301-2

Can a Dewpoint Hygrometer Measure Water Potential at Field Capacity?

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Background

Dewpoint hygrometers measure dewpoint temperature of air in vapor equilibrium with a soil sample and sample temperature to determine relative humidity. The relative humidity of air in vapor equilibrium with the sample is related to water potential by the Kelvin equation:

$$Water\ \ potential\ (MPa) = \frac{RT}{M_w}\ln(rh)$$

where R is universal gas constant (8.314 J mol^{-1} K^{-1}, T is temperature (K), M_w is the molecular mass of water (18.02 g mol^{-1}), and rh is relative humidity. Because of the logrithmic relationship between water potential and rh, this method is well suited to dry end measurements, but struggles to maintain the necessary precision in the wet end.

- Current dewpoint hygrometers (WP4, WP4T) are limited to ±100 kPa accuracy in the wet end
  - 0 to -100 kPa change in water potential is 100% to 99.927% change in rh
  - To measure ±100 kPa change in water potential, need better than 0.012˚C temperature resolution
- Vapor sorption on sample chamber slows vapor equilibrium and creates errors
- Current calibration and measurement routines not optimized for best performance
- Impossible to measure soils at field capacity (-10 to -33 kPa; see Figure 1) accurately with current dewpoint hygrometer technology

