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A new approach to treat discontinuities in multi-layered soils

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The water infiltration into two (or more) layered soils can give rise to preferential flow paths at the interface between different soils. The deep understanding of this phenomenon can be of great interest in modeling different environmental problems in geosciences and hydrology. Flow through layered soils arises naturally in agriculture, and layered soils are also engineered as cover liners for landfills. In particular, the treatment of the soil discontinuity is of great interest from the modeling and the numerical point of view, and is still an open problem.

Assuming to approximate the soils with different porous media, the governing equation for this phenomenon is Richards' equation, in the following form:

$$C_1(\psi)\frac{\partial \psi}{\partial t} = \frac{\partial}{\partial z}\left[K_1(\psi)\left(\frac{\partial \psi}{\partial z} - 1\right)\right], \quad \text{if} \quad z < \overline{z}, \tag{1}$$

$$C_2(\psi)\frac{\partial \psi}{\partial t} = \frac{\partial}{\partial z}\left[K_2(\psi)\left(\frac{\partial \psi}{\partial z} - 1\right)\right], \quad \text{if} \quad z > \overline{z}, \tag{2}$$

where $\overline{z}$ is the spatial threshold that identifies the change in soil structure, and C_1 C_2, K_1, K_2, the hydraulic functions that describe the upper and the lower soil, respectively. The ψ-based form is used, in this work.

Here we have used the Filippov's theory in order to deal with discontinuous differential systems, and we handled opportunely the numerical discretization in order to treat the abovementioned system by means of this theory, letting the discontinuity depend on the state variable.

The advantage of this technique is a better insight on the solution behavior on the discontinuity surface, and the no-need to average the hydraulic conductivity field on the threshold itself, as in the existing literature.