Measuring Soil Properties and Processes with Thermo-Time Domain Reflectometry Sensors

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Introduction

The thermo-time domain reflectometry (TDR) sensor, which combines TDR and heat pulse sensors, measures soil thermal and electromagnetic properties. Recent advancements in fine-scale measurements of soil thermal and electromagnetic properties with the thermo-TDR sensor enable measuring soil state variables (temperature, water content, and ice content), thermal and electrical properties (thermal diffusivity, heat capacity, thermal conductivity, and bulk electrical conductivity), structural indicators (bulk density) and fluxes (heat, water, and vapor) simultaneously. ***Thus, it is a powerful tool to include in hydrological observation stations.***

Thermo-TDR sensor configuration

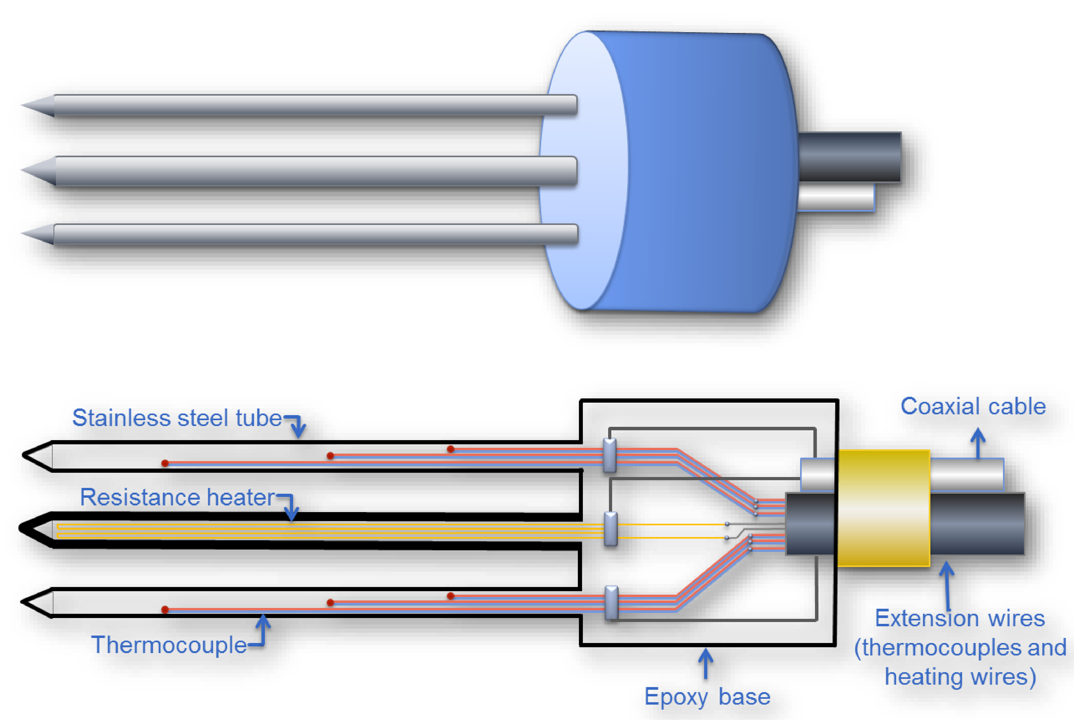

Fig. 1. A schematic diagram showing the design of the new thermo-TDR sensor. The drawing is not to scale.

