that this is also an important difference between temperate and semiarid catchments that needs to be included in the manuscript.

We have carefully revised the introduction and the discussion sections of our manuscript. Now, we specify the differences between temperate and semiarid regions mentioned above, and we clearly refer to studies performed in either temperate or semiarid catchments.

Regarding stream-riparian hydrological interactions, the former paragraph P9507.12 has been modified as follows (changes are underlined):

> "In arid and semiarid regions, where streams usually lose water toward the aquifer (Martí et al., 2000), highly conductive coarse sediments enhance the retention of nutrients from the stream because the alluvium enlarges water storage zones, increasing hydrological retention and thus, attenuating the advective transport of streamwater (Valett et al., 1996; Morrice et al., 1997; Martí et al., 1997). By contrast, in temperate streams where aquifer-to-stream fluxes prevail most of the time, highly conductive coarse sediments in the alluvium can favour that hillslope groundwater passes through the riparian area, thus lowering the mean residence time of groundwater in this compartment and diminishing the ability of riparian biota to remove nutrients from groundwater (Vidon et al., 2004b)".

Moreover, the following sentences have been included in the first paragraph of the discussion (P9517.26):

> "Most of the current knowledge addressing the effect of catchment position and riparian zones on hydrological and biogeochemical processes at the catchment-scale is based on studies performed in temperate regions. The hydrological connectivity between the hillslope and riparian zones in temperate catchments tends to be high, especially during snowmelt when most of the annual water and solute export occurs (e.g., Jencso et al., 2009, 2010). However, we studied two catchments that had no snowpack and that suffered water limitation during long periods (as indicated by AI < 1)".

Regarding hydrological connection between the hillslope and riparian zones, the following sentences have been added in the introduction section:

> "Recent studies performed in temperate regions have revealed that the ability of the alluvial-riparian zone to modulate water and nutrient fluxes at the catchment-scale increases with its size (relative to the hillslope area) and with the turnover time of the groundwater in this compartment, that is inversely related with the hydrological connectivity between the hillslope and riparian zones (Jencso et al., 2010; Pacific et al., 2010). In contrast to temperate catchments, hydrological connectivity between hillslope and riparian zones tends to be low in

> semiarid catchments where high water demand by vegetation limits water availability (Piñol et al., 1999). Consequently, the mobilization of water and solutes from the hillslope to the stream is limited to large storm events when hydrological connectivity can eventually increase (Meixner and Fenn 2004; Meixner et al., 2007)".

2) *The authors further refer to previous studies with regard to the functioning of the riparian zone. In most of these studies the riparian zone is seen as a part of any headwater catchment, i.e. also the 'hillslope' catchment used here would have a riparian zone. This difference in definition should be clarified.*

The reviewer is right when saying that many studies consider that headwater catchments do have riparian zone. The riparian zone is defined as the interface between upland and a stream, and in this sense, the two studied streams had riparian zone *sensu stricto*. In our study, however, the two riparian zones differed very much from each other. While the riparian zone at the valley-bottom had a well developed alluvium (50-130 m width), the hillslope riparian zone did not have any identifiable alluvial zone (Figure 1 of the manuscript). In addition, the riparian forest at the valley-bottom zone was well developed (20-40 m width, both sides), and it was composed mainly by phreathophitic and deciduous tree species such as black alder and plane tree. By contrast, there were only few isolated black alders at the hillslope riparian zone and evergreen oak predominated (the same species covered most of the hillslope area at the Fuirosos Stream Watershed). Now, we have emphasized these differences and we have avoided using the expression "*with no alluvial-riparian zone*" when referring to the hillslope site throughout the text. For example, the former sentences from P9508.16-21 now read as follows:

> "The two catchments were drained by intermittent streams, though only the valley-bottom stream was surrounded by a well developed alluvial-riparian zone and lost water toward the alluvial-riparian zone during hydrological transitions (from dry-to-wet and from wet-to-dry conditions) (Butturini et al., 2003). By contrast, the alluvial-riparian zone at the hillslope stream was minimum and hillslope groundwater flowed directly into the stream all the year around (Bernal and Sabater, 2008)".

