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Using Thermal Infrared Imaging to Estimate Soil Hydraulic Parameters: A Novel Approach

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MSGC

Can the surface temperature of a soil reveal how water moves through it?

Fluid transport in the unsaturated zone of the soil column is a key part of the hydrologic cycle. The properties that control fluid transport (known as soil hydraulic parameters, or SHPs) are difficult to measure and often vary widely within a short distance. Traditional measurement techniques are slow, labor intensive, and only provide point measurements. This study investigates the use of infrared imaging to provide estimates of these SHPs .

Methods

A 5 gallon bucket was placed under a 1500 watt heat lamp and filled with soil material. Thermocouples, soil moisture sensors, a heat flux plate, and a net radiometer were set up to constrain the energy budget. A FLIR E8 thermal infrared (TIR) camera was mounted on a tripod and placed adjacent to the bucket. A known volume of water was then applied to the bucket, and surface temperature was recorded at 5 minute intervals.

After the experiment, an ecohydrologic model (ECH_2O) was fit to the surface temperature time series using a Levenberg-Marquardt least squares minimization.

$$C_s(\theta) = (1-n)c_p\rho_p + \theta c_w\rho_w + (n-\theta)c_a\rho_a$$
$$K_T(\theta) = (1-n)K_p + \theta K_w + (n-\theta)K_a$$

