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Estimating in-situ soil moisture dynamics from soil thermal dependencies

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Soil moisture plays an important role for the understanding of hydrological processes due to its influence on water and energy fluxes between the soil surface and the atmosphere. Knowledge of soil water dynamics is especially critical in water-scarce areas. In agroforestry systems, for instance, excessive competition for water between the trees and crops might outweigh the benefits of the system, thus preventing a successful implementation.
Several techniques exist for measuring soil moisture and commercial devices vary widely in cost, reliability and efficiency. An alternative approach could be to estimate soil moisture dynamics from soil thermal dependencies. Similar approaches are already being used in remote sensing, as soil moisture influences the soil thermal properties and thus the surface energy balance and soil heat transfer. However, few studies have tested the feasibility of estimating in-situ soil moisture dynamics from soil temperature dynamics within a soil profile. Temperature sensors are cheaper, smaller and technically robust and could thus provide an interesting alternative to available commercial soil moisture sensors.
In this study, we quantify the effect of soil moisture on phase shift and amplitude attenuation of soil temperature to estimate soil moisture content. We investigate these relationships from two different angles. Firstly, we use virtual measurements in coupled model simulations of soil water and soil heat dynamics to infer the general feasibility and precision of the method in an idealized error-free world. A sensitivity analysis can give insights on how the parametrization of the thermal diffusivity affects the precision and feasibility. Secondly, we compare findings from these simulations to results from analyzing time series of both soil moisture and soil temperature measured in an agroforestry field site in South Africa. A tentative analysis of these time series reveals that the amplitude attenuation and phase shift in the daily temperature signal is clearly sensitivity to changes in soil moisture. Finally, we aim to setup a coupled model for the study site based on the available soil hydraulic and textural data and compare simulated with observed phase shifts and attenuations at different depths.