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Research papers

Estimating the drainage rate from surface soil moisture drydowns: Application of DfD model to in situ soil moisture data

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ABSTRACT

The large heterogeneity in soil surface conditions makes it impracticable to obtain reliable estimates of soil hydraulic parameters for areas larger than few squared kilometers. However, identifying these parameters on a global scale is essential for many hydrological and climatic applications. In this study, a new approach named Drainage from Drydown (DfD) is proposed to estimate the coefficients of drainage using soil moisture observations. DfD firstly selects multiple drydown events when surface runoff and evapotranspiration rates are negligible compared to the drainage rate. Secondly, by inverting the soil water balance equation, the drainage coefficients are obtained. Synthetic experiments are carried out in order to tune the overall procedure. DfD is then tested with in situ observations at 8 different sites worldwide characterized by different climates and soil types. The reliability of the DfD is evaluated by using the DfD drainage coefficients in a physically based soil water balance model (SWB) for simulating soil moisture and a rainfall estimation model (SM2RAIN). The results indicate that the climate and the soil conditions exert an important role in the occurrence and magnitude of drainage rate. DfD is found capable of correctly identify periods in which drainage rate is the dominant process. Drainage coefficients obtained from DfD are consistent with the expected soil hydraulic properties based on the soil texture and land cover at each site. By using DfD drainage coefficients to estimate rainfall and soil moisture via SM2RAIN and SWB, promising results are obtained with median correlation of 0.83 and 0.91 between estimated and in situ data. However, in sites characterized by high rate of evapotranspiration (> 700 mm/year) and low permeable soil (e.g., clay) the DfD performance is reduced. Overall, DfD demonstrates the ability to decouple drainage and evapotranspiration processes and to estimate the drainage coefficients from in situ observations.

1. Introduction

Soil hydraulic properties (SHP) are important parameters controlling the partitioning of water and energy in the soil (Vereecken et al., 2016) and parametrization of SHP is essential for land surface and hydrological modeling (Montzka et al., 2017). Soil properties are usually estimated through field survey but SHP are often not included among the measurements (Patil and Singh, 2016). Moreover, even though SHP are normally collected through ground measurements or hydraulic tests, they are available at spatial scales much smaller than what is needed in land surface and hydrological models (Ines and Mohanty, 2008; Mohanty, 2013).

To overcome this scale gap, different approaches were suggested by the soil science community. For instance, it is often assumed that the system behaves similarly at small and large spatial scales and thus the same equations can be applied. However, the large spatial heterogeneity in SHP appeared to introduce tremendous uncertainty to this over simplification. This problem is also tackled using statistical approaches like Pedo-Transfer Functions that use the readily available soil data (e.g., soil texture, bulk density and soil organic matter) to estimate SHP (Wösten et al., 2001). However, the insufficient number of training samples and the inherent uncertainty in the input variables (e.g., soil texture map) limit the accuracy of the estimated SHP (Deng et al., 2009). The problem of spatial scale is also dealt with using a top-down perspective by inverse modeling (Mohanty, 2013). In this approach, physically-based hydrological modelling is applied and by minimizing

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