3) *The authors claim that the difference of water export (=runoff volume) is related to climate conditions. That might be ok, but I do not agree with the motivation being based on the correlation of T and deltaQ (fig 2b). This figure and the text indicate a causal relationship, which I find difficult. Rather the correlation is caused by seasonal variations of BOTH T and deltaQ.*
*Another problematic correlation analysis is fig 5. The correlation between deltaQ and deltaE (runoff and solute exports) is spurious as Q obviously is used to calculate the solute exports!*

We agree with the reviewer that stream runoff does not only depend on temperature but also on the precipitation regime. In arid/semiarid catchments, precipitation (P) is lower than potential evapotranspiration (PET), especially during the vegetative period, and forest growth is water limited, so that water demand by vegetation can strongly control stream discharge (e.g., Piñol et al., 1991). Therefore, a variable such as AI (aridity index = P/PET) may be a better indicator of the monthly climatic conditions than T alone.

We have reanalyzed the data set and we have found a significant positive correlation between monthly AI and monthly Q for both, the hillslope and the valley-bottom catchments (Spearman $\rho = 0.7$ and $\rho = 0.63$ for the hillslope and the valley-bottom, respectively; in both cases $n=24$ and $p < 0.001$). This result indicates that water availability in the catchment drives stream water export, as expected for semiarid catchments such ours. Interestingly, we observed that during the transition period, when semiarid conditions predominate, stream water export from the valley-bottom tends to be lower than from the hillslope catchment for a given AI value (Figure S1A). By contrast, the AI-Q relationship was similar between the hillslope and the valley-bottom catchments during the wet period (Figure S1B). These results suggest that differences in stream water export between the two catchments are accentuated under dry/semiarid conditions. We have changed the former Figure 2b by the new panels shown in Figure S1, as well as the corresponding text in the Results section (P9515.14-17).

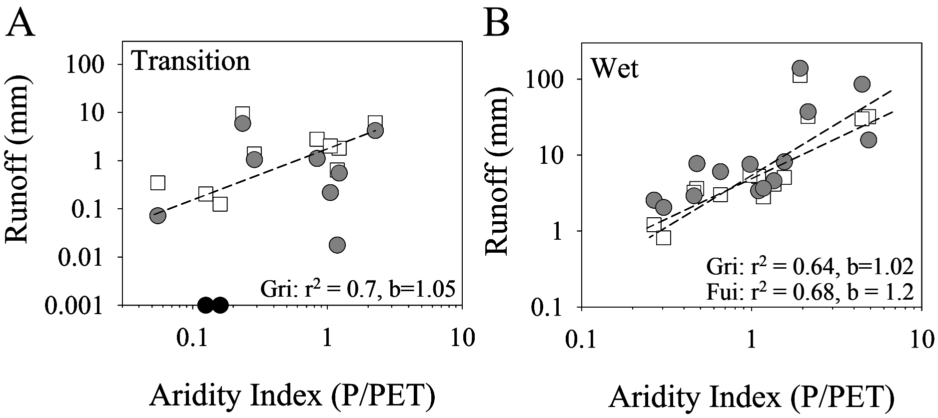

Figure S1. Relationship between the aridity index and stream runoff at the hillslope (GRI, squares) and the valley-bottom (FUI, grey circles) catchments during the (A) wet, and (B) transition periods. The dashed lines indicate the power fit between the two variables only when significant (in the three cases $p < 0.01$). The goodness of fit and the exponent of the power fit are shown in each case. The back circles correspond to months when the Fuirosos stream ran dry.

Regarding the deltaE-deltaQ relationship, we agree that we fail to explain the reason why we included this analysis. As pointed out by the reviewer, there is an obvious relationship between deltaQ and delta E, since deltaQ is used to calculate deltaE. However, the interesting point of this analysis is to analyze the departures from the 1:1 line. These departures indicate those moments during which differences in solute export between the hillslope and the valley-bottom catchment are larger than differences in water export between the two catchments. Or in other words, the departure from the 1:1 line indicate when hydrology alone can not explain the differences in solute export observed between the two catchments, so that other factors such as biogeochemical transformation or additional sources need to be taken into account. Moreover, differences between the two locations could be due to intrinsically distinct chemical signatures at the hillslope and the valley-bottom groundwater, because the later integrates new and old inputs of water and solutes and thus, it integrates temporal variation in water sources and routing (as suggested by rev#2).