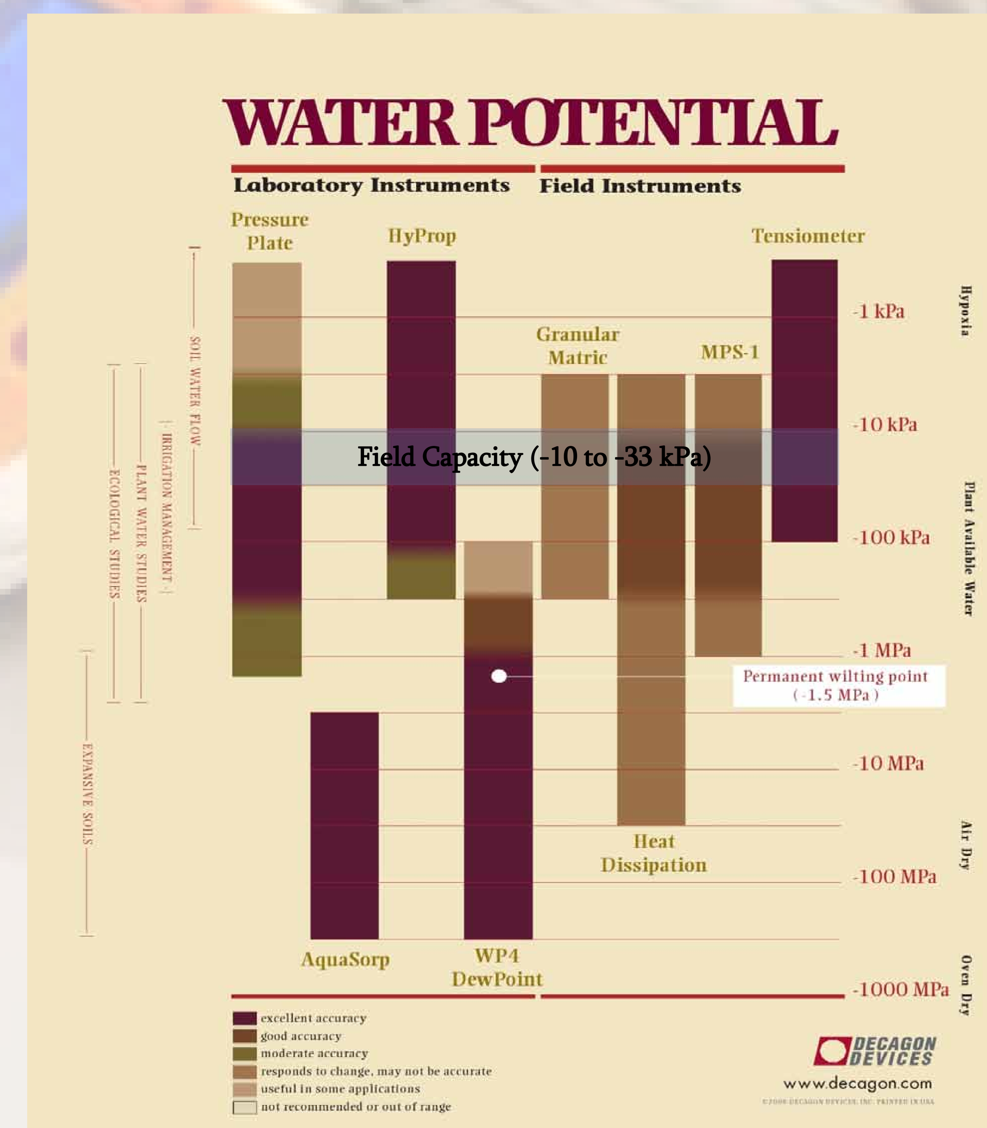


Figure 1. Measurement ranges of currently available water potential instrumentation with field capacity range called out. Note that current dew point instrumentation cannot make meaningful measurements near field capacity, and cannot make measurements in tensiometer range.

Solutions

- New 24 bit A/D converter can resolve thermopile and thermocouple electronic signals corresponding to better than 0.001˚C temperature resolution
  - This corresponds to about ±8 kPa resolution in water potential
- Hydrophobic Teflon™ impregnated Nickel chamber coating reduces vapor sorption
  - Vapor equilibrium is achieved more quickly
  - Reduced hysteresis when changing from moist to dry samples (and vice versa)
- New "precise" mode compares successive readings until measurement stabilize
- New calibration routine allows more accurate calibration

Performance Evaluation

Methods

- Used precision-mixed KCl osmotic solutions to evaluate accuracy in wet end
  - Ran instrument in temperature buffered environment
  - Used "continuous" mode for best possible precision
  - Calibrated all data by applying offset determined for -2200 kPa KCl solution
- Generated Soil Moisture Characteristic Curves (SMCCs) for two volcanic soils
  - Low electrical conductivity soils – negligible osmotic potential
  - Pushed WP4C into wet end as far as possible
  - Measured wet end SMCC independently with T5 tensiometer
  - Fit Shiozawa and Campbell (1989) SMCC model to experimental data

$$w = w_1\left(\frac{\ln \Psi}{11.51}\right) + A\left[1+(\alpha\Psi)^4\right]^{-1/m}$$

where w is gravimetric water content (g/g), w1 is w at -1 meter water potential, Ψ is water potential (m water) and A, α, and m are van Genuchten (1980) parameters.

Performance Evaluation (cont)

Results

- Using the best-practice methods described above, we were able to achieve accuracy within ± 25 kPa in the wet range on all four separate WP4C units tested (see Figure 2)
  - Far exceeds what has been possible before
  - This at least approaches the wet end accuracy necessary to measure samples at field capacity

