Geophysical Research Abstracts
Vol. 15, EGU2013-621, 2013
EGU General Assembly 2013
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A new water retention and hydraulic conductivity model accounting for contact angle

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The description of soil water transport in the unsaturated zone requires the knowledge of the soil hydraulic properties, i.e. the water retention and the hydraulic conductivity function. A great amount of parameterizations for this can be found in the literature, the majority of which represent the complex pore space of soils as a bundle of cylindrical capillary tubes of various sizes. The assumption of zero contact angles between water and surface of the grains is also made. However, these assumptions limit the predictive capabilities of these models, leading often to enormous errors in the prediction of water dynamics in soils.
We present a pore scale analysis for equilibrium liquid configurations (retention) in angular pores taking the effect of contact angle into account. Furthermore, we propose an alternative derivation of the hydraulic conductivity function, again as a function of the contact angle, assuming flow perpendicular to pore cross sections. Finally, we upscale our model from the pore to the sample scale by assuming a gamma statistical distribution of the pore sizes. Closed form expressions are derived for both sample water retention and conductivity functions.
The new model was tested against experimental data from multistep inflow/outflow (MSI/MSO) experiments for a sandy material. They were conducted using ethanol and water as the wetting liquid. Ethanol was assumed to form a zero contact angle with the soil grains. The proposed model described both imbibition and drainage of water and ethanol very well. Lastly, the consideration of the contact angle allowed the description of the observed hysteresis.