Vadose zone characterization & monitoring, HYD210, 2015

- Soil moisture
- Soil water potential
- Soil water solute concentration
- Telemetry
- Parameter optimimzation
- Field Applications

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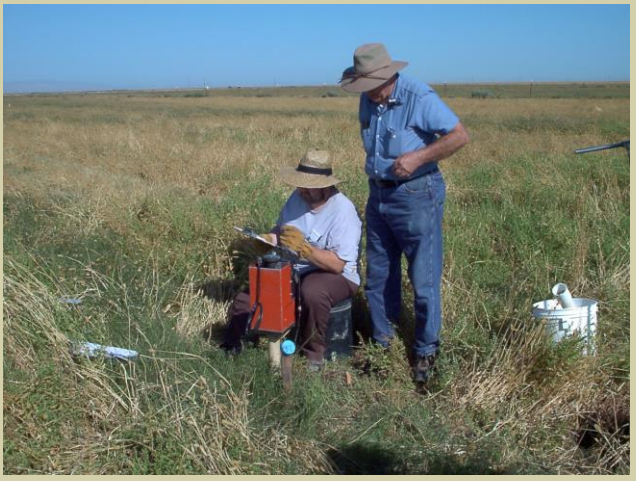
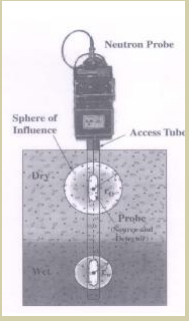
Soil Moisture – neutron probe

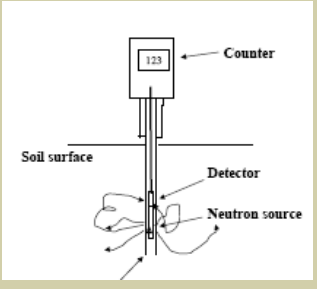


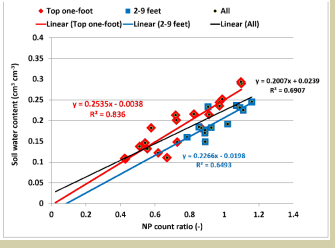
Soil Water content-neutron probe



- Based on emission of neutrons (^{1}n) by a radioactive source through radioactive decay
- Use ^{214}Americium-Be source, where Am produces ^{4}He (alpha-particles), which subsequently interact with the ^{9}Be to yield nuclear reaction:

$$^9_4\text{Be} + ^4_2\text{He} \longrightarrow ^1_0\text{n} + ^{12}_6\text{C} + \text{energy}$$





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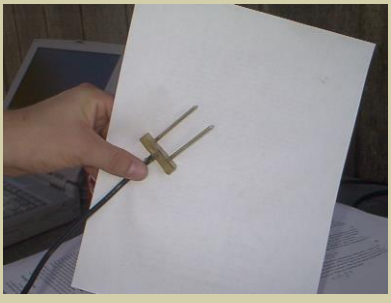
Soil moisture-neutron probe

Soil moisture: Dielectric measurements

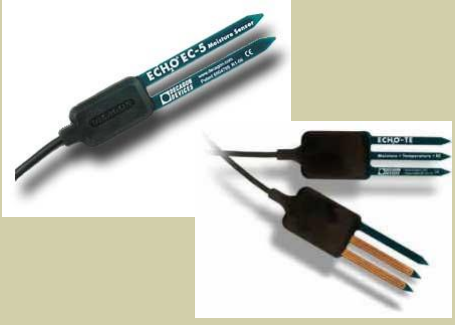
Soil moisture – TDR

(Time domain reflectometry)

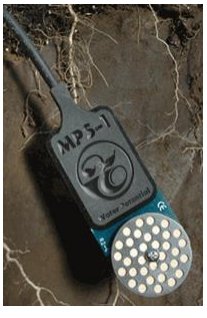


Soil moisture: Capacitive probes

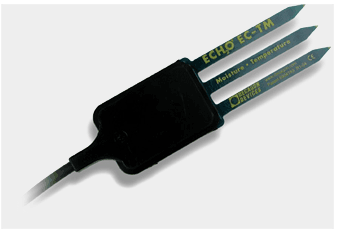
(Charge time of capacitor increases with higher soil dielectric)