DeltaE values close to the 1:1 line indicate that differences in solute export between the hillslope and the valley-bottom catchment are close to what would be expected based solely on hydrological processes. This pattern was exhibited by chloride, as would be expected for a conservative solute little affected by biogeochemical processes (Figure 5a, former solute).

DeltaE values above the 1:1 line indicate that solute export from the valley-bottom catchment is larger than what would be expected based solely on hydrological processes. We observed this behaviour especially for DOC during the wet period (Figures 5d, former manuscript). This pattern suggests an extra source of DOC at the valley bottom such as organic matter production within the stream (as suggested by rev#2), and/or flushing of DOC from organic-rich soil horizons in the valley bottom due to groundwater elevation during storm events (as suggested by rev#1).

DeltaE values below the 1:1 line indicate that solute export from the valley-bottom catchment is lower than what would be expected based solely on hydrological processes. We observed this behaviour especially for nitrate during the transition period (Figure 5b, former manuscript). This pattern may result from biogeochemical processes within the stream since the riparian soil tends to release nitrate during the transition from dry to wet conditions (Butturini et al., 2003). These results were already discussed in the former version of the manuscript (P9522.12 to 9523.2).

The correlation between deltaE-deltaQ reflects how relevant departures from the 1:1 line are. For example, deltaE-deltaQ showed the strongest correlation and a slope close to 1 for chloride, the passive solute. Contrastingly, departures from the 1:1 line were remarkable for bio-reactive solutes (nitrate, DON, and DOC), and consequently, they showed only a moderate deltaE-deltaQ relationship.

Now, we have explained better the hypothesis underlying the deltaE-deltaQ analysis in the Material and Methods (section 3.2.4). The following sentences have been included (P9514-4):

> "To investigate whether $\Delta E_i$ was related to hydrological processes and/or also affected by biogeochemical processes, we explored the relationship between $\Delta Q$ and $\Delta E_i$ and the departures from the 1:1 line. We expected values of $\Delta E_i$ to fall close to the 1:1 line when differences in solute export between the two catchments are mostly driven by hydrological processes, such as expected for passive solutes little affected by biogeochemical processing. Values of $\Delta E_i$ above the 1:1 line indicate that solute export from the valley-bottom catchment is larger than what would be expected based solely on hydrological processes; $\Delta E_i$ values below the 1:1 line indicate the opposite".

We have rewritten the results to make clear the link between the departures from the 1:1 line and the statistical analysis applied. The following text (underlined) has been added (P9516.22):

> "Departures from the 1:1 line during the transition period were observed especially for $NO_3^-$ that showed $\Delta E_{NO3} < \Delta EQ$ (Fig. 5b). During the wet period, $\Delta E_i$ varied greatly, especially for $NO_3^-$ and DOC that exhibited extremely high $\Delta E_i$ values (i.e.,>200%) (Fig. 5b and d). Departures from the 1:1 line were small for $\Delta E_{Cl}$ (Fig. 5a). Consequently, there was a strong linear relationship between $\Delta EQ$ and $\Delta E_{Cl}$, and the $\Delta EQ$ vs. $\Delta E_{Cl}$ slope was not significantly different from 1 (t-test,

> d.f.[degrees of freedom] = 21, t = 0.47, p<0.001). Departures from the 1:1 line were common for bio-reactive solutes, and the relationship between ΔEQ and $\Delta E_i$, was only moderate for $NO_3^-$, DON and DOC (Fig. 5b-d). The ΔEQ vs. $\Delta E_i$ slope was not significantly different from 1 only for $NO_3^-$ (t-test, d.f. = 21, t = 1.71, p <0.01), and DON (t-test, d.f. = 21, t = 1.89, p< 0.05), yet the statistical significance was lower than for $Cl^-$".

