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What could we learn from simulations in virtual soil systems?

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In this contribution, we motivate the use of simulation studies in virtual soil systems using high performance computing systems. We focus on the scale of a field or a field plot, which is the unit cell of land management and of hydrologic simulation models. Processes in the vadose zone of such a unit cell are strongly dependent on the spatial variability of soil properties within this unit cell. Typical for this spatial heterogeneity is its multi-scale or hierarchical nature. A first key question is therefore how heterogeneities at different scales influence the averaged behaviour of the system at a larger scale. In order to address this question using simulation studies, small scale heterogeneities must be resolved while the extent of the simulation domain should be sufficiently large to represent the effect of larger scale heterogeneities. A second key question is what information can be obtained from measurements that are made in such a system. Simulations of the processes in soil system with realistic heterogeneities in combination with simulations of measurements of fluxes and state variables in this system are useful for identifying the information content of measurements. Such measurements can be either local measurements or measurements that integrate local information such as geophysical measurements. A third key question is how parameters of models that describe averaged processes in these unit cells depend on the inner structure of the system. To address these questions, simulations in 3-D heterogeneous soil blocks of a sufficiently large extent are needed leading to problems in the order of 109 unknowns. Methods to simulate and manage the input and output efficiently making use of high performance super computing infrastructure were developed.