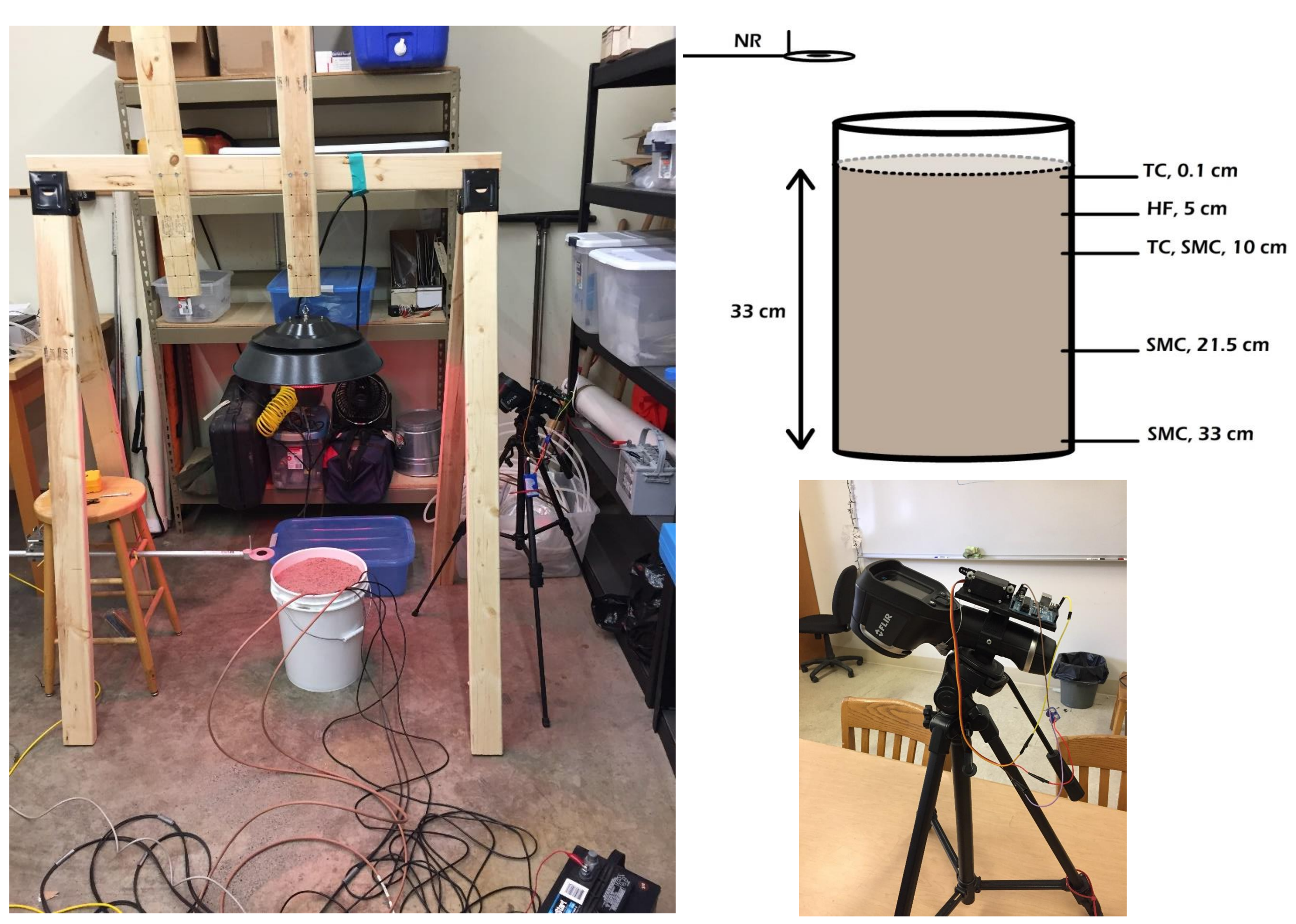


Figure 1. (Left) Experiment setup. (Top right) Schematic of bucket and sensor placement. (Bottom right) FLIR E8 TIR camera