4) *It is unfortunate that there are no groundwater level/concentration measurements. These would have allowed a better assessment of possible processes, which now remain rather speculative.*

We agree with the reviewer that it would have been great to be able to measure water and solute dynamics at the two streams and at the valley-bottom groundwater simultaneously. Characterization of the hydrological and biogeochemical processes in riparian groundwater is essential to understand how the alluvial-riparian zone regulates stream water and solute dynamics at the catchment scale. Fortunately, we had previously studied stream-groundwater hydrological interactions as well as solute transformation (chloride, inorganic nitrogen, and DOC) in the FSW alluvial-riparian zone (Butturini et al., 2002, 2003; Bernal et al., 2003; Sabater et al., 2003; Vázquez et al., 2007). These studies were performed at the plot-scale, and there was no previous knowledge on how the alluvial-riparian zone could change stream water and solute fluxes at the catchment scale. Without the existence of these previous studies, it would have been extremely difficult to interpret the results obtained in the present study. We agree with the two reviewers that it is important to clarify that the present study is a continuation of the work already done in this watershed, and that we seek to understand how processes observed at the plot-scale transfer to larger scales. Although some aspects of our data set are limited, we are convinced that this study is a useful exercise because there are not many semiarid catchments as studied as the Fuirosos Stream Watershed. Please, the specific changes we have made in the manuscript in this regard can be found in our responses to Specific comment (2) from rev#2.

5) *The importance of different landscape units is discussed in detail, whereas the importance of time variable flow pathways within the units is discussed less. In other studies, the latter has been found to be quite important. With higher gw-levels additional flow pathways can be activated, which might control stream chemistry, as has been shown for the case of DOC in several catchments.*

This mechanism was missing in the former version of the manuscript, and we agree with the reviewer that it should be definitively included in the new version of the manuscript. There are several studies reporting that groundwater elevation results in increased solute fluxes in both temperate (e.g., Bishop et al., 1994; Hornberger et al., 1994; Pacific et al., 2010) and semiarid regions (e.g., Valett et al., 2005). At the FSW, these hydrological flushing of solutes may be especially noticeable in the valley bottom because riparian soils usually show higher DOC and nitrate concentrations than hillslope soils. In particular, average DOC concentration in the first 10-cm of soil was 82.4 ± 72.6 mg C/l (n=36) at the valley-bottom riparian zone and 40.1 ± 24 mg C/l (n=13) at the hillslope during the study period (S. Bernal, unpublished data).

The following sentence has been added in the discussion section 5.2 (P9519.26):

> "Organic matter stored in the riparian forest floor is ready to be flushed to the stream, and the hydrologic flushing of DOC from shallow organic riparian soil layers during storm flow has been well documented in temperate [e.g., Bishop et al., 1994; Hornberger et al., 1994] as well as in semiarid regions [e.g., Valett et al., 2005]".

6) *Please provide more information on the measurements. In particular please state how many salt-dilution measurements you made to establish the rating curves and which interval they include (e.g. exceeded in x % of the time).*

We overlooked this information in the former version of the manuscript and we thank the reviewer for noticing it. We have added the following sentences at the end of the paragraph P9511.13 (section 3.1):

> "Slug-additions were performed under a wide range of hydrological conditions at Fuirosos (n = 36, from 0.8 to 1425 l/s) and at Grimola (n = 27, from 0.8 to 480 l/s). The range of values covered by the slug-additions was representative of the stream discharge occurring >99% of the time during the period of study".

7) *It remained a bit unclear to me how many water samples were taken at which frequency, please clarify. I assume part of my confusion comes from the use of the term sample/sampling compared to sensing, which might be the better term in some cases. An example for this is P9513, 13 where it says that flow was interpolated between discharge at different 'sampling' dates. I would assume that flow/discharge is calculated based on continuous water level measurements, so honestly I do not understand what is meant here.*

The reviewer is right in that we did not include many details regarding the automatic sampling protocol. Hydrographs during storm events were flashy during the transition from dry-to-wet conditions, while the catchment response to rain events was usually slower and smoother during the wet period. Thus, we had to adjust the frequency of the automatic sampling collection depending on the period of the year. Only in this manner, we were able to capture changes in stream water chemistry during the rising and the recession limbs of different types of storm hydrographs. We have included this information in the new manuscript. The former sentence in P9511-19 (section 3.1):

> "[...] water samples were collected at hourly and sub-hourly intervals during stormflow conditions.",

now reads as follows:

> "To capture changes in stream chemistry during the rising limb of the storm hydrograph, the automatic samplers were programmed to collect water samples at intervals of 30-60 minutes during the first 2-4 hours; subsequent samples were collected at intervals of 4-6 hours".

