Estimation of the Thermophysical Properties of the Soil by Inverse Problem, using Experimental Data during Liquid/Vapour Phase Change

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ABSTRACT

In this work, we introduce a numerical strategy to estimate the thermophysical properties of the soil of a saturated porous medium (volumetric heat capacity $(\rho C)_s$, thermal conductivity λ_s and porosity $\emptyset$) where a phase change problem (liquid/vapour) appears due to intense heating from above. An inverse problem is used to estimate these properties knowing the experimental heating history curves at selected positions of the porous medium throughout the whole heating duration. The system (to be solved) is composed of the heat diffusion equation together with three sensitivity equations resulting from differentiating that equation with respect to the three unknown parameters.

We use the Apparent Heat Capacity Method (AHC) [1] to deal with the phase change problem in which the phase change temperature interval ΔT plays an important role [2]. The choice of ΔT has a big influence on the accuracy of the solution of the heat equation and consequently on the solution of our inverse problem so we adopted a special technique related to the choice of ΔT and the assurance of better convergence. This technique is based on chaining the inverse problems using different values of ΔT and initial guess parameters' set, i.e., when an inverse problem using a certain initial guess parameters' set fails to converge we increase the value of ΔT to assure convergence and then we use the convergent set of parameters as initial guess in the inverse problem using the optimal value of ΔT. The difficulty of such a problem lies in the fact that the experimental temperature is obtained at few sensors only and not at every point of the soil. Moreover, we must emphasize that the exact location of each thermal sensor is very difficult to be determined after the experiment and thus experimental errors obtained might strongly affect the results of our ill-posed inverse problem.

We use the least square criterion to solve the inverse problem where we try to find the soil properties that best minimize the discrepancy between the experimental temperatures and the calculated ones using the well-known Levenberg Marquardt Algorithm [3]. We propose a global approach based on the method of lines where the space discretization is done using a vertex-centered finite volume method and discretization in time is done via an ODE solver that uses a BDF scheme and a modified Newton method. The code validation stage – performed previously – is based on the comparison between synthetic data and the calculated ones and gave excellent results [4].

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