Hydrology and Earth System Sciences

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Discussions

Interactive comment on "Nonlinear effects of locally heterogeneous hydraulic conductivity fields on regional stream–aquifer exchanges" *by J. Zhu et al.*

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Introduction

The Authors show computational experiments performed to evaluate the effects of locally heterogeneous conductivity fields on regional exchanges of water between stream and aquifer systems in a basin of northwestern China.

They assume, among the others, that i) small-scale heterogeneities of hydraulic conductivity significantly affect simulated stream–aquifer water exchanges in river basins and ii) systematic biases arise in estimates of exchanges if small-scale heterogeneities are smoothed by aggregation into a few sub-regions. With these assumptions they try

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to prove, by means of computational experiments, that the biases result from slow-paths in groundwater flow that emerge due to small-scale heterogeneities.

The manuscript is well structured and well written. Nevertheless, I have some concerns regarding the mathematical model used to validate their objective and about the assumption of random hydraulic conductivity values uncorrelated in space. For this reason I recommend major revisions.

The reasons of my decision are described below.

General comments

The study area is a sedimentary basin and the aquifer thickness ranges from 50 to 800 m. Hu et al. (2007) state that "*The lithology can be classified into clay, loose sand with gravel, fine-grained sand, and weathered granite and they are interlaced in the northern part of the study area. The maximum number of layers of aquifers and aquitards can reach 8. Many of the wells intercept more than one aquifer and are therefore multi-layered wells. All these characteristics demonstrate that vertical flow is significant in the study area, therefore, a three-dimensional model is necessary to represent the flow system.*" They found also, the groundwater level data about some wells in different layers to have vertical differences of groundwater level. Nevertheless, the Authors simulate the regional exchanges of water between stream and aquifer systems using a two-dimensional (single-layer) flow model (discretized into 155 rows and 172 columns, with each cell size 1km×1km) in saturated conditions. Unsaturated flow is simulated by the the stream package of Modflow that uses Richard's equation but assuming vertical, gravity-driven flow and neglecting the capillarity. Moreover, they assume the streambed conductance the same for all simulations. In my opinion, in this way, still remaining valuable their study, the results of the mathematical model could be little realistic respect to the Middle Heihe River Basin (MHRB) and they cannot

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contribute to the management of water resources in this area as the Authors state.

Another important issue that is questionable is the assumption of random hydraulic conductivities uncorrelated in space. The base model domain is divided in 16 hydrologic zones characterized by constant effective values of horizontal conductivity and specific yield estimated using the PEST inverse code. In the local-scale model, several realizations of conductivity fields are generated with different levels of heterogeneity driven by the coefficient of variations. Local-scale analyses at different levels of heterogeneity are based on a sample of 10 realizations of log-normally distributed random conductivity fields for different coefficient of variations and grid point values are sampled independently, so no correlation structure is imposed on local conductivities. In order to evaluate the effects of locally heterogeneous conductivity fields on regional exchanges of water between stream and aquifer systems the Authors compare stream–aquifer fluxes produced by a base model to fluxes simulated using realizations of the MHRB characterized by local heterogeneity. So, in my opinion, there are some concerns that arise with this assumption because: i) real porous media are spatially correlated and the groundwater flow is influenced heavily by the hydraulic conductivity spatial correlation, ii) Authors compare stream–aquifer fluxes produced by the base model spatially correlated (thanks to the inversion with PEST) to fluxes simulated using uncorrelated conductivity realizations in the local scale model and iii) according to theoretical results of Matheron (1967) and Gutjahr et al. (1978), the assumption of hydraulic conductivity log-normally distributed (spatially uncorrelated) could strongly influence the findings of this study: i.e. greater is the CV and bigger is the difference between base and local model results, but a great CV could be not so consistent with the heterogeneity patterns of the aquifer.

Specific comments

- "*The zones were defined in previous hydrogeological studies of the MHRB (Hu et al., 2007)*: but in their work, Hu et al. divide the aquifer in 8 layers too. Could be, please, more precise?

- in section 2.2 the author state "*All stream–aquifer interactions are simulated using the numerical modeling tool MODFLOW with the stream package (STR) for one-dimensional stream flow and twodimensional groundwater flow*: I suppose that is true for this study and not for all, and after "*The stream package (Leake and Prudic, 1991) simulates stream flow with Manning's equation and interactions with groundwater flow using Richard's equation, which assumes vertical, gravity-driven flow and neglects capillarity. This is an acceptable assumption for typical alluvial sediments of the kind found in the MHRB (Spanoudaki et al., 2009; Huang, 2012)*: this assumptions depends on the objective study too!

- "*Seepage is calculated from the product of the head gradient times a streambed conductance*: I suppose that seepage was calculated from the product of the head difference times the streambed conductance.

- " *Stream inflow at the YLX Gauge and groundwater lateral recharges from mountain areas are used as an upper boundary, and outflow at the ZYX Gauge is taken as a lower boundary (Zhou et al., 2011)*: Could you, please, explain as these flowrates were estimated?

- I have some problem to understand the figure 2c) :is the legend correct?

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