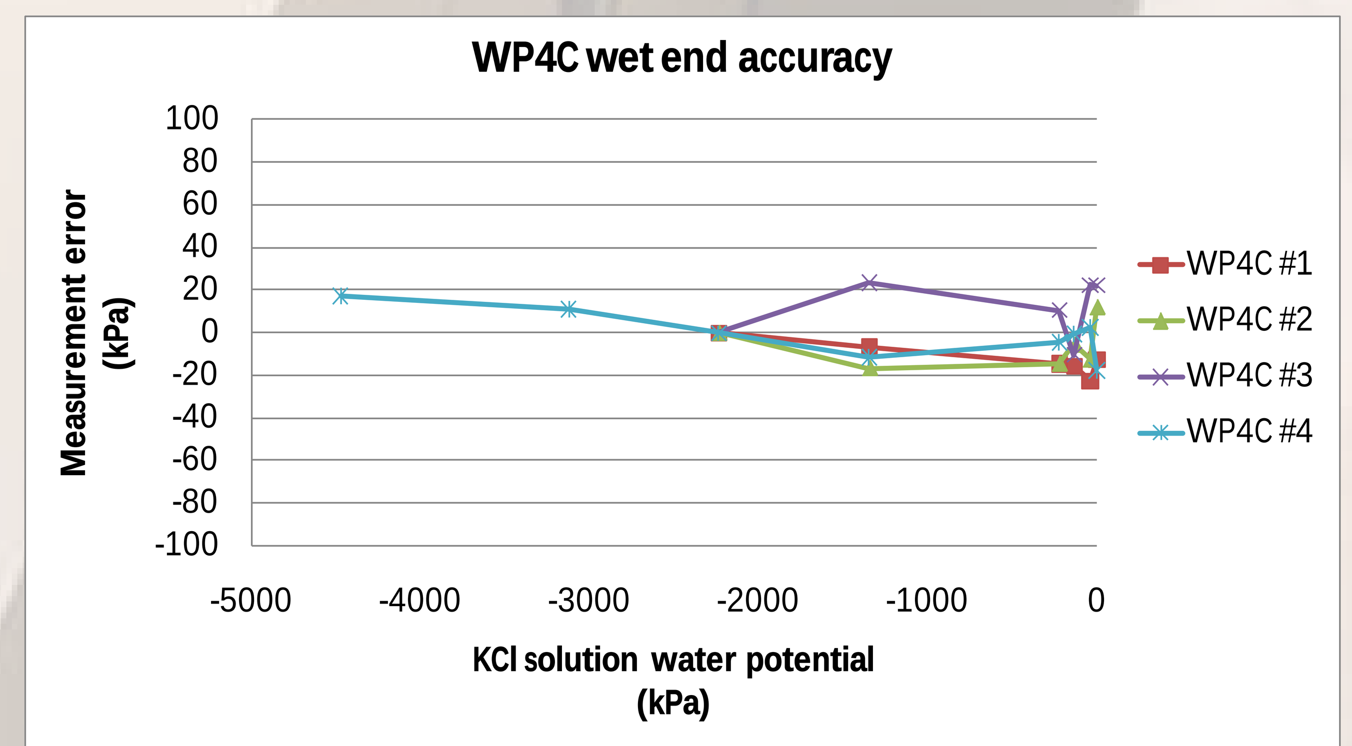
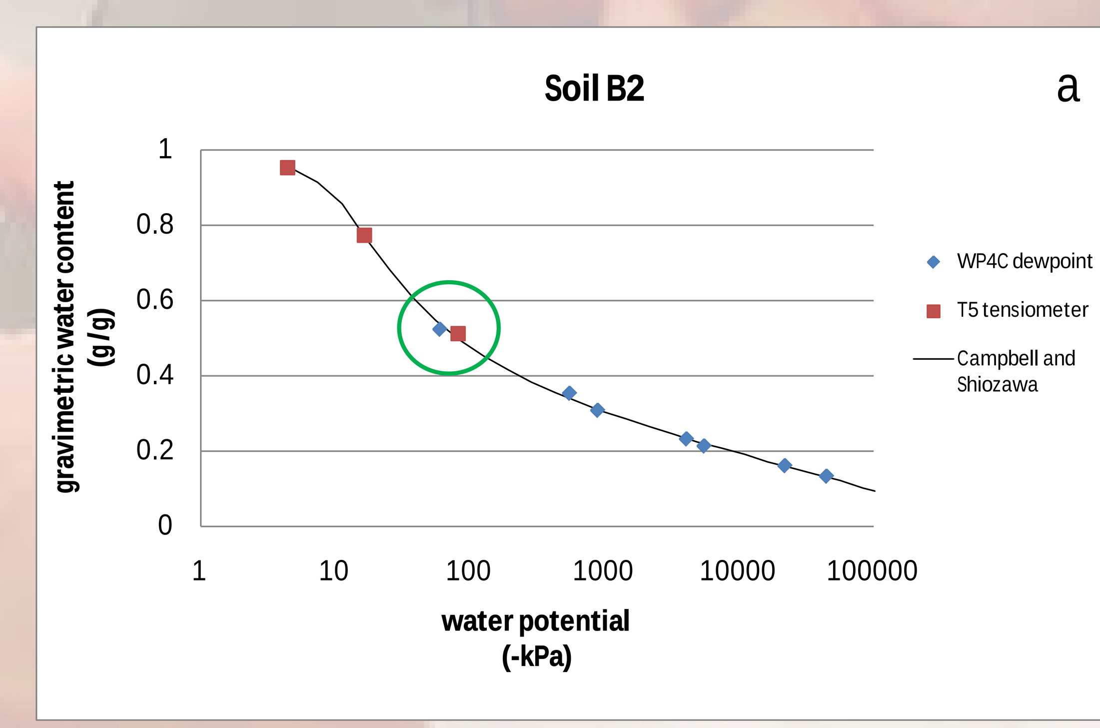


Figure 2. Absolute error of wet-end water potential measurement for four WP4C units.