In addition, we have clarified the information about how stream water level was recorded. When saying that it was measured continuously, we meant that we had a continuous record of stream water level taken at 30-minutes intervals. This information is now included in the former line P9511.8. Thus, when saying, "*we estimated monthly stream water export by linear interpolating instantaneous discharge* *between sampling dates*" (P9513.11, section 3.2.2) we meant that we interpolated discharge between consecutive values. The former sentence has been clarified as follows:

> "We estimated monthly stream water export (Q, in mm month$^{-1}$) from the Grimola and the Fuirosos catchment by linearly interpolating instantaneous discharge between <u>consecutive dates</u> and summing up values for each month."

## *<u>Minor comments</u>*

We have considered all the minor comments highlighted by the reviewer, and we have revised our manuscript accordingly. Please find our responses to the reviewers' questions below.

P9511.19: *what do 2-3 cm mean in l/s?*

Without no doubt, the reviewer is right when suggesting that to provide the switch-on threshold of the automatic samplers in l/s is more informative than in cm, since the same increase in cm could imply different increases in l/s. This is because the relationship between *depth of the water column* and *instantaneous stream discharge* can change over space (between streams and/or between different reaches of the same stream) and over time (within the same stream during different periods of the year) depending on streambed morphology.

Thanks to the reviewer's question, we have realized that there was some misleading information in the former version of the manuscript: 2-3 cm was the threshold for the SIGMA sampler located at the valley-bottom site (Fuirosos), but the threshold was 0.5-1 cm for the sampler located at the hillslope catchment (Grimola). Specifically, an increase of 2-3 cm at the Fuirosos site implied an increase in stream discharge of 3-5 l/s (dry period) and 7-10 l/s (wet period). At the Grimola site, an increase of 0.5-1 cm of the water column implied an increase of 2-3 l/s (dry period) and 7-9 l/s (wet period). The former sentence at P9511-17 (section 3.1) has been rephrased as follows (changes are underlined):

> "The automatic samplers at the Fuirosos and Grimola sites were programmed to start collecting water samples at an increment in streamwater level of 2-3 cm <u>and 0.5-1 cm, respectively</u>. <u>Such an increase in the water level was equivalent to an increase in stream discharge of 2-10 l/s depending on the previous base flow conditions</u>."

P9514, 24: *what is a scattered distribution?*

By *scattered* we meant *spread out* or *disperse*; our intention was to use an adjective that help to illustrate what *skewness* mean. We agree with the reviewer that *scattered* is not needed here and that can bring to confusion. Thus, this adjective has been deleted.

## *Response to comments from Anonymous Referee #2*

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General comments

*1) The role of catchment position as a mediator of hydrologic and biogeochemical processes is an important area of current research. Arid and semi-arid watersheds are particularly challenging in this regard because of the dramatic spatial and temporal variation in the direction and magnitude of connectivity among landscape elements. This paper extends previous work at this study site to address these dynamics. As such, this paper has the potential to make a somewhat limited but nonetheless meaningful contribution to the relevant watershed literature, but the contributions of this work are not clearly articulated or defended by this paper. This shortcoming should be addressed if the paper is to be published in HESS. The primary limitation of this paper is the weak links between the observations within this channel network and broader questions about catchment hydrologic and biogeochemical behavior. The paper presents some interesting patterns, but their broader implications need to be more clearly articulated, particularly in the introduction, as do the novel contributions of this manuscript (either conceptual or methodological). Reading the present manuscript, I had only a limited sense of what data to expect, or what the implications of different potential findings might be. Clearer presentation of the hypotheses to be tested (with more in-depth treatment of the relevant literature) and the predictions that follow from them would make the paper much easier to understand. Essentially, the authors need to be more direct about what they think we have learned from this work. See specific comments below.*

We agree with the reviewer that we have not done a good job when explaining the novelty of our approach and how this work relates to previous works done at this and other study sites. Moreover, thanks to the reviewers' comments we have realized that the former introduction needs to be improved and that we must work on the development of the hypothesis underlying our work. We appreciate very much the constructive and helpful comments of the reviewer in this regard. We have substantially changed the introduction to solve these shortcomings.