CZO Soil Moisture Sensors



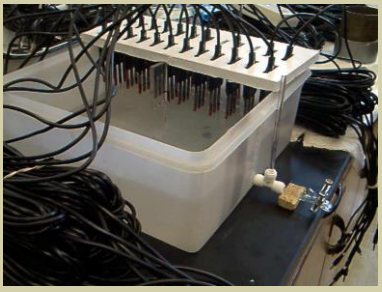
MPS-1
Matric Potential

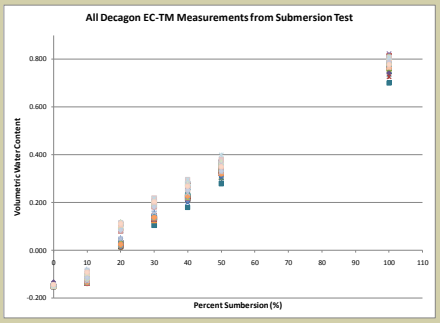


ECH_2O-TM
Water Content, Temperature

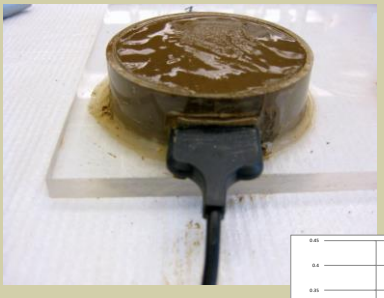
5TE
Water Content,
Temperature,
Conductivity

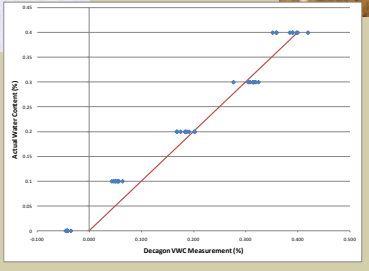
EchoTM and TE– Decagon – laboratory calibration by immersion





EchoTM and TE– Decagon – laboratory soil calibration for KREW soil





Frequency, electrical conductivity and temperature analysis of a low-cost capacitance soil moisture sensor

F. Kizito [a], C.S. Campbell [b], G.S. Campbell [b], D.R. Cobos [b], B.L. Teare
B. Carter [b], J.W. Hopmans [a,*]

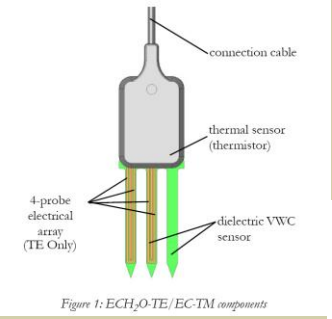
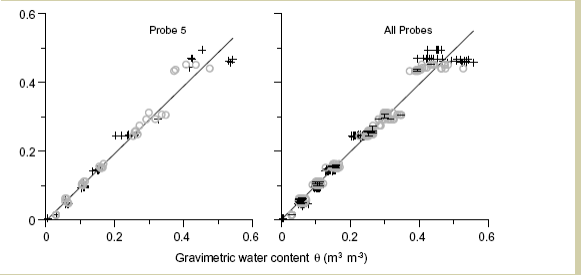
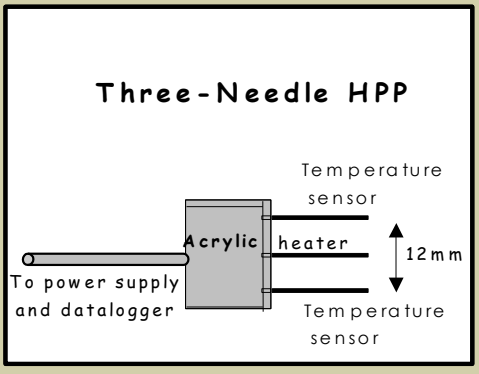