- The combination of dry end SMCCs from the WP4C and wet end SMCCs from the T5 tensiometer were fit well with the Campbell and Shoizawa model for the two coarse textured, volcanic soils (see Figures 3a and 3b)
- Extended wet end range of WP4C allowed overlap of WP4C and tensiometer ranges
  - This has never been done before to our knowledge
  - Agreement between WP4C and T5 tensiometer was excellent



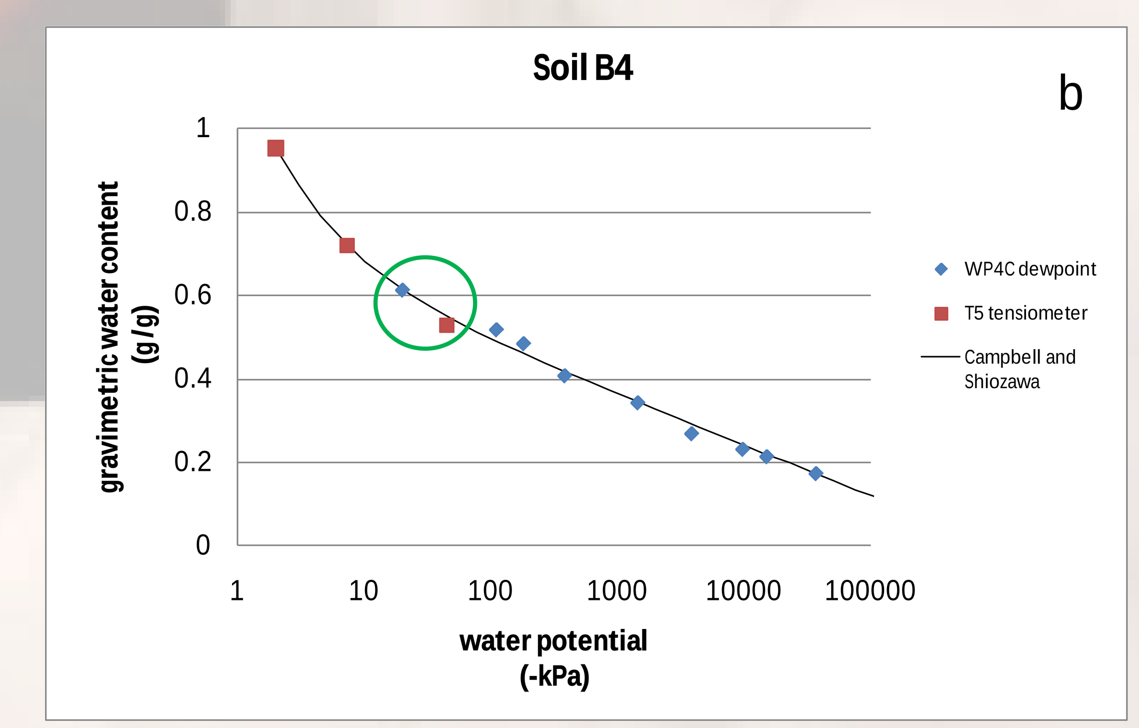


Figure 3 (a and b). SMCCs for soils B2 and B4. The dry end data were generated by the WP4C dewpoint hygrometer and the wet end data were generated by the T5 tensiometer. Optimized fit of Campbell and Shiozawa (1989) SMCC model is plotted in black. Note the overlap in the ranges and excellent agreement between the two instruments highlighted by the green circles.

References

G.S. Campbell and S. Shiozawa. 1989. *Prediction of Hydraulic Properties of Soils Using Particle-Size Distribution and Bulk Density Data.* In: Proceedings of the International Workshop on Indirect Methods for Estimating the Hydraulic Properties of Unsaturated Soils. M. Th. van Genuchten, F.J. Leij, and L.J. Lund eds.

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