A new stochastic hydraulic conductivity approach for modeling one-dimensional vertical flow in variably saturated porous media[1].

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The degree of carbon climate feedback by terrestrial ecosystems is intimately tied to the availability of moisture for photosynthesis, transpiration and decomposition. The vertical distribution of subsurface moisture and its accessibility for evapotranspiration is a key determinant of the fate of ecosystems and their feedback on the climate system.

The goal of this exploratory work is to develop new algorithms of deep subsurface water dynamics that could improve the CESM representation of subsurface hydrology and transpiration especially with extreme precipitation.

A time series of five years of high frequency (every 30 min) observations of water table at a research site in Northern California shows that the water tables, 18 meters below the surface, can respond in less than 8 hours to the first winter rains, suggesting very fast flow through micro-pores and fractured bedrock. Not quite as quickly as the water table rises after a heavy rain, the elevated water level recedes, contributing to down-slope flow and stream flow.

The governing equation of our model uses the well-known Richards' equation, which is a non-linear PDE, derived by applying the continuity requirement to Darcy's law. The most crucial parameter of this PDE is the hydraulic conductivity $K(\theta)$, which describes the speed at which water can move in the underground. We specify a saturation profile as a function of depth (i.e. $K_{sat}(z)$) and allow $K(\theta)$ to vary not only with the soil moisture saturation but also include a stochastic component which mimics the effects of fractured flow and other naturally occurring heterogeneity, that is evident in the subsurface.

A large number of Monte Carlo simulation are performed in order to identify optimal settings for the new model, as well as analyze the results of this new approach on the available data.

Initial findings from this exploratory work are encouraging and the next steps include testing this new stochastic approach on data from other sites and also apply ensemble based data assimilation algorithms in order to estimate model parameters with the available measurements.

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