Figure 1: ECH$_2$O-TE/EC-TM components



Insertion Tool for Echo TE Installation

Soil moisture: Heat pulse probe



Heat Pulse Probe (HPP) measurement

- Temperature, T
- Thermal properties
  - Heat capacity, C
  - Heat conductivity, λ
  - Thermal diffusivity, κ
  - Heat dispersion, D
- Hydrologic properties
  - Water flux, q_w
  - Water content, θ
  - Electrical conductivity, EC_b

same time
+
same place
+
same scale

Heat transfer in variably saturated soil

- Heat

$$\rho C_p \frac{\partial T}{\partial t} + \nabla \cdot \bar{q} = Q$$

  - Heat flux

$$\bar{q} = -\lambda \nabla T + \rho C_p T \bar{u}$$

  - Heat capacity

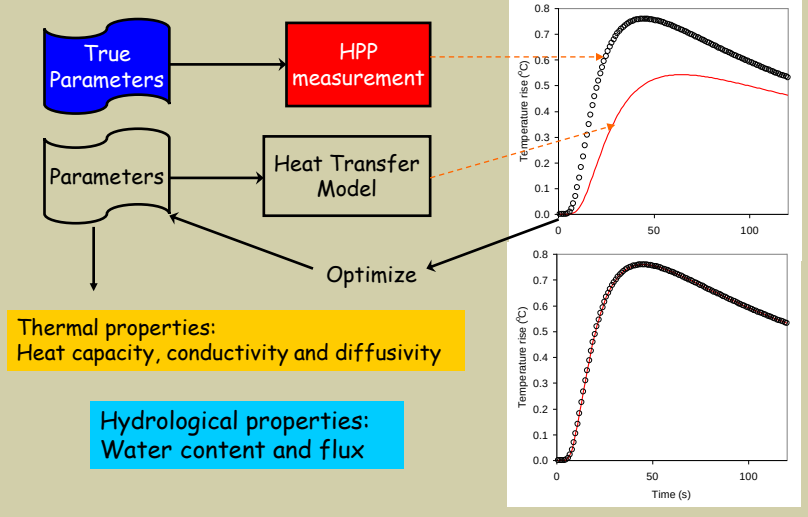
$$\rho C_p = C_{bulk} = C_s (1 - \phi) + C_w \theta$$

- Water flow

$$\bar{u} = \left[-\bar{\bar{K}}(\theta) \nabla \bar{H} \right] \theta^{-1}$$

Parameters Estimation using Heat Pulse Probe (HPP) measurement

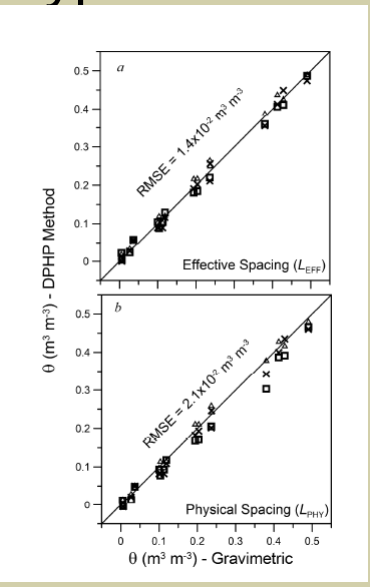
Produce heat → Measure Temperature



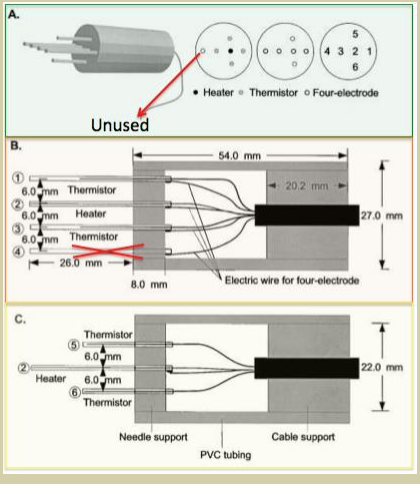
Thermal properties:
Heat capacity, conductivity and diffusivity

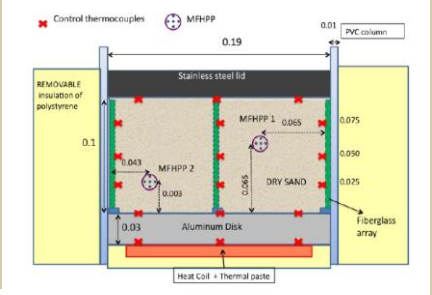
Hydrological properties:
Water content and flux

