Comments on “A Set of Analytical Benchmarks to Test Numerical Models of Flow and Transport in Soils”

The increasing demand for detailed information on hydrological processes as they are influenced by land use, soil characteristics, and water management have encouraged the development of dynamic process-oriented models. Currently applied models are not perfect and have to be thoroughly tested and validated. The awareness of the need for good modeling practice protocols is increasing outside the academic community as well. Testing protocols include verification of (numerical) model codes and validation against field experiments. Therefore, we were very pleased with the paper by Vanderborght et al. (2005) on benchmark tests for numerical models that use Richards’ equation for water flow and the convection–dispersion equation for solute transport.

For the case with high infiltration into a soil profile with clay above sand, the SWAP model (Van Dam et al., 1997; Kros and van Dam, 2003) reproduced exactly the water balance but showed deviations in the computed soil water pressure head profile. Vanderborght et al. (2005) attributed these deviations to the use of volumetric water content changes as a stopping criterion in the iteration procedure, instead of soil water pressure head changes.

Further inspection of the model and the SWAP computer code for this case indicated the following:

1. Changes in both the volumetric water content and the pressure head are used to test progress of the iteration cycle. The criterion for the volumetric water content is user-supplied, while the criterion for the change of pressure head is fixed in the model code.

2. When progress of the numerical solution is not sufficient within six iterations, the time step is decreased and the iteration cycle starts again. It appeared that the maximum number of six was not sufficient for this case. After increasing this maximum to 20, the model generated a stable pressure head profile, although results were still not accurate.

3. The hydraulic conductivity is described as a function of relative saturation (\(S_e\)) using the analytical Mualem–van Genuchten function (van Genuchten, 1980) (MVG). Near saturation the SWAP model uses a not well documented linearization of this function: in the range \(0.99 < S_e < 1.00\), the hydraulic conductivity is linearly interpolated between its value at \(S_e = 0.99\) according to van Genuchten (1980) and the saturated hydraulic conductivity at \(S_e = 1.00\). Figure 1 shows the effect of this linearization. In the benchmark test the final relative saturation of the clay layer was >0.99 and the linearization caused higher conductivity values than would be the case for the analytical MVG model.

After increasing the maximum number of iterations and disabling the linearization of the conductivity near saturation, the SWAP model was then able to reproduce the analytical solution. However, it still exhibited deviations from the exact analytical infiltration case.

While the benchmark tests presented by Vanderborght et al. (2005) are very useful to test model performance, they may question whether they are representative for practical applications. Especially the parameterization of the soil seems to lack any physical basis. Due to that, the difference between \(k(h)\) at \(-1\) cm pressure head is very large (Fig. 1). At \(h = -0.1\) cm the conductivity was less than \(25\%\) of \(k_{\text{sat}}\). At this pressure head, the air entry value of clay soils will not yet be reached, and the clay layer is not yet saturated. Therefore, such a large drop in conductivity is not realistic. Vogel et al. (2001) found that the linearization of the \(k\) function near saturation can have a large impact on variably saturated flow predictions, and our model depicts the linearization employed by the SWAP model. This linearization causes the conductivity at the saturated pressure head to be overestimated by a factor of 8.75 times.

Our main conclusions are that the input parameterization of the SWAP model were insufficient for direct application to the infiltration case of a clay soil on top of coarse sand. The linearization of the MVG relation near saturation can be a hidden model option useful for practical applications. This also caused deviations from the pressure head profile. To increase user flexibility we will release a new version of SWAP that offers input of \(k(h)\) directly in tabular form in addition to analytical functions. Documentation will be improved and an extensive test set will be made available for download from our web site (www.swap.alterra.nl [verified 13 Jan. 2006]).

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