Thermo-TDR measurements

Thermo-TDR technique

- Heat pulse measurement
  - Temperature response curves: ΔT (z, t)
  - Thermal properties
  - Fluxes
- TDR measurement
  - TDR waveforms: reflection coefficient vs apparent distance
  - Electrical properties
  - Salinity
- Bulk density, Ice content

Soil thermal properties and heat flux

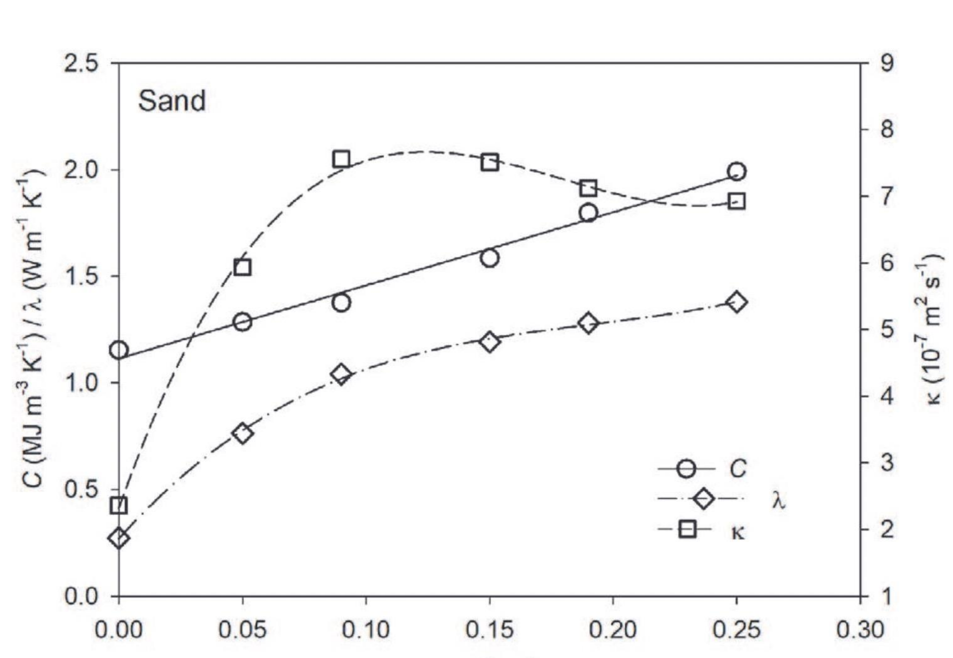

Fig. 2. Thermo-TDR determined thermal properties of a sand as a function of water content.

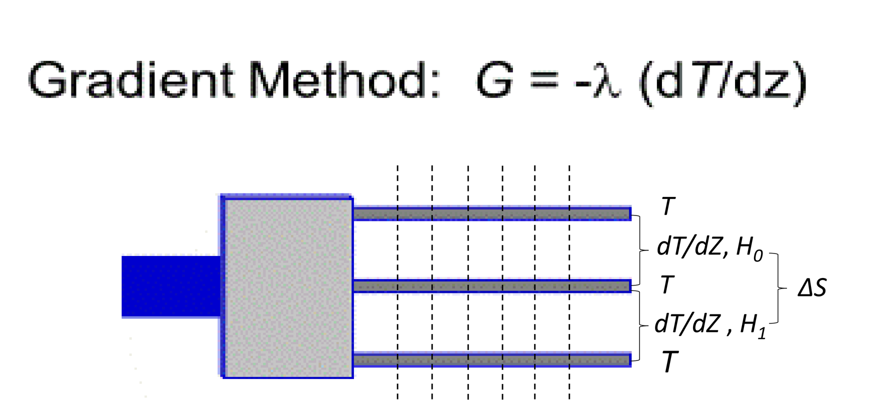

Fig. 3. Thermo-TDR probe and measurement interpretation for heat balance calculation. Symbols denote temperature (T), temperature gradient (dT/dz), soil heat flux (H_0 and H_1), and change in heat storage (ΔS).