Now, we have strengthened the introduction by emphasizing that one of the current challenges in watershed hydrology is transferring the knowledge gained at the reach- and plot-scales to the catchment-scale. We explicitly say that in this paper we extend previous work performed in a riparian-plot at the FSW valley bottom by addressing how water and solute fluxes change with catchment position and with the development of the alluvial-riparian zone at the catchment-scale. Our study contributes to gain knowledge on how riparian zones, traditionally studied at the plot-scale, regulate water and solute export at the catchment-scale, which is an important topic of current research in watershed hydrology and biogeochemistry.

Now, we highlight that our study is focused on semiarid systems, which have been traditionally less studied than humid systems and thus, our knowledge of their functioning is still limited. Semiarid catchments are water limited and show lower hydrological connectivity between the hillslope and riparian areas than temperate systems. In this sense, semiarid catchments represent an interesting end-member system to test current hypothesis on how hydrological connectivity between hillslope and riparian zones regulates the effect of riparian zones on stream water and solute dynamics. Moreover, and following the suggestions of the two reviewers, we emphasize the differences in hydrological processes between semiarid catchments, like ours, and humid catchments (see also our response to comment (1) from rev #1).

We detail below the specific changes done in the introduction (see our responses to the specific comments regarding the introduction section).

*2) In terms of mechanisms and processes that might be important within this (and other) arid catchment, I encourage the authors to consider that the spatial decoupling of various solutes might reflect differential temporal lags within the hillslope and valley-bottom stream. That is, because of the large storage volume associated with alluvium, the water parcels passing the downstream station may be much older than the water sampled in the hillslope location. Differences between these locations may therefore represent either greater transformations within the valley bottom alluvium OR distinct inputs to that alluvium resulting from temporal variation in water source and routing. If this is a hypothesis the authors considered, the manuscript does not make that as clear as it could be.*

We agree with the reviewer that differences between the two locations could result from greater biogeochemical transformation of water passing through the alluvial-riparian zone and/or because hillslope and valley-bottom groundwater may have intrinsically different chemical signatures because the residence time of water in these two compartments is different. This is a possibility that we did not mention explicitly in the former version of the manuscript. We agree that it will be worthy to mention it and to link it to the hypothesis underlying the study. We have added the following sentences in the introduction:

> “A well develop alluvial-riparian zone can store a large volume of water and thus, integrate the temporal variation of new and old solute inputs resulting from different water sources in the catchment (Burns et al., 2001; Shaman et al., 2004). In this sense, the alluvium can act as well-mixed groundwater reservoir and exhibit a chemical signature distinct from hillslope groundwater”.

*3) Last, the manuscript would benefit from a thorough edit for grammar and word usage. I have attempted in my specific comments to identify common errors, but cannot guarantee that these corrections address all of the necessary changes. In particular, I occasionally found it difficult to understand whether ‘differences’ referred to spatial variation between the sampling stations or temporal changes in one or both stations over time.*

We have carefully revised the manuscript and we have taken special care to clarify whether “differences” refer to spatial variation between the hillslope and valley-bottom sites, or to temporal changes in one or both stations in the results section. We are willing to ask to a native English speaker to revise the use of language if the editor finally encourages us to submit a revised version of the manuscript to HESS.

## *Specific comments*

1) ***Abstract.*** *The abstract should more explicitly state the questions and hypotheses under investigation, and the conceptual and methodological contributions.*

Following the reviewer's suggestions, we have improved the abstract. The following sentences have been added at the beginning of the abstract:

> "Our understanding of the ability of riparian zones to change water and nutrient fluxes at the catchment-scale is still limited. In temperate catchments, hydrological connectivity between hillslope and riparian zones can control the influence of riparian zones on stream water and solutes. In contrast, riparian zones are usually disconnected from hillslopes in semiarid catchments experiencing water limitation. We investigated the potential of the riparian zone to change stream water and nutrient fluxes during hydrological transition periods (dry conditions) and wet periods in a semiarid catchment. To do so, we compared monthly stream water fluxes as well as chloride, carbon and nitrogen dynamics between one catchment located at the hillslope and another one located at the valley bottom that had a large alluvium and a well-developed riparian forest".