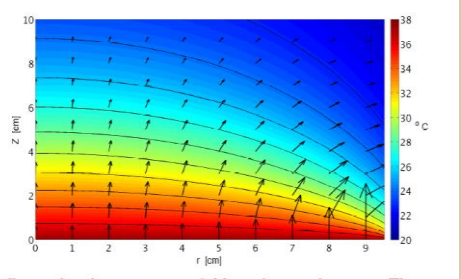
Two-needle HPP
Independent of Soil Type



Multi-needle HPP
soil heat flux measurements



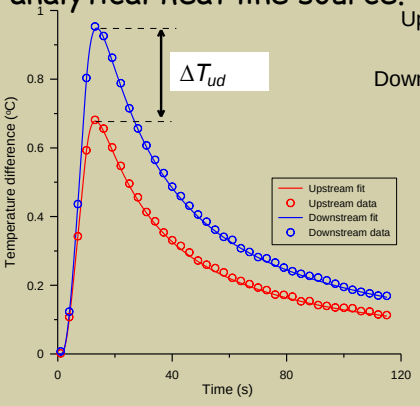


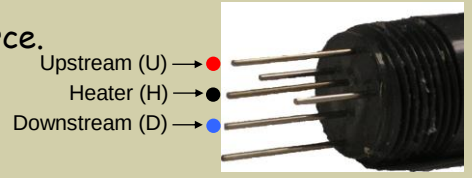


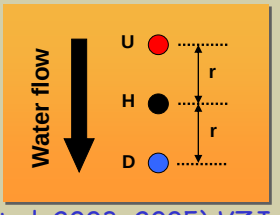
2D simulated temperature field at the steady-state. The arrow

Conventional Heat Pulse Probe (HPP)

Thin needles –
analytical heat line source.

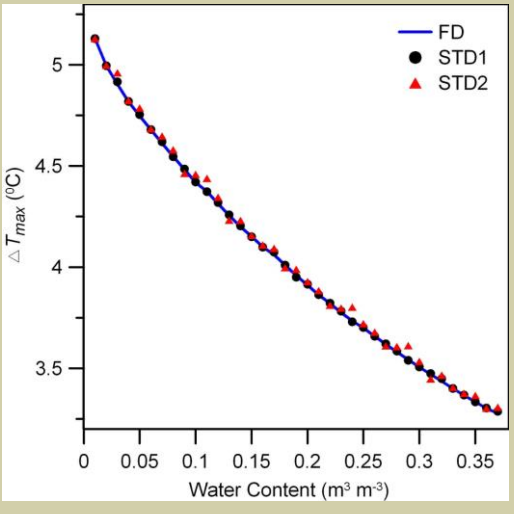






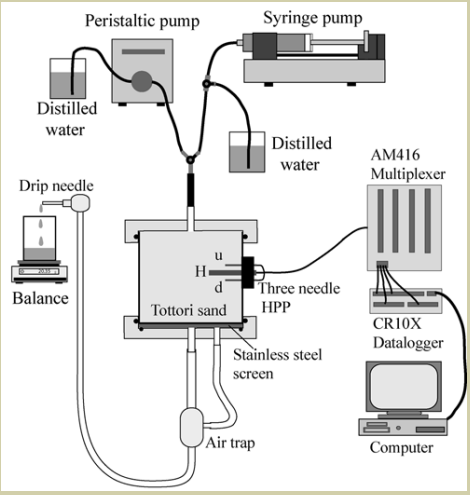
(Mori et al. 2003; 2005) VZJ

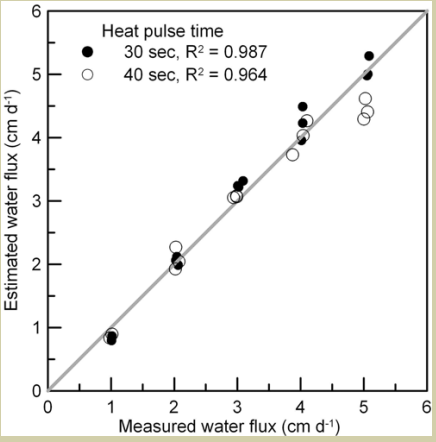
Ring-heater button HPP – Max temperature rise



