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Interactive Comment

Interactive comment on "Continental hydrosystem modelling: the concept of nested stream–aquifer interfaces" *by* N. Flipo et al.

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We would like to thank reviewer 1 for his first comments. We answer hereafter point by point.

1. Comment : "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. "

We agree with the fact that the term 'multi-dimensional' is not very clear. In the revised version, it will be replaced by multi-scale to highlight the multi-scale nature of hydrolog-

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ical processes. To emphasize the core argument of the paper, as reformulated by the reviewer, we will include this point at the beginning of the last paragraph of the introduction. However, it should be noted that this peculiar point is the main line of the paper's argumentation. First, in Section 2 " The concept of nested stream–aquifer interfaces", we define the multi-scale nature of the interface (with the support of Fig. 1). Then we set up the fact that the support of the up and downscaling of hydrological fluxes is the river network (Section 3.1 "A multi-scale issue structured around the intermediate scale – the river"). After describing the processes at the two extreme spatial scales, we clearly emphasize which hydrological parameters and variables have to be up and downscaled around the river and also for which models (section 4.5 "Up and downscaling stream-aquifer exchanges"). Given the usage of the MIM methodology, we were able to show that the scaling of processes from the local to the watershed scale is structured around river reaches of 1-10m (Section 5.1 "Coupled in situ-modelling approaches: from local to watershed scale"). We also analyzed the question of the modelling of stream-aquifer exchanges at the continental scale, and paved the way for a further usage of remote sensing data, which should improve global hydrological budgets (Section 5.2). We finally concluded, based on the MIM analysis, that further developments in modelling and field measurements have to be performed at the regional scale to be able to model stream-aquifer exchanges from the local to the continental scale properly.

2. Comment: "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."

Besides the tables, which are the review material, the paper is not devoted to a listing of different available models. We looked at the issue by reviewing the number of model applications built up at various scales. Based on this review, it appears that the larger the scale (scale in the sense of model dimension), the less understood the interfaces. Our claim here is to urge for the development of such models as they are of the utmost importance for water resources managers (as stated in the last paragraph of section 3.3 “The stream–aquifer interfaces at the regional and continental scales – the alluvial plains”, and also mentioned in the conclusion of the paper). Overall, the whole section 3 is devoted to the stream-aquifer interfaces at the various scales of interest, which display different physical processes. Moreover, we think that such a literature review is important for the development of further research on stream-aquifer interactions. This is why we developed the MIM framework, for researchers to be able to position their research based on a more holistic view of the hydrosystem. MIM is also a valuable tool to define strategies for combining field measurements and modelling approaches more easily.

3. Comment: ”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 stream-aquifer 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.”

This is a very important point, which is implicit throughout the paper. We will make it explicit in the introduction. A number of published papers address the problem of transport through the stream aquifer interface. These papers imply sophisticated models, which represent the dynamics of pollutant at the local scale (See for instance Frei et al., 2012. Surface micro-topography causes hot spots of biogeochemical activity in wetland systems: A virtual modeling experiment J. Geophysical Research, VOL. 117, G00N12, doi:10.1029/2012JG002012) fairly well, taking into account the effect of micro-topography on the exchanged fluxes. Also at the regional scale models are able to simulate pollutants elimination (see for instance Seitzinger et al., 2002. Nitrogen retention in rivers : model development and application to watersheds in the northeastern u.s.a. Biogeochemistry 57/58, 199–237, or Ledoux et al. 2007. Agriculture and groundwater nitrate contamination in the Seine basin. The STICS-MODCOU modelling chain. Sci. Total Environ. 375, 33–47.). However, at this scale, models do not account for sub-cell fluxes, which results in an underestimation of the total water flux flowing up or downward through the sharp geochemical gradient of the stream-aquifer interface. The aim of this paper is therefore to pave the way towards a multi-scale modelling of the stream-aquifer interface, with the ambitious goal of being able to simulate the complexity of the processes occurring at the local scale in a regional scale model. The main idea is that this is feasible with a multi-scale modelling approach, coupled with specific infrastructures. The design of this coupled approach can be performed with the MIM methodological tool. Once the present hydrological analysis is published, we agree with reviewer 1 that a literature review on the role of stream-aquifer interfaces on chemical fluxes, which would integrate the multi-scale nature of stream-aquifer hydrological processes, would be of great interest for the scientific community. However, to our knowledge, such a review might be very limited due to a lack of consistent studies at the watershed-regional scale, for which models failed to integrate the multi-scale nature of hydrological processes at the interface until now. This paper is a first step for the integration of this multi-scale nature in hydrological models, which seems a necessary primary step before the assessment of its impact on geochemical fluxes.

4. Comment: “Two examples are given of measurement techniques relevant to stream-aquifer inter-actions 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.”

As explained in section 4.3 “The conductance model at the regional scale”, the in-stream water level is a boundary condition for the conductance model. The SWOT mission will provide, among others, distributed measurements of water levels along stream networks. As illustrated by Saleh et al. (2011), river stage must be taken into account as a boundary condition to compute exchanges between aquifers and rivers. SWOT by itself will not provide a direct measurement of these exchanges, but coupled with a conductance model, it should provide valuable observations at regional and continental scales. If necessary, we can also emphasize this argumentation line at the end of section 5.2, where SWOT is presented.

5. Comment: “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.”

We agree with reviewer 1 on the fact that MIM is shortly presented at the beginning of section 5. Even if the methodology is developed in sections 5.1 and 5.2 with two examples, we agree that we need to explain in a more detailed way the advantage of the method at the beginning of section 5, which is mainly to visualize the potential outcome of a joined sampling and modelling strategy in terms of spatial representativeness of the approach. It is a powerful tool as it also allows the determination of the dimension of the objects, which need to be studied, to be able to scale processes.

For the Orgeval basin (case study presented in section 5.1), the identification of the intersection on the modelling axis between the watershed modelling strategy and the thermo-hydro one clearly points out the dimension of the scaling object (1-10m). The next experiment, aiming at determining the upscaling law for the conductance coefficient at the watershed scale, will thus be designed based on the specificities of a river stretch at this scale (i.e., the study of a riffle-pool sequence). In that specific case, the spatial rationale behind the new experiment is an outcome of the MIM analysis, which defines the size of the objects to be studied. Another interest of MIM is the interpolation axis. As explained in section 5.1, it is clear that the LOMOS measurements have to be distributed along the stream network. As it is irrelevant to implement too many stations along 6 km of a river network, there is a problem for interpolating the LOMOS measurements along the stream network. As displayed by the area of the coupled hydrological-hydrogeological model in Fig. 4, the interpolation step will be defined by the size of the cells of the distributed model. In that case we suggest the usage of FO-DTS in the paper. To summarize, MIM enables to quickly view the potential outcomes of a given approach before undertaking the research. It also helps to identify potential issues related to scale. For instance, the usage of MIM brought to light the fact that one of the main challenges in stream aquifer studies is to connect, experimentally and conceptually, physical processes that drive stream-aquifer exchanges at the watershed scale to the ones occurring at regional scale.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 11, 451, 2014.