Paris, May 15, 2014

Dear Editor,

Please find enclosed the revised version of our paper "Continental hydrosystem modelling: the concept of nested stream–aquifer interfaces » by N. Flipo, A. Mouhri, B. Labarthe, S. Biancamaria, A. Rivière, and P. Weill. First of all we would like to thank the two reviewers for their detailed and fruitful comments, which helped improving the manuscript significantly.

The paper aims at rationalising the modelling of stream–aquifer interfaces within a consistent framework, which fully accounts for the multi-scale nature of the stream–aquifer exchange processes. It is a necessary primary step before the assessment of the hydrological impact on geochemical fluxes. Following the reviewers advice, we clarified the overall message of the paper. A new abstract, as well as parts of the introduction, were re-written, and the paper was re-structured completely. The new version consists of only three main parts:

1. "The concept of nested stream–aquifer interfaces": a full description of the stream-aquifer interfaces is proposed from the local to the continental scale.
2. "Modelling stream–aquifer exchanges": the description of the modelling approaches used to simulate the interface is undertaken, with a special emphasis on the regional scale.
3. "The MIM methodology: from concepts to practice": the methodological tool MIM is described. MIM aims at rationalizing the combined usage of sampling systems and models dedicated to the understanding of stream-aquifer functioning at various scales

The outcomes of this literature review are:

1. The identification of a hierarchical order of the multi-scale control factors of stream-aquifer hydrological exchanges
2. The identification of the river network and its extension, the hyporheic corridor, as the support of hydrological processes scaling
3. An upscaling framework from the local to the watershed scale
4. An iterative scaling procedure of the conductance parameter from the intermediate to the regional scale
5. The inclusion of space borne data as useful information for the assessment of stream-aquifer exchanges at the regional and continental scales
6. Recommendations for the study of stream-aquifer interfaces at the regional scale

We believe that the message of the paper is now clearer, and hope that it meets HESS publication standards. Please find below our point-by-point response to reviewers comments.

Best regards
Nicolas Flipo (On behalf of the co-authors)

Reviewer 1:

« To the best of my understanding, the central argument in this paper, based on the first author's dissertation, is that stream-aquifer interaction varies on multiple space and time scales, and that new modeling strategies can be inspired by the multiscale (also, confusingly, referred to as "multi-dimensional") nature of the phenomenon. However, the argument is not made very clearly. Much space is devoted to a listing of different available models and the respective resolutions they have been used in; such a listing tells us little about the physical nature of stream-aquifer interactions. »

[R1.1] Reviewer 1 understood well the overall message of the paper. We agree that multi-dimensional was confusing. We removed it from the new version. The new structure of the paper is clearer with a distinction between the stream-aquifer interface functioning (section 1) and the modelling task (section 2). To simplify the text, two tables were removed. Only one table remains, from which most of the references are cited in the text. We believe that this table is important because it is a straightforward way to identify the scale of interest of the numerous modelling exercices already published. It also tells by itself that very few studies focused on the regional scale.

« A more useful type of material to compile, in my view, would be quantitative estimates of the importance of stream-aquifer interactions to water and chemical budgets at different scales. Such estimates should be the main basis for deciding whether to take streamaquifer interactions into account at all in a particular hydrological investigation, and if so, what modeling approaches and measurements to employ. Since little of this sort of information is currently detailed in this paper, the investigations pursued are not well motivated and their relevance to applied hydrological studies is not solidly established. I recommend at least presenting and explaining several such quantitative estimates and the basis for them. »

[R1.2] Reviewer 1 makes a very important point. We therefore developed this issue in the introduction, which justifies our search for the rationalisation of the stream-aquifer interfaces modelling across scales. Although models are able to account for the impact of complex flow paths on biogeochemical fluxes at the local scale, they fail to integrate the hydrological spiralling of poole et al. (2008) at the regional scale. Therefore hydrological models have to be improved to tackle this specific issue. This is the aim of the current review.

« Two examples are given of measurement techniques relevant to stream-aquifer interactions at different scales. The first is in-stream sensors of water temperature and pressure that can identify groundwater inflow. The second is the planned SWOT mission's measurement of river surfaces, though it is not clear to me how this sort of remote measurement is supposed to meaningfully inform assessments of stream-aquifer interaction. »

[R1.3] SWOT will not provide a direct measurement of stream-aquifer exchanges. However it will provide a direct measurement of the surface water levels. The continental scale models also use the conductance model to simulate stream-aquifer exchanges. As the water levels correspond to boundary conditions of the conductance model, nadir altimeters data or SWOT data can be assimilated at the regional scale. In the new version of the paper, more details on the usage of satelitte data are given.