Soil electrical conductivity

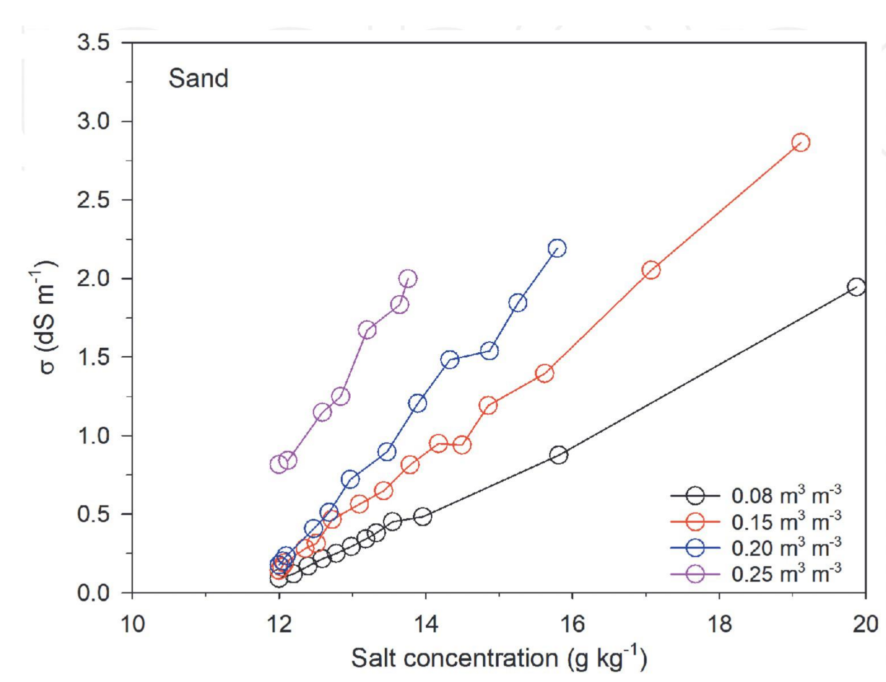

Fig. 4. Thermo-TDR measured bulk electrical conductivity of a sand soil as a function of KCl salt concentrations used to wet the soil to four selected water contents.

Soil water content

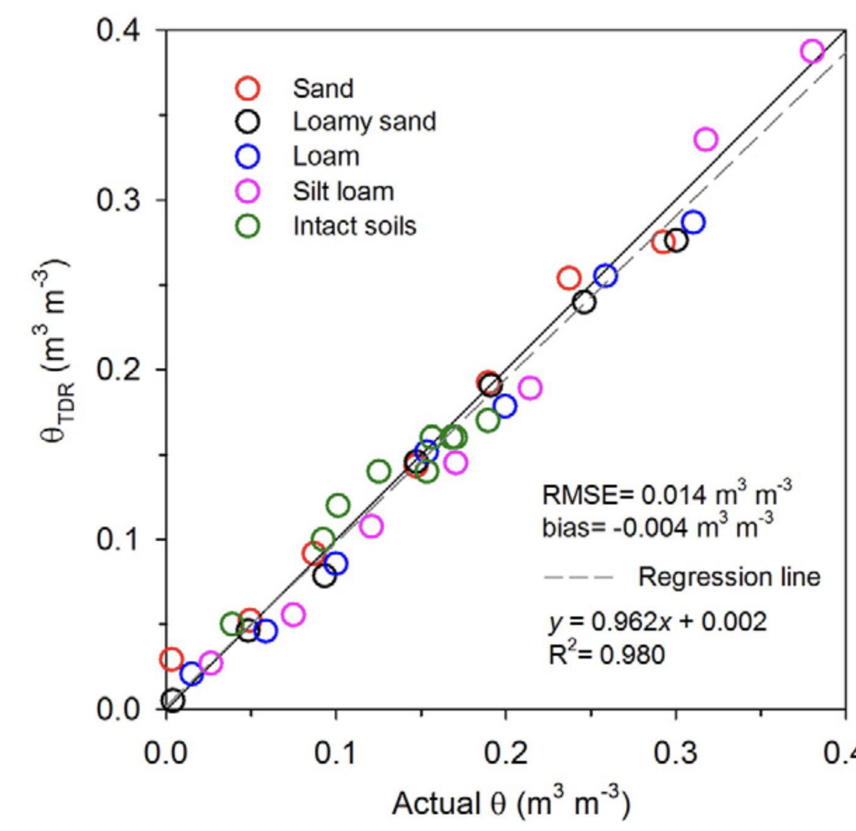

Fig. 5. Comparison of thermo-TDR derived water content vs. actual values by oven drying samples.

