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Interactive comment on "Subgrid spatial variability of soil hydraulic functions for hydrological modelling" *by* P. Kreye and G. Meon

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We thank anonymous reviewer 3 for her/his detailed comments. This will help us to improve the manuscript.

Specific comments

> *ROSETTA is a calibrated model which has effective parameters itself, as it is based on an imperfect model structure. This means that parameters found suitable for ROSETTA might not be very applicable in a distributed hydrological model. This was found by Koch et al. (2016) where parameters from a surrogate model*

> *(HYDRUS1D) were passed on to distributed models and it became clear that parameters are not easily interchangeable between models.*
> *Along these lines it may be doubtful that the regression model between parameters of one model is transferable to another model. I would ask the authors to reflect on their assumption that the regression models found in ROSETTA are still valid in a more complex distributed hydrological model.*

First, we would like to add some information regarding ROSETTA. This software is based on neural network analyses and servs as pedotransfer function for the estimation of van Genuchten water retention parameters (VGP) and the saturated hydraulic conductivity (Ks). Data with different level of detail can be used as input, starting with texture classes and going up to more detailed (experimentally determined) information (Schaap et al., 2001). However, ROSETTA doesn't fit VGPs and Ks by means of measured time series of e.g. soil moisture or pressure head. Hence, we prefer to define ROSETTA as "pedotransfer function" rather than using the term "model". Koch et al. (2016) used the model HYDRUS 1D to fit VGPs (thank you for this reference). This was done by means of continuously measured time series of soil moisture at different locations and depths. HYDRUS also incorporates a ROSETTA interface, but here inverse modelling was used to fit VGP. I totally agree with you, that it could be troublesome to transfer the VGP, which were determined by this manner, from HYDRUS to more complex hydrological models (but this isn't what we did). To parametrize their model, Koch et al. (2016) homogeneously used the same VGP at every spatial location for hydrological modelling. In a second (heterogeneous) scenario they used spatially differentiated porosity (saturated water content), but all other VGP are still homogenously distributed. Hence, they nicely conclude that "*future work must focus on other possibilities to further distribute the remaining VGM parameters*". One possibility to achieve this on the mesoscale is what we introduce in our study. Summary: We use ROSETTA as pedotransfer function to estimate VGP.

Section 3.3 nicely presents the workflow of the presented approach. However I would like to ask the authors to clarify how the VGP sets are incorporated in the hydrological model. Again, how can the authors support that the mean Ks value obtained from ROSETTA can be regarded as the mean Ks value for the more complex hydrological model, that may requires model dependent effective parameters (p.12,l.20). Instead a prior calibration of the hydrological model could be used to obtain suitable mean Ks values.

We feed ROSETTA with texture information based on soil maps (in our case, the soil map of Lower Saxony, 1:50.000). Therefore, the Ks values estimated by ROSETTA are effective that are values valid for the spatial resolution of the soil map. The simulations of soil water dynamics inside the hydrological model operate on the same spatial resolution as the soil map, because the spatial distribution of our hydrological model (PANTA RHEI) is based on polygons. To establish subgrid variability, we create distribution functions of Ks and VGP as described in the manuscript. But (and this is an important fact), we don't change the effective VGP/Ks set in order to calibrate the hydrological model.

How many sets of VGP sets should be used (p.12,l.24)?

The number of sets is up to the user. At least three sets should be used. In our manuscript we recommend five sets by using the 10%, 30%, 50%, 70% and 90% percentile of the Ks distribution function. Of course, more sets are possible.

Also, the authors should give guidance how the subgrid spatial variability can be quantified after all VGP sets are executed (p.12,l.20)? The standard deviation of soil moisture at each cell?

Yes, a possibility to account for subgrid variability is to analyse the standard deviation of soil moisture as a function of the number of applied VGP sets. Further, the spatial soil moisture patterns could be compared in dependence of the number of applied VGP sets, similar to Samaniego et al. (2010) (thank you for this reference). We compared breakthrough curves (1D) with different numbers of VGP sets and with different standard deviations of the Ks distribution functions. We also compared spatially distributed simulation results of the hydrological model for soil moisture with remotely sensed satellite data, but this goes beyond of this study. We are working on a pursuing manuscript focusing on the hydrological model and its calibration.

Also I did not fully understand if the authors suggest having multiple model scenarios, where each scenario is based on a different Ks value drawn from the Ks distribution for each soil class? Or if they suggest to generate stochastic fields of Ks values that are applied in the distributed model?