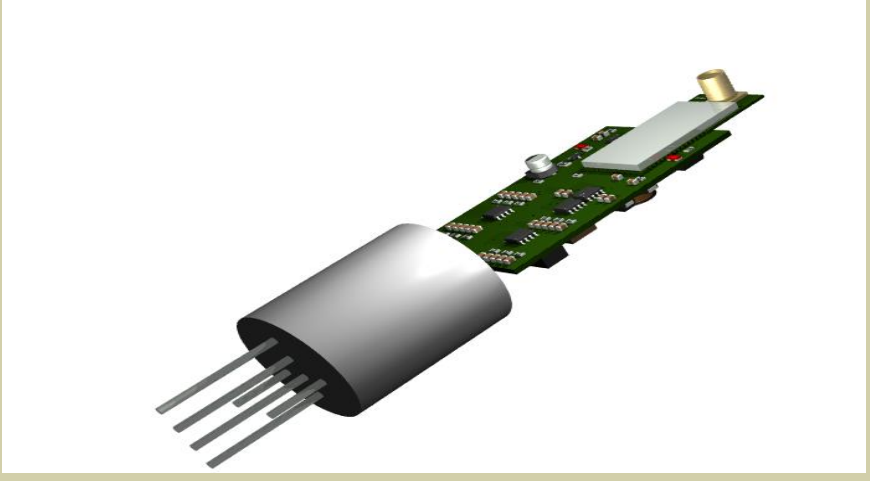
- No needle deflection
- Larger sensitivity to water content
- Non Invasive

HPP Darcy water flux measurement





Wireless HPP development



Heat pulse probe with solar panel and wireless

Soil water potential: porous blocks

WaterMark

Gypsum Blocks

MPS-1 Water Potential Sensor

MPS – Decagon – laboratory calibration

MPS Calibration

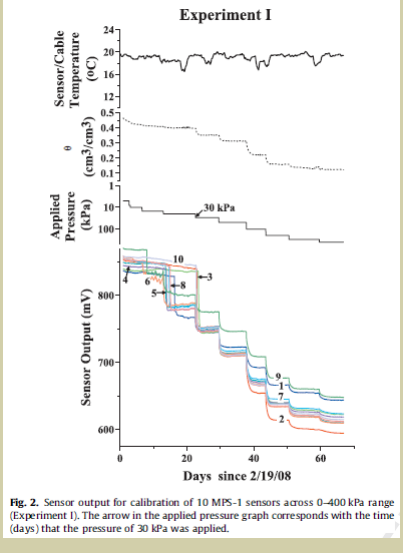
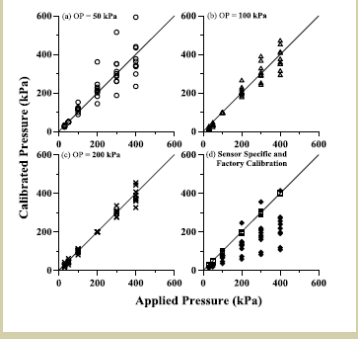
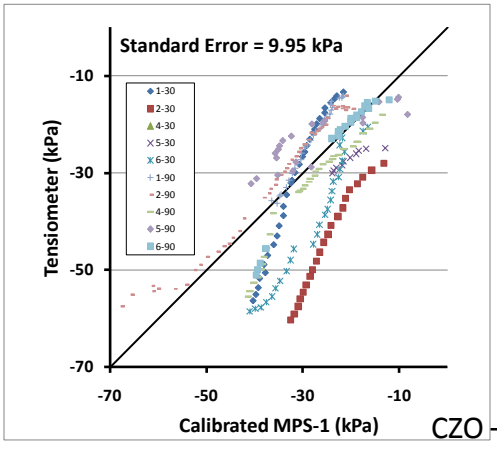


Fig. 2. Sensor output for calibration of 10 MPS-1 sensors across 0–400 kPa range (Experiment I). The arrow in the applied pressure graph corresponds with the time (