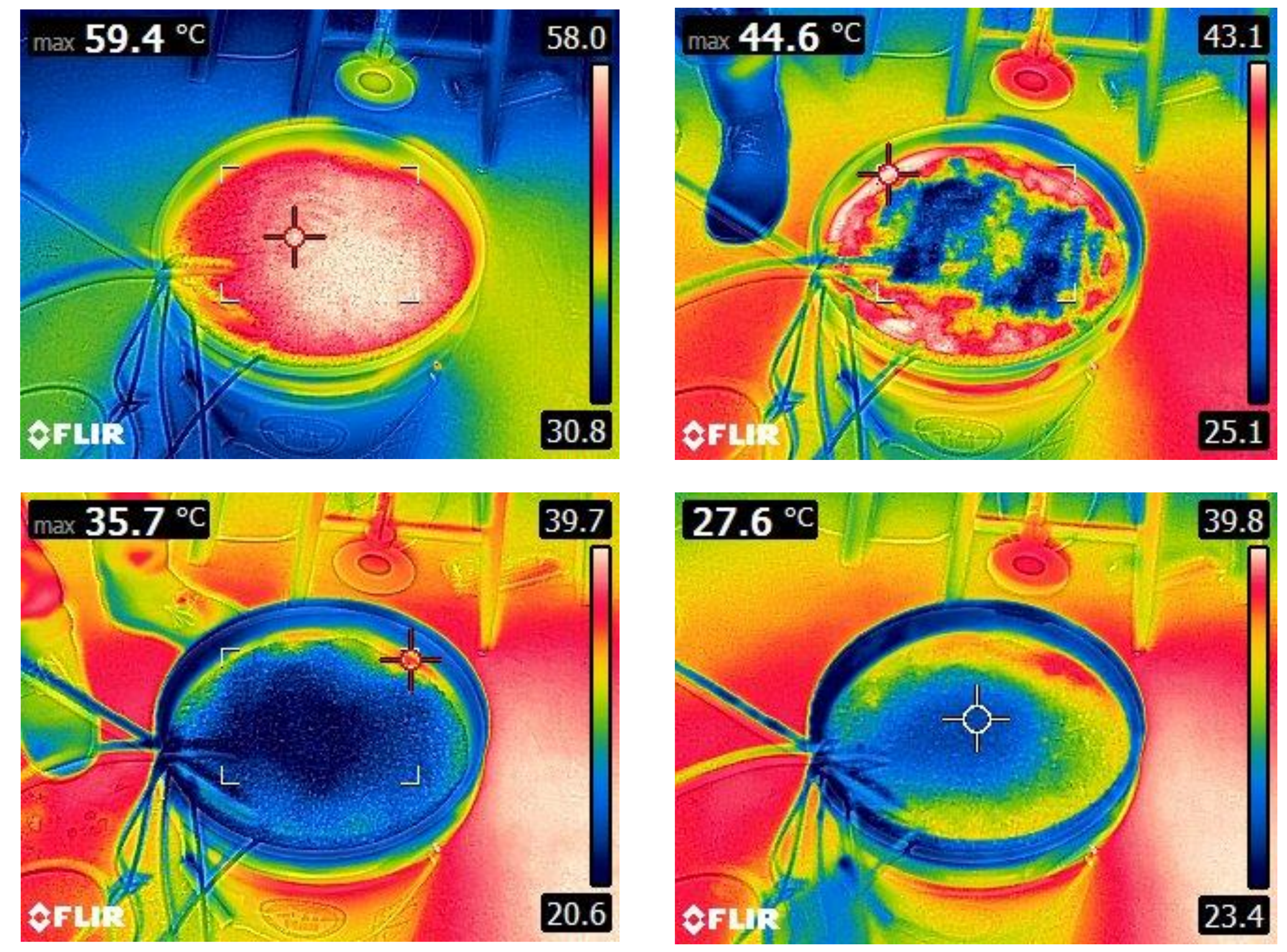


Figure 2. TIR images of before water application (Top Left), during (Top right), immediately after (Bottom left), and 5 minutes after (Bottom right)

Surface temperature recovery varies between soil types

The surface temperature time series acquired with the TIR camera show that there is an identifiable signal difference between the two different soil types. This shows that differences in how the soils drain play a role in controlling surface temperature.

