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Lateral Exchanges in the Evaporation from Field-Scale Heterogeneous Surfaces

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Classical representation of evaporation from a field-scale homogeneous plot consists of 1-D Richards' equation for the flow in porous media coupled at the interface to a (turbulent) mass exchange model for free flow. Lateral exchanges of heat and mass in the soil as well as airflow change this picture drastically when the soil surface wetness is spatially variable. Evaporation fluxes from wet patches in a background of dry soil may be different from homogeneous fluxes depending on the characteristic length of the wet patch. On top of that, smaller scale phenomena at the interface between free flow, dried out top layers, (partially) saturated soil and airflow adds more complexity to the exchange pattern at the interface. Developing a model that is capable of simulating such a system with reasonable computational efforts yet not oversimplified, is the aim of this work. A solver for 2D/3D Richards' equation is developed coupled to a 2D/3D (Navier-) Stokes solver for turbulent velocity field of the airflow, a solver for 2D/3D (turbulent) mass transport equation and a solver for energy conservation equation (temperature). In the case of heterogeneous medium, the parabolic and nonlinear - degenerate Richards' equation has low regularity, which makes it very challenging to be solved numerically. We use lower order mixed finite element method for the discretization of the Richards' equation, which provides strict mass conservation. To handle the interface complexity in continuum scale, a more sophisticated wall function is used to consider the effect of roughness, slip velocity and convective airflow in top layers. Comparing the result of such a model to data from more accurate simulations at smaller scales (including different combinations of higher order simulation of turbulent free flow and high resolution continuum scale or pore network modeling of transport in porous media) is essential for judging the importance of different contributors in the model. This will be the next step of the project. Finally, the model will be verified against experimental data and after calibration used to predict evaporation under more realistic field scale conditions.