Soil bulk density

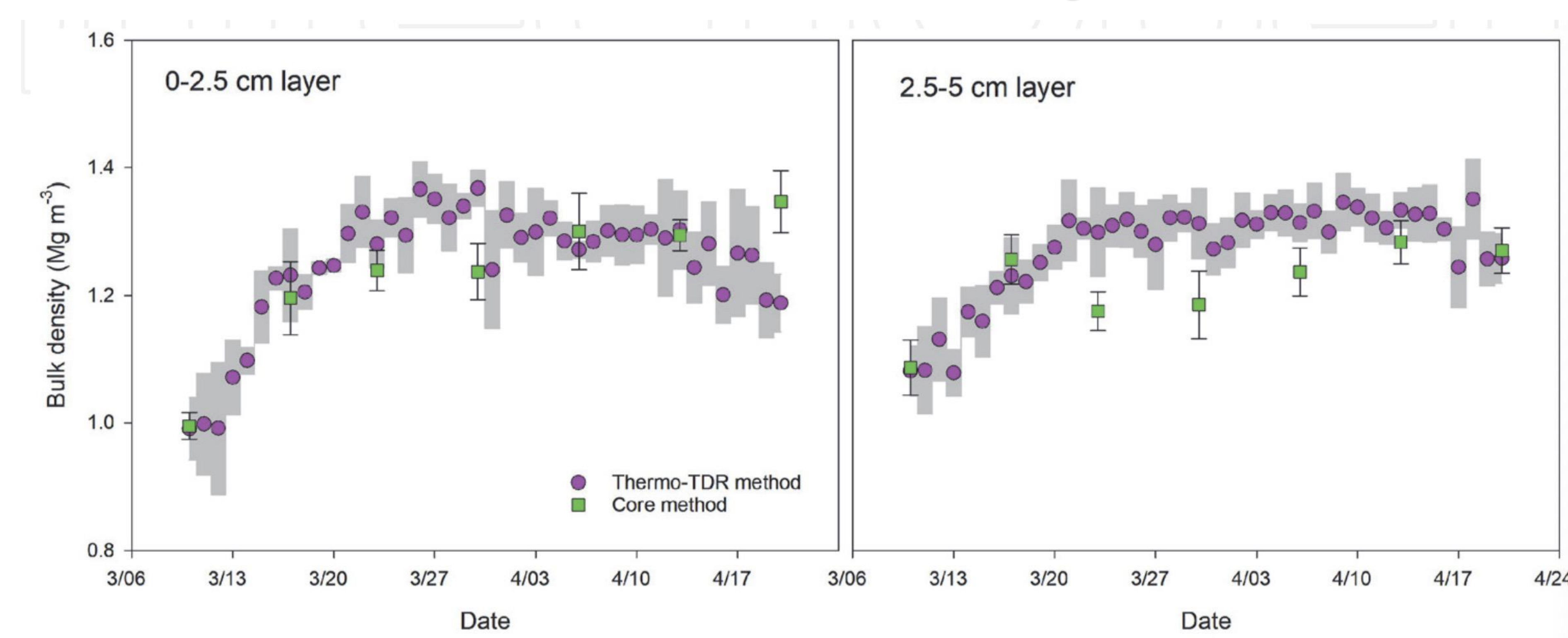

Fig. 6. Dynamic thermo-TDR measured bulk density (ρ_b) values for two soil layers plotted along with independent ρ_b values from soil core measurements.