2) ***Introduction.*** *The introduction would be improved by explicitly stating the questions and hypotheses that this research will address. Revisions should also clearly identify the contributions of this paper in terms of the novelty of the approaches and study site and how these relate to previous studies. What do we expect to learn from this paper that is not already known?*

9508.8-10: *These are the observations that motivate the work, but how does this study address them? Need to link observations to broader concepts more directly.*

9608:20: *The authors present expectations based on some imprecisely defined hypotheses, but this section would be more useful if the predictions that follow from alternative hypotheses were also clearly articulated. The author's a priori expectations are not particularly relevant to subsequent interpretation of the data.*

As already mentioned, we have substantially improved the introduction by more explicitly stating our hypothesis and contribution to the current knowledge. In the new version, we treat in depth the literature that addresses how catchment position and landscape units influence hydrological and biogeochemical processes at the catchment scale. We now explicitly state the hypothesis underlying our work and we link our expectations to it. Moreover, we have made an effort to include the novelty of our work as well as our contribution to the existing scientific literature.

Regarding the novelty of our approach and the hypothesis underlying our work, we have substituted the former sentences P9504.26 to P9508.10 with the following paragraph:

> "Although previous studies showed that alluvial-riparian zones could strongly affect stream hydrology and nutrient cycling, most of this research is based on reach- and plot-scale

> experiments and thus, our current understanding of how this ecotone regulates water and nutrient export at the catchment-scale is still limited. Recent studies performed in temperate regions have revealed that the ability of the alluvial-riparian zone to modulate water and nutrient fluxes at the catchment-scale increases with its size (relative to the hillslope area) and with the turnover time of the groundwater in this compartment, that is inversely related with the hydrological connectivity between the hillslope and riparian zones (Jencso et al., 2010; Pacific et al., 2010). In contrast to temperate catchments, hydrological connectivity between hillslope and riparian zones tends to be low in semiarid catchments where high water demand by vegetation limits water availability (Piñol et al., 1999). Consequently, the mobilization of water and solutes from the hillslope to the stream is limited to large storm events when hydrological connectivity can eventually increase (Meixner and Fenn 2004; Meixner et al., 2007). Thus, we hypothesize that the potential of the alluvial-riparian zone to change stream water and nutrient fluxes should be high in semiarid systems, especially during dry periods when the turnover time of groundwater in the alluvium may be high due to low hydrological connectivity. To test this hypothesis, we compare monthly stream water fluxes as well as carbon and nitrogen dynamics between two semiarid nested catchments, one located at the hillslope and the other located downstream at the valley bottom".

Regarding the contribution to previous knowledge and our expectations, the former sentences P9508.21-26 in the introduction read now as:

> "Previous plot-scale studies in this area have shown contrasting carbon and nitrogen patterns between the transition and wet periods at the alluvial-riparian zone located at the valley bottom (Butturini et al., 2003; Vázquez et al., 2007). This paper extends previous work at this study site by exploring differences in water and solute fluxes with catchment position between these two contrasting hydrological periods. We expect that differences in water and solute dynamics between the two catchments will be accentuated during transition periods due to the hydrological disconnection between the hillslope and riparian zones. In particular, we expect a decrease in water and solute fluxes between the hillslope and the valley-bottom catchments during hydrological transitions because stream-to-aquifer water fluxes increase hydrological retention at the valley-bottom stream".

3) ***Study Site.*** *It would be useful to clarify how this site differs (if at all and if known) or might differ from other studies where similar studies have been conducted.*

Following the reviewer suggestion, we have added in the study section that it rarely snows in the FSW (P9509.11). This is one of the main differences between this study and others performed in temperate regions, where the main part of the water and solute export occur during the snowmelt period. Moreover, we have now emphasized in the first paragraph of the discussion the main aspects differentiating semiarid and temperate systems (P9517.26) (see our responses to comment (1) from rev#1).

