Natural temperature variations and soil moisture content in the vadose zone

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Soil moisture content and temperature are two of the most important control parameters for many biogeochemical and physical processes in the vadose (unsaturated) zone. As such, estimation of both quantities is crucial for many near-surface groundwater investigations. Recent developments in groundwater heat tracing have demonstrated the utility of passive measurements in studying surface water-groundwater interaction. Novel applications of heat-tracing to the vadose zone provide ample opportunities for further insight. Two approaches are taken to investigate saturation levels in the subsurface using temperature. Firstly, a first- principles analysis of heat transport in unsaturated porous media, combined with an empirical model of porous media thermal conductivity, is used to develop a semi-analytical model that can be used to estimate soil moisture content from passive temperature measurements. Secondly, a fully-coupled finite-element model of a highly-transient estuarine inter-tidal system is constructed and compared with field measurements. The diurnal temperature amplitude and phase parameter space of our semi-analytical model for soil moisture content is analysed to understand the applicability of the model. The model is also tested with finite-element modelled data that combines Richard's equation with the physics of heat transport in porous media. Soil moisture and temperature measurements from a field campaign at Korogoro Creek in Hat Head, NSW are compared with modelled results based on air temperature and surface water level and temperature measurements, as well as thermal and soil moisture retention curves determined from grab samples. The coupled nature of soil moisture and temperature in the vadose zone allows for models that exploit natural temperature variations to estimate soil moisture content. In highly transient systems, a coupled modelling approach allows for the dynamics of the vadose zone to be understood, which in turn can inform studies of biological and geochemical processes.