Soil water evaporation

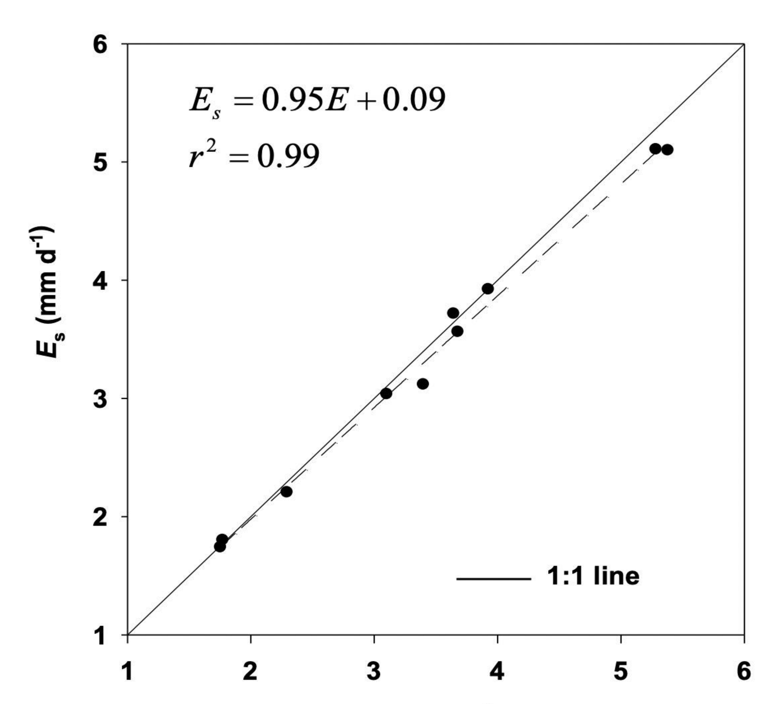

Fig. 7. Comparison of soil water evaporation estimated with the thermo-TDR probe versus weighing lysimeter.

Water flux density

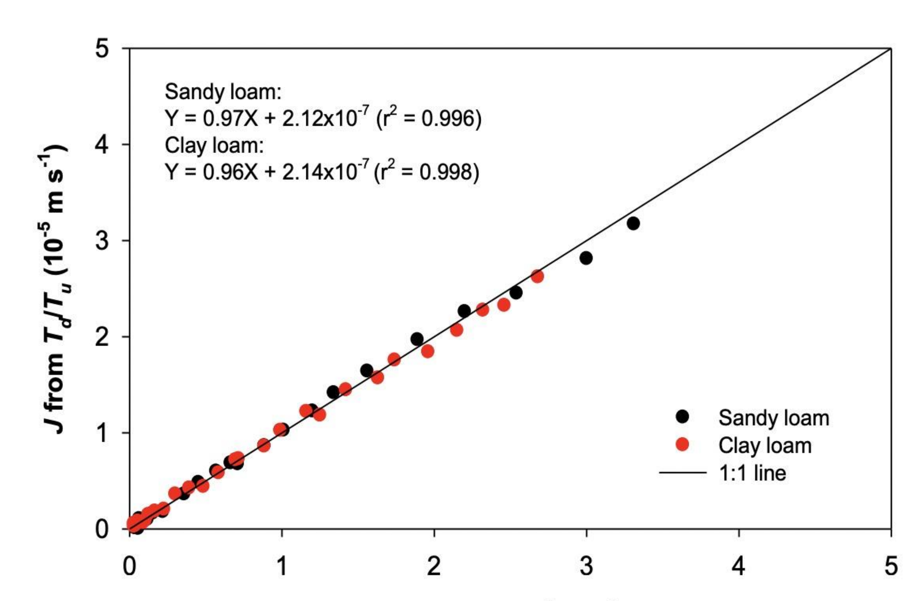

Fig. 8. Comparison of thermo-TDR derived water flux vs. actual values.

Summary

The thermo-TDR sensor measures a variety of soil properties, and it has the ability to monitor in-situ soil heat and water fluxes in the vadose zone.

Acknowledgements

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