4) ***Methods.***

9511.17: *Was time-of-day held relatively constant within and among sampling stations? When were samples collected? Is there any evidence for diel variation in solute chemistry?*

The reviewer is right in that biological activity within the stream can lead to diel variation of stream solute concentrations (especially for inorganic nitrogen). Although the metabolism at the FSW streams is highly heterotrophic (Acuña et al., 2004), it could well be that primary producers modulate day/night stream solute concentrations during some periods such in early spring. This interesting topic may deserve future research at the Fuirosos stream. The present study, however, did not seek to capture this type of variation. We are confident, however, that this potential source of variation may explain almost nothing or very little of the observed differences in stream water solute concentrations between the valley-bottom and the hillslope catchments because of how field campaigns were designed. First, field work usually started around 11 am and we visited all the study sites (Fuirosos, Grimola, and Ef-4) within 2-5 hours, so that all grab samples were collected with sun light and around noon (solar time). Second, although automatic samplers collected stream water during day- and night-time, they did so only during storm events when surface/subsurface catchment water flow paths were the main contributors to stream runoff. Thus, the potential influence of in-stream processes on stream water chemistry was minimum at these moments. Following the reviewers' suggestion, we have specified at which time of the day samples were collected (P9511.16)

> "Field campaigns started at ~9 am (solar time) and stream water samples from the different sampling stations were collected within 2 to 5 hours".

5) ***Discussion.*** *[...] The discussion might flow better if the order of sections 5.2 and 5.3 were reversed, since the inorganic solute dynamics seem much more closely tied to the water fluxes dynamics.*
We agree and we have shifted these two sections as suggested.

9520.10-20: *That solute fluxes are closely related to discharge seems intuitive and not particularly noteworthy, unless there is significant reason to expect deviations from that relationship (e.g. evaporation, OM production). Be more explicit about what hypotheses are being assessed via this analysis.*

Reviewer #1 also highlighted this shortcoming, and we agree with both reviewers that we need to state more explicitly the meaning of the deltaE-deltaQ relationship. Please see the specific changes done in the revised version of the manuscript and our responses to comment (3) by reviewer #1 ($2^{nd}$ part).

Regarding the specific point discussed at 9520.10, we agree with the reviewer that this part of the discussion was not particularly meaningful, and consequently we have decided to delete the sentence in P9520.16-18.

## *Technical corrections*

We have considered all the technical corrections made by the reviewer and we have revised the new version of the manuscript accordingly. We include below detailed responses and/or the specific changes made in the new version of the manuscript when needed.

9510.7: *It would be helpful if this sentence clearly identified how the catchments are similar and different: '. . .draining nested catchments that differed in X, Y and Z' so that readers can quickly understand the rationale and limitations of this comparison.*

We agree. We have added the following (underlined):

> "For the present study, we monitored intensively two third-order streams draining nested catchments: Fuirosos that was surrounded by well developed alluvium and a large riparian forest, and Grimola with a minimum alluvial-riparian zone".

9518.1: Replace 'specially' with 'specifically' or 'only', as differences during other periods seem to be minimal.

We agree with the reviewer that differences in water export and solute dynamics were more remarkable during transition periods. However, there were also differences between the two catchments during the wet period. For instance, we found that deltaQ > 0 for some months (Figure 2b, former manuscript) and also that instantaneous DOC concentration was significantly higher in the valley-bottom stream than in the hillslope stream during the wet period (Figure 4d). Moreover, Figure 5 showed that deltaE was sometimes different than zero during the wet period. Thus, we think that it is more correct to use "specially" instead of "specifically" in this particular case.

9519.5-7: This sentence is unclear.

The former sentence has been substituted by:

"Further studies are needed to investigate patterns of hydrological connectivity between hillslope, riparian and stream zones in semiarid catchments".

9519.16-19: Is the implication really limited to these two catchments? Consider rephrasing to broaden this conclusion.

We have rephrased the former sentences P9519.14-18 as followed:

> "These findings suggest that hydrological processes and stream runoff generation at the FSW were linked to climatic conditions, and that aridness accentuated differences in stream water export between the hillslope and the valley-bottom catchments. This result implies that future warming could exacerbate differences in stream water flux between hillslope and valley-bottom catchments, especially in regions where water is scarce."

9521.9: See also Lutz et al. 2012 L&O 57(1):76-89.

This is a great paper, and it addresses an important issue with a novel approach. We have enjoyed very much reading it, and we find it is very appropriate to cite it in our discussion about sources of DOM to streams. Thanks.

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