**Determination of Subsurface Soil Evaporation using a Heat Pulse Probe Array**

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**Introduction**

Soil water evaporation is a critical component of both the surface energy balance and the hydrologic cycle, coupling heat and water transfer between land and the atmosphere. Recently introduced heat pulse probes (HPP) allow in-situ measurements of subsurface stage-2 soil water evaporation (Heitman et al., 2008a,b).

In the presented study, soil water evaporation was measured with an array of heat pulse probes embedded in a soil column.

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**Experimental Setup**

Simple evaporation process from a saturated soil column.

Surface boundary conditions are influenced by continuous supply of heat and a uniform wind velocity over the surface.

Subsurface evaporation rates are calculated based on the sensible heat balance determined using the equation:

\[ LE = \left( \frac{T_1 - T_{surf}}{x_1 - x_{surf}} \right) - \left( \frac{T_{surf} - T_2}{x_{surf} - x_2} \right) - \Delta S \]

- \( LE \): Subsurface evaporation rate (mm/s)
- \( L \): Volumetric latent heat of vaporization (kJ/m³)
- \( G \): Sensible heat flux of conduction
- \( S \): Soil Thermal Conductivity (W/m°C)
- \( T \): Soil temperature (°C)
- \( Z \): Soil depth (m)

The determined graph is distorted due to noise potentially due to averaging thermal conductivity across both sides of a heater needle.

- Discrepancies among 1, 3, and 6 mm observation results are largest for stage 2 evaporation.
- As the drying front deepens with time, these differences diminish.

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**Subsurface Evaporation Rate**

**HPP method** (Heitman et al., 2008a,b)

\[ LE = G_{1.2} - G_{1.2} - \Delta S \]

**Energy Balance**

\[ LE = G_{2.3} - G_{3.2} - \Delta S \]

- \( G_{i.j} \): Heat flux (W/m²)
- \( \Delta S \): Sensible heat flux of conduction
- \( T \): Soil temperature (°C)
- \( x \): Depth (m)
- \( t \): Time (s)

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**Results and Discussion**

Subsurface evaporation rates were calculated with Eq.(1) from soil temperatures with different observation grids (1.5 mm, 3 mm, 6 mm) using a Heat pulse probe array in a soil column.

**Summary**

- A PHPP provides estimates of soil thermal properties and heat flux.
- Subsurface evaporation estimates are derived from thermal property assessment with measurable depth dependent on number of PHPP in the array.
- A PHPP array experiment is underway to determine the level of accuracy for subsurface evaporation estimates.

**Future Work**

- A laboratory evaporation experiment using diurnal atmospheric boundary conditions is underway.
- The PHPP can be used as a multi-purpose research tool combining soil evaporation monitoring with estimates of soil water flux (e.g., from irrigation or precipitation).

**References**


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