You are right, we have to be more precise. After the different sets of VGP (e.g. 5) are derived, we use all of them to parameterize the soil model, which is incorporated in the hydrological model (PANTA RHEI). We assume, that one effective set of VGP cannot express subgrid variability (as described in the manuscript). Secondly, we assume, that many different sets of VPG are able to do so. That's why the soil model is parameterized many times, whereby the structure and equations were not changed. These different models (domains) operate simultaneously and at the same spatial location and are connected to each other. Please take a look to the attached figure. At every spatial location (the resolution is determined by the soil map) we have different effective VGP and for every spatial location we parameterize 5 different VGP sets. The attached figure shows the idea at an abstract level, in fact our model is polygon based (and not grid based). Summary: we don't have multiple model scenarios. It is one model with multiple parameterizations.

> *In section 3.3 the authors address the problem of scale and that a pseudo accuracy can be created if the model is operated at smaller scales than its input. Often model input comes at various scales and in fact hydrological processes take place at various scales as well. Here, the mHm model (Samaniego et al., 2010) provides a very flexible platform at account for differences in scale in the input data and parameters. The authors should mention modelling alternatives in their manuscript.*

We didn't want to focus too much on the hydrological model. However, we agree to add more information here. Thank you again for the reference, we will pick this up in our manuscript. A big difference between our hydrological model PANTA RHEI compared to many other models is the number of model parameters that are used for calibration. We work with catchment based model parameters, which have different effects on the sub-catchment scale controlled by physiographic characteristics. This leads to (only) 6-8 model parameters in total to calibrate the model for an area of a few hundred square kilometres.

> *The authors mention that regression between Ks and the VGP could be artiflcially caused by ROSETTA. If this is the case, how do the authors support their suggested approach at all? What are the "real" regression models between Ks and other VGP and how wrong*

> *is ROSETTA? Again, this should be linked to the question if the same regression model can be assumed valid in a more complex hydrological model?*

Results of ROSETTA are estimations and anyhow effective values. These effective values are “never correct” if compared to experimentally derived ("real") values. However, the advantages of ROSETTA are scale equality and that no experimental measurements are necassary. For that reason, these parameters are suitable for hydrological modelling. But, if we use one VGP set it may not be possible to describe all conditions of soil water in a plausible way. For instance, soil water dynamics could be well approximated for wet situations, but provide inadequate simulations for dry situations (this was also a problem of the simulations performed in Koch et al. (2016)). Hence, we use more than on set of VGP.
Connections between (experimentally derived) Ks and VGP are found in many studies, as described in our manuscript. Using ROSETTA we find quite strong connections. That's why we discuss at which proportion this could be enhanced by the artificial network. However, we think, that even if ROSETTA boost the connections between Ks and VGP it is admissible to generate distribution functions based on these connections as our focus is finding different “possibilities” to describe soil hydraulic behaviour within a certain framework.

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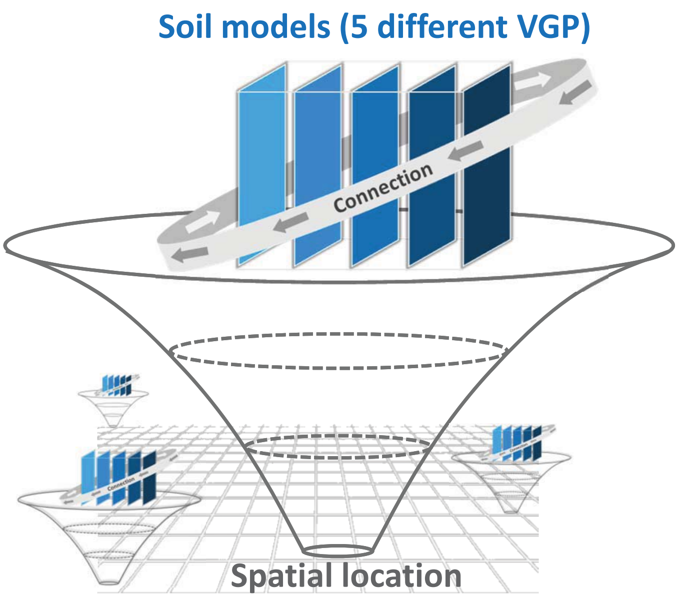

Fig. 1.