FIELD SOIL MOISTURE AND TEMPERATURE MEASUREMENTS

Laosheng Wu
Department of Soil & Environmental Sciences
University of California - Riverside
Phone: (909) 787-4664; E-mail: LAOWU@mail.ucr.edu

Topics:

- Temperature sensors
- Soil-water content and potential measurement
- Automated measurements in the field

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Measurement of Soil Temperature

Thermocouple:

- A thermocouple consists of two wires, each of different metal or alloy, which are joined together at each end.
- When there is a temperature difference at the two junctions, a voltage is produced

  $V = f(T1, T2)$

  ±.5 °C
- With a third metal introduced between the two wires with junctions at the *same* temperature, while a portion of the third metal is held at an arbitrary T without disturbing the thermoelectric voltage;
- With the reference junction temperature (T2) and the voltage (V) measured, we can calculate the temperature of T1.

Thermistors

- Semiconductor - Resistance changes with temperature.
- High accuracy, but the measurement is more complicated (calibration, more complex circuits)

  ±.1 C

- Heat Capacity → High w/ high water content = highly buffered
- Heat Conductivity (no fast relationship / complex)

Soil-Water Content and Potential

- Soil-water content measures the amount of water in the soil--quantitative (volumetric and gravimetric).

- Soil-water potential measure the availability of the water to plants--qualitative.

$H = h + Z$

soil matric potential + length of tens.

Methods of Soil-Water Content Measurement

Gravimetric method

- Dry the moist sample in an oven at 105°C for 24 h.

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- Reliable, inexpensive, considered as the standard method
- Time consuming

*Neutron Probe (*Neutron attenuation)

- The instrument consists of a radiation source and a detector
- The radiation source emits high-energy (fast) neutrons, which colloid with elements and slow down to "thermal velocities". Of all the elements, H is the most effective in slowing down fast neutrons.
- The detector counts the number of slow neutrons
- A calibration curve is needed to establish the relationship between θ_v and the counts (actually the counting rate fraction: $C_f = C_{soil}/C_{std}$): $\theta_v = a + b C_f$

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- It measures a sphere of about 30 cm in dia. (How about a dry soil compares with a wet soil?)
- Background H may influence the measuring results
- Radioactive

Time domain reflectometry (TDR, θ_v)

- The pulse velocity, *v*, expressed in a electrodynamics term:

  $$v = c/\sqrt{K_a}$$

  where $c = 3\times10^8$ m s^{-1} is the velocity of light in vacuum, K_a is the dielectric constant.

- The pulse velocity, *v*, expressed in a mechanical term: (signal)

  $$v = 2l/t$$

- Thus the dielectric constant, K_a, can be expressed as:

  $$K_a = [c\ t/2\ l]^2;$$

- In a soil system, K_a is predominantly determined by *liquid* water.

- TDR measures the transit time ($t = L_s/c$, L_s is the trace distance shown on TDR screen), for the pulse travels through the wave guides (2 *l*);

- One of the calibration equations is

  $$\theta_v = -0.1758 + 0.1138 * K_a$$

© **Comments**

- Easy to be automated to make continuous observations
- Dose not work well in soils with high clay content and/or EC, but it can be used to measure EC at the same time one measures water content
- Equipment cost is very high

Capacitance Probe

- Two electrodes and the soil close to the electrodes form a capacitor
- Capacitance is related to dielectric value K

  $$c = gk$$

  where g is instrument dependent.
- In a soil system, K_a is predominantly determined by *liquid* water.
- Calibration between c and water content
  - Enviroscan →

Methods of Soil-Water Potential Measurement

Absorbent Blocks (Water marks, gypsum blocks)

- Two electrodes embedded in the gypsum or nylon blocks measure the electrical conductivity (resistance);
- For gypsum blocks, effect of solute on conductivity was shielded by the dissolving gypsum;
- For the nylon blocks, it can only be used under conditions where salts do not affect the calibration curve unduly.
- Blocks can be used under drier conditions than the tensiometers and are more sensitive for $Y<-100$ kPa.

Limitations: hysteresis; salt effect

Tensiometers

- Consists of a porous cup (sensor) and a manometer (water/mercury column, vacuum gauge, pressure transducer)
- When the system reaches equilibrium, the equilibrium principle discussed before can be applied: (Fig. 2.10 and Example 2.11)
- Tensiometer measures the total of air pressure, matric (hydrostatic pressure), and overburden pressure potential
- Can be automated if equipped with pressure transducers
- Limitations: narrow pressure range and slow response to rapid change in matric potential

Soil Psychrometer

- The soil (thermocouple) psychrometer consists of two thermocouples (TC):
  - one TC measures the air temperature of non-evaporating surface in thermal equilibrium with the ambient air (T_a);
  - the other uses the Peltier effect - an applied electromotive force (emf) cools down the TC and the TC then forms a wet bulb thermometer (T_w).
- It measures the relative humidity (RH = actual vapor pressure (e) / saturated vapor pressure at the same air temperature (e_0)):
- e and e_0 relate to T_a and T_w through:

$$e = e_0 - \lambda (T_a - T_w)$$

$$e_0 = 0.61078 \exp\left(\frac{17.269 T_a}{T_a + 237.30}\right)$$

$$RH = e / e_0 = \exp(M_w \psi_w / \rho_w RT) \qquad or$$

$$\psi_w = (\rho_w / M_w) RT \ln(RH)$$

- Psychrometer measures both matric and solute (osmotic) potentials.

Field Data Acquisition Systems - *Data loggers*

- Data acquisition systems (data loggers) measure the signal (voltage, resistance, or current) produced by the sensors, and
- record the data at specified time intervals. A data logger is actually a micro-computer which uses its own language.
- Like a computer program, a data logger program usually consists of
    1. Time interval for measurement
    2. Program body (instructions)
    3. Output (control output format, manipulation of the data from sensors).

Program:
Flag Usage:
Input Channel Usage:

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*    1      Table 1 Programs
  01: 0.0000  Sec. Execution Interval

02:  P87     Beginning of Loop
  01: 0000    Delay
  02: 16      Loop Count

05:  P14     Thermocouple Temp (DIFF)
  01: 2       Reps
  02: 1       5 mV slow Range
  03: 2       IN Chan
  04: 1       Type T (Copper-Constantan)
  05: 1       Ref Temp Loc PANEL T
  06: 2--     Loc [:TC#1     ]
  07: 1       Mult
  08: 0.0000  Offset

11:  P77     Real Time
  01: 110     Day,Hour-Minute

12:  P71     Average
  01: 33      Reps
  02: 1       Loc PANEL T

17:  P       End Table 1
```