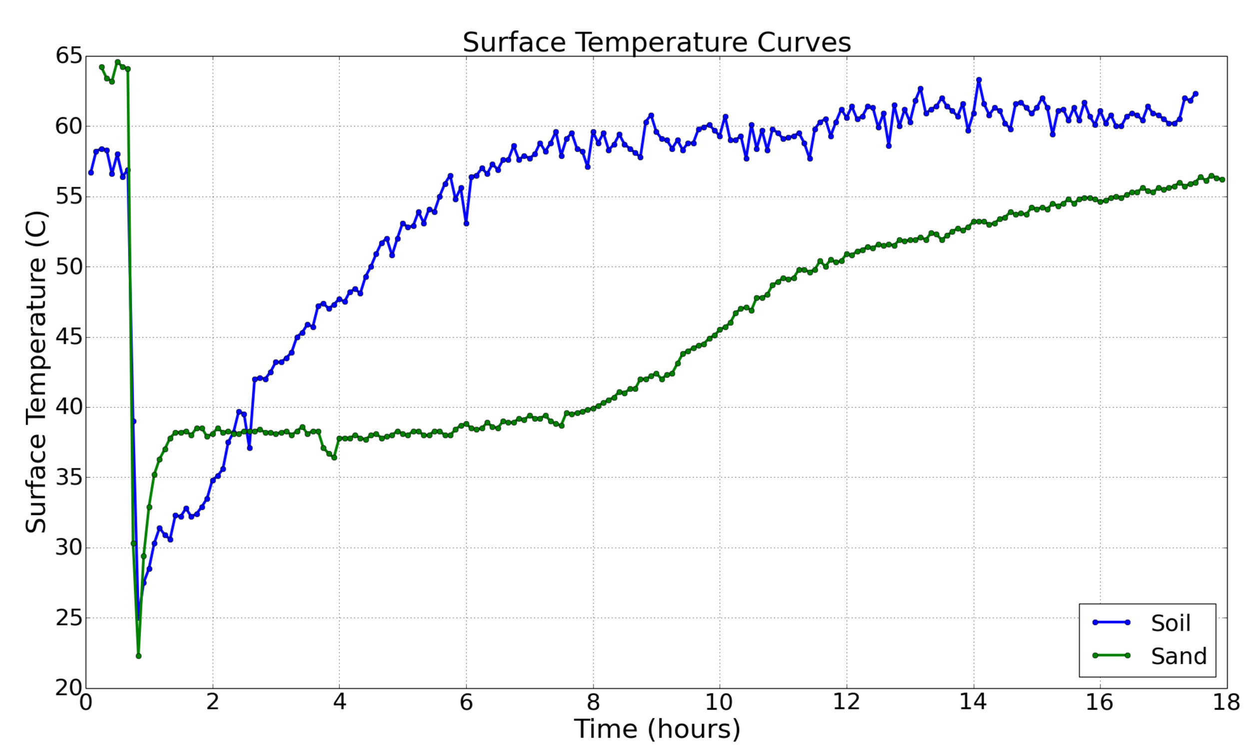
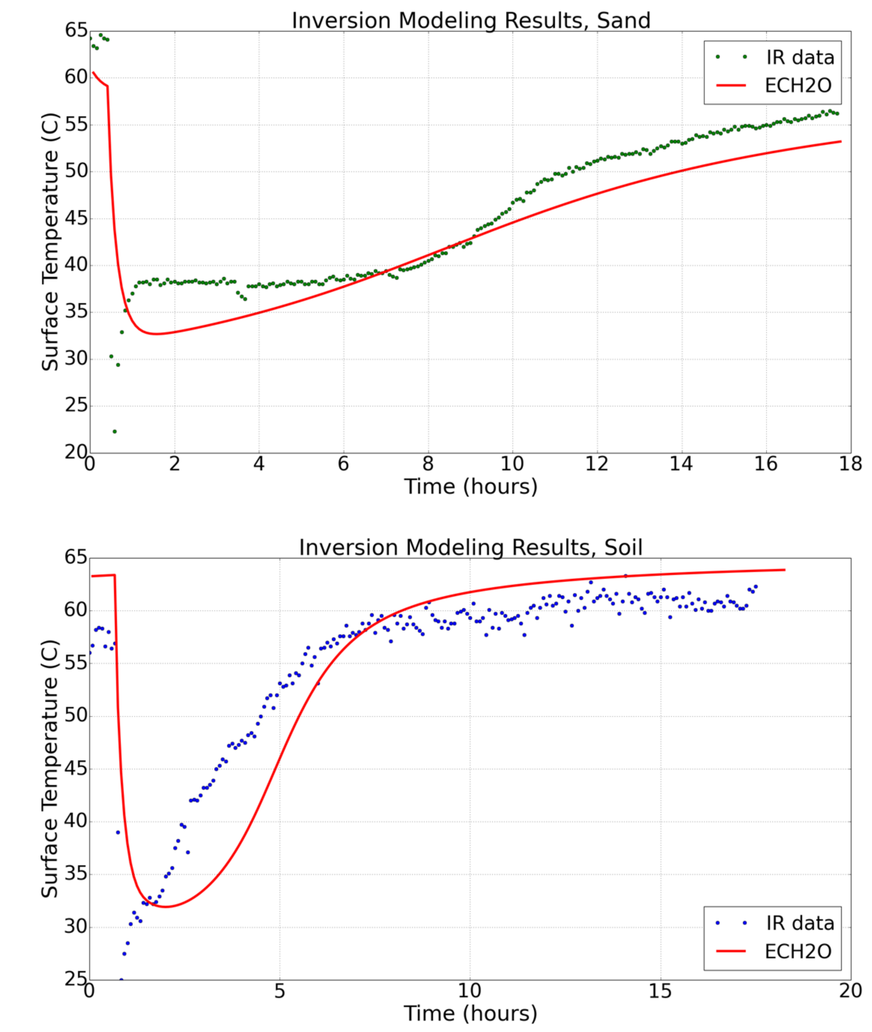


Figure 3. Surface temperature recovery curves from the TIR camera.

Inversion of ECH_2O provides reasonable SHP estimates

The curve fitting method provided reasonable estimates of ψ_{ae}, λ, and n. These estimates are within the normal bounds for these soil types.



	Sand	Soil
Porosity, n	0.18 (2.25%)	0.48 (6.23%)
Air-entry pressure, ψ_{ae} (m)	0.97 (6.88%)	0.01 (23.12%)
Brooks-Corey lambda, λ	3.36 (2.19%)	2.50 (4.56%)

Figure 4. (Top, Middle) Modeled best fit curves for sand and soil, respectively. (Bottom) Table showing best fit SHP values with % uncertainty

Conclusion

Surface temperature data acquired with a TIR camera can be used to estimate difficult to measure SHPs via inversion modeling. If this holds in the field, this method could provide a quick way to acquire point SHP estimates at each pixel in an aerial image.

Acknowledgments

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