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Understanding fast heat transfer in the shallow subsurface

Martine Rutten (1), Susan Steele-Dunne (1), Jasmeet Judge (2), and Nick van de Giesen (1)

(1) Delft University of Technology, Water Resources Section, Civil Engineering, Delft, Netherlands (m.m.rutten@tudelft.nl), (2) Center for Remote Sensing, Agricultural and biological engineering department, University of Florida, Gainesville, FL USA

Understanding the temperature profile of the shallow subsurface is of great importance for interpreting remote sensing observations and modeling land-atmosphere interaction. Remote sensing observations are translated to surface characteristics, such as vegetation and soil moisture, using radiative transfer schemes that are sensitive to skin temperature estimation. The surface temperature is also a key variable in the heat partitioning of net radiation into sensible, latent and soil heat flux at the interface between land and atmosphere.

The temperature profile of the soil is determined by the processes of radiative, convective and conductive heat transfer. Whereas radiative and convective heat transfer are dominant at the soil-air interface, heat transfer within the soil is typically assumed to be governed by conduction and as such is described with a diffusion model. The thermal diffusivity of the soil depends mainly on mineral composition and moisture content and is described in many empirical models.

Using temperature data from experiments conducted in Florida (MicroWex 2) and the Netherlands (Monster), we show that diffusion cannot describe heat transfer within approximately the upper ten centimeters of the soil. The heat transfer is significantly faster than would be predicted with a diffusion equation. Diffusivity values, estimated using an inversion approach to the diffusion equation, fall outside the physically reasonable range, which is defined by available soil diffusivity models. The extent of this strongly thermally active layer depends on vegetation conditions, and possibly moisture conditions.

We investigate mechanisms that may explain the fast heat transfer in the shallow subsurface. Possible mechanisms include heat transfer by convective heat transfer processes such as latent heat formation and heat transfer due to water percolation. We estimated the size of the heat sink-source at depth and compared these to observations of latent heat and estimates of heat transfer by percolation. The magnitude of the sink-source reached values up to the same order of magnitude as the latent heat flux and decreased with depth. The sink-source terms were large, especially for low vegetation conditions and showed a distinct diurnal cycle. The possible contribution of percolation to heat transfer was minor compared to the magnitude of the sink-source term.

Finally, we compared an empirical heat flow model, which includes formation of latent heat in the shallow subsurface, with our data. We found this model could not sufficiently describe the fast heat transfer in the shallow subsurface. Ongoing work is on a physically based model to describe fast heat transfer in the shallow subsurface.