Specific Heat Capacity of Soil Minerals and Its Influence on Heat Pulse Measurement of Soil Water Content

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INTRODUCTION

- The heat-pulse method has been used widely for measuring soil water content (θ). The accuracy of θ depends on the specific heat capacity of soil minerals (cₘ). The value of cₘ varies with soil texture and a range of data exists.
- For oven-dried (105°C) samples, specific heat capacity of soil solids (cₛ) is determined by the specific heats of minerals, organic matter (OM), and tightly bound water.
- The objectives of this work are to: (1) partition the contributions of soil minerals, OM, and tightly bound water to cₛ; (2) evaluate reliability of the commonly applied cₘ value of 0.725 MJ Mg⁻¹ °C⁻¹ from de Vries (1963); and (3) investigate the influences of cₘ value selection on θ measurements from the heat-pulse method.

RESULTS & CONCLUSIONS

- Specific heat capacity of soil:
  - cₘ: a mean of 0.736 MJ Mg⁻¹ °C⁻¹ (0.717 - 0.759 MJ Mg⁻¹ °C⁻¹). The common value of 0.725 MJ Mg⁻¹ °C⁻¹ (de Vries, 1963) slightly underestimated cₘ.
  - cₛ: a mean of 0.750 MJ Mg⁻¹ °C⁻¹ (0.718 - 0.772 MJ Mg⁻¹ °C⁻¹)
  - cₘ and cₛ correlate significantly to SA and clay content (Fig. 1). For improved accuracy, it may be necessary to estimate soil-specific cₘ values from SA or clay content measurements.
- Contributions of soil constituents to cₛ:
  - The contributions of OM and tightly bound water to cₛ increased with their contents in the soil (Fig. 2). On average, soil minerals, OM, and tightly bound water accounted for about 95%, 3%, and 2% of cₛ, respectively.
- Soil θ measured with the heat-pulse technique:
  - Heat-pulse θ was consistently higher than that of the gravimetric method (Fig. 3).
  - When the cₘ value of 0.725 MJ Mg⁻¹ °C⁻¹ (de Vries, 1963) was replaced with DSC measured cₘ values, the relative error in heat-pulse θ was reduced by 6%, 7%, and 10% for soils 6, 8, and 9, respectively.
  - Although θ accuracy with heat-pulse technique is improved with soil-specific cₘ data, θ errors mainly come from other sources (e.g., uncertainties of heat-pulse measurements of volumetric heat capacity of bulk soil).

MATeRIALS & METHODS

- Samples: 9 soils with various textures and OM (Table 1).
- Specific surface area (SA) of samples: WP4-T dewpoint meter.
- Specific heat capacity of soil samples: differential scanning calorimetry (DSC).
  - cₛ and cₛ₂₀⁰°C: samples with OM dried at 105°C and 200°C, respectively
  - cₘ: OM-removed samples dried at 200°C
- Contributions of soil minerals, OM, and bound water to cₛ were estimated using the de Vries (1963) model. Specific heat of OM was 1.92 MJ Mg⁻¹ °C⁻¹.
- Heat-pulse θ were measured on repacked samples of soils 6, 8, and 9, with a θ range of 0.025 - 0.285 cm³ cm⁻³.

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References:

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