Response to comments of Anonymous Referee 2

We would like to thank the referee for the valuable comments and suggestions, which improved the quality of the paper. Below is our response to the comments and suggestions.

Comment on hess-2022-298

My impression is that the novelty that this work brings is scarce. Probably this is partially due to the presentation of the derivation and the results that is quite confusing. I suggest the authors revise completely the paper by improving the description of the mathematical approach and by relating it to the state-of-art to underline the advancements introduced by the study. I also suggest revising the figures that presently are of poor quality and not so explicative. I ask the authors to rethink the graphical representation of the results and to add more graphical insights to help the comprehension. In summary, I suggest major revisions to the manuscript even if I'm aware that the sum of all the revisions would lead to a very different version of the manuscript.

Response

1. To make it clear that this is a new and original work and the results of this work are important, the novelty of this study is added in the introduction section as follows (Line 59 on page 5):

   "The traditional approach to regional groundwater flow problems introduces the transmissivity parameter to describe the ability of a confined aquifer to transmit water throughout its saturated thickness. The effect of the thickness of the aquifer is implicitly reflected in the transmissivity parameter. It is very difficult to assess the effect of thickness on the flow field and thus on solute transport at a regional scale. The stochastic approach presented here provides an efficient and rational way to analyze flow and solute transport fields affected by the non-uniform thickness of confined aquifers, which has not been previously presented in the literature. This work shows that variability in aquifer thickness can lead to nonstationarity in hydraulic head fields and thus to nonstationary flow velocity fields and anomalous longitudinal dispersion. This implies that neglecting the variability of aquifer thickness when predicting the longitudinal displacement of solutes at large times can lead to a significant underestimation of longitudinal dispersion. The stochastic theory presented here improves quantification of the variance of the solute displacement in natural confined aquifers of random thickness fields."

2. In order to make the manuscript clear and easy to read, we made major adjustments to the structure of the manuscript.

   a. A brief preview of this work is added on page 5 (Line 74) as

      "In the present work, the convection velocity of solute particles is first developed based on the relationship between the two-dimensional depth-averaged solute mass conservation equation and the Fokker-Planck equation, so that the convection velocity can explicitly reflect the effects of hydraulic conductivity and aquifer thickness. Using the perturbation approach to solute convection velocity, the covariance function of solute convection velocity is then developed, which allows a general expression for the variance of the displacement of a solute particle in the mean flow direction to be developed. A closed-form expression for the solute displacement variance is also developed for the case where solute transport is dominated by advection and the random fields of log conductivity and log thickness of the confined aquifer are second-order stationary. Finally, the influence of variations in log hydraulic conductivity and log aquifer thickness on the variability of solution displacement is analyzed."

   b. To facilitate understanding, we have restructured the manuscript so that the main text of the manuscript focuses on the step-by-step development of the variance of the solute displacement, while many details of the mathematical derivations related to the flow fields have been moved to Appendices A and B, such as the detailed solute convection velocity derivation and the cross-covariance and covariance functions of the flow velocity fields. **For details, please see the revised manuscript.**

3. Further insight is provided to better understand the idea behind Figures 1-2 (Line 280 on page 17):

   "When taking samples from a field, one obtains a histogram from which a certain value of the variance can always be calculated. However, for many phenomena, the experimental variance is actually a function of the field. In particular, it increases as the field increases, i.e., many phenomena have an almost unlimited capacity of dispersion and cannot be adequately described by ascribing to them a finite a priori variance. In this case, the use of the semivariogram is an appropriate way to measure the variability of the variation."

Yes, major revisions to the manuscript result in a very different version of the manuscript.