Experimental and numerical study of two dimensional heat and mass transfer in unsaturated soil with and application to soil thermal energy storage (SBTES) systems

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Abstract. A promising energy storage option to compensate for daily and seasonal energy offsets is to inject and store heat generated from renewable energy sources (e.g. solar energy) in the ground, oftentimes referred to as soil borehole thermal energy storage (SBTES). Nonetheless, it is widely recognized that the movement of water vapor is closely coupled to thermal processes. However, their mutual interactions are rarely considered in most soil water modeling efforts or in practical applications. A common assumption in most SBTES modeling approaches is to consider the soil as a purely conductive medium with constant hydraulic and thermal properties. However, this simplified approach can be improved upon by better understanding the coupled processes at play. The goal of this work is to better understand heat and mass transfer processes for SBTES. In this study, we implemented a fully coupled numerical model that solves for heat, liquid water and water vapor flux and allows for non-equilibrium liquid/gas phase change. This model was then used to investigate the influence of different hydraulic and thermal parameterizations on SBTES system efficiency. A two dimensional tank apparatus was used with a series of soil moisture, temperature and soil thermal properties sensors. Four experiments were performed with different test soils. Experimental results provide evidences of thermally induced moisture flow that was also confirmed by numerical results.