« A key concept, according to the abstract, is "the innovative methodology MIM (Measurements-Interpolation-Modelling)". However, the only explanation of it is in the opening paragraph of Section 5. The utility and applications of this "methodological tool" need to be explained much more carefully. »

[R1.4] Explanations were added at the beginning of the last section, as well as for each example.

There are also many details of the phrasing that need to be revised for syntax and clarity. A very incomplete listing is given below.

[R1.5] All these remarks were taken into account, and the new version was corrected carefully.

Reviewer 2:

« The paper discusses continental hydrosystem modelling of nested stream-aquifer interfaces. I have read the paper twice and find the key-massage very hard to see. Right now it more reads like a rather detailed list of not always well-connected references, it will need quite a bit of work to develop a message. Because the overall message is not very clear I find it very hard to comment on the paper. »

[R2.1] Following Reviewer 2 comments, we restructured and clarified the paper. As mentioned to the editor, the paper contains only three main parts organised as follows :

1. "The concept of nested stream–aquifer interfaces", which fully describes the stream-aquifer interfaces from the local to the continental scale.
2. "Modelling stream–aquifer exchanges", which describes the modelling approaches used to simulate the interface, with a special emphasis on the regional scale.
3. "The MIM methodology: from concepts to practice", which describes the methodological tool MIM.

Please see also [R1.1] for more details.

« I also find that the link between individual chapters is not always as clear as it could be. For example section 3.2. Most of this section is a recitation of Marlad, but I struggle to see how it integrates. An option to fix this could be to make a link between physical controls on connection/disconnection and the hyporheic zone. Another example is the remote sensing part at the end. It is not integrated well in the paper, and therefore the practical use of this section remains unclear. Before a decision can be made, the authors should distill the messages in a clearer way. However, I believe the paper has potential and encourage the authors to submit a revised version. »

[R2.2] This advice of reviewer 2 motivated us for the global restructuration of the text. For instance, we removed from the first section any considerations for the models. This gave us space for providing more explanations on hydro-sedimentary processes that shape the geometry and the heterogeneities of stream-aquifer interfaces.

Below more detailed comments that might help.
â˘A ´c Generally I got the impression that the authors cited many papers but that these papers did not always really fit to the context. I would suggest to very carefully recheck if the citations are appropriate.

[R2.3] For rechecking the references, we benefit from the rewriting.

â˘A ´c Page 453, line 24: Why is this a paradox? I disagree, as considering the streamaquifer interface as a continuum does not exclude that there are different functions and behaviors within this continuum. It just depends on the perspective and the questions asked. I think the reason why hydro systems modeler like turn away from a clearly defined line between these interfaces is that is just very hard to identify them.

[R2.4] We agree, this part was poorly expressed. We removed it.

â˘A ´c Page 468, line 9 (Fig 2): Even though the authors cite a paper by Brunner et al 2010 it is not picked up in the discussion of the conductance concept. Figure 2 and many more points made in this context have been discussed in detail by Brunner and should be mentioned at this place. Note that the paper by Mehl and Hill 2010 did not

consider any clogging, e.g. the hydraulic conductivity is equal to the aquifer. Also, the cited paper by Irvine et al should be mentioned in this paragraph. They showed under which hydraulic conditions simplifying heterogeneity will not bring along uncertainty. As far as I know they did not directly comment on the conductance concept as is suggested elsewhere in the paper.

[R2.5] This section was completely rewritten. We now propose an iterative procedure to ensure the consistency of stream-aquifer exchanged flux between the intermediate and the regional scales. The references of Brunner et al. (2009a, 2009b, 2010, 2011) as well as Irvine et al (2012), have been taken into account in due place in the new version of the manuscript.

â˘A´c The recent work by Partington et al has been missed and is highly relevant for this paper. The hydraulic mixing cell method allows to deconvolute the stream-discharge of the model into its individual components (eg Partington et al Water Resources Research Volume 49, Issue 9, 2013, Pages 5501-5519 or Partington et al Environmental Modelling and Software Volume 26, Issue 7, July 2011, Pages 886-898)

[R2.6] In the paper we assume that stream-aquifer interfaces are distributed objects, that we try to simulate with distributed models. This is why we did not focuse on the deconvolution issue. However we thank reviewer 2 for bringing this paper to our attention as it will be very helpful for further publication on the subject.

â˘A´c There is little mention of uncertainty in the paper. This is a deficit, as the models will always be wrong, but the choice of model complexity is related to this uncertainty. It would be very useful to at least mention that there a large range of methods that can be applied to estimate this uncertainty (See e.g. the papers by John Doherty).

[R2.7] This is indeed a very important comment. As, many papers and literature reviews already exist on this issue, we preferred to clarify the message of our paper, which already benefits from an extensive literature review.