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Reply to comment by H. Vereecken et al. on "Field observations of soil moisture variability across scales"

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[1] We welcome and appreciate the comments of *Vereecken et al.* [2008] on our recent paper [*Famiglietti et al.*, 2008]. Their comments provide the opportunity to reemphasize the complex nature of the processes driving the observed behavior of soil moisture variability across scales presented by *Famiglietti et al.* [2008].

[2] *Vereecken et al.* [2008] suggest that the spatial variability of soil moisture content versus its field mean, as presented in *Famiglietti et al.* [2008], can be largely explained by the shape of soil moisture retention curves for a homogeneous soil, and, for a heterogeneous soil, it is related to soil variability of the constitutive model parameters which control the shape of retention curves. As an example, *Vereecken et al.* [2008] show soil moisture content (θ) versus soil water capacity $C(\theta)$ and $\Delta\theta$ on the basis of the van Genuchten model, which forms concave curves with peaks exiting between the two end-members (i.e., residual water content and porosity) of soil moisture. Indeed, the behavioral similarity between the variability observed by *Famiglietti et al.* [2008] and the curves calculated using stochastic theory of unsaturated flow [*Vereecken et al.*, 2007, 2008] has encouraged us to explore the fundamental causality that may exist between them. And we agree with *Vereecken et al.* [2008] in that, with given uniformly distributed suction head in a homogeneous soil, soil moisture variability peaks in the medium range of mean soil moisture content, and that progressively decreasing unsaturated hydraulic conductivity implied in the moisture retention curve plays an important role in reducing soil moisture variability toward the dry end of field mean soil moisture content.

[3] However, we would like to point out that some of the basic assumptions underlying the stochastic theory are rarely if ever met in the real field conditions, which makes it difficult to directly link our observations to the theory. For instance, a heterogeneous soil in *Vereecken et al.* [2007] and *Zhang et al.* [1998] is defined as a uniform texture soil with hydraulic properties that are stationary random variables (e.g., $\ln K_s$, α, β). On the contrary, most regional-scale fields (e.g., 50-km-scale fields) in *Famiglietti et al.* [2008] contain more than one classes of soil texture, and the different drainage rates among the textural groups are an important source of high soil moisture variability in the midrange of mean soil moisture content. Another important source of peak variability in the midrange of soil moisture content is fractional rainfall coverage that typically occurs within regional-scale fields. In fact, *Ryu and Famiglietti* [2005] show that, at the regional scale, fractional rainfall has larger impact on soil moisture spatial variability than soil heterogeneity. Even at local ($\sim$800-m) scales, lateral redistribution of soil moisture by topography can play a dominant role in creating soil moisture variability [*Mohanty et al.*, 2000]. These examples, i.e., nonstationary heterogeneity in soil hydraulic parameters, highly heterogeneous atmospheric forcing, and lateral soil water flow, illustrate some of the frequently observed field conditions that are not considered by the stochastic theory.

[4] We agree with *Vereecken et al.* [2008] that existing theories in stochastic unsaturated flow can give an important insight into the behavioral features of soil moisture variability under many circumstances. However, the above-listed examples highlight a number of other important factors that contribute to the high variability observed in the midrange of mean soil moisture content. Additional examples can be found in section 5.1 of *Famiglietti et al.* [2008]. The complex interplay of processes driving soil moisture variations at larger scales was an important motivation for us to conduct a behavioral analysis rather than a process-oriented study. Owing to the existence of multiple controlling factors on observed soil moisture variability, we suggest that the similarity between the observed concavity of *Famiglietti et al.* [2008] and the simulated curves of *Vereecken et al.* [2007] (e.g., location of the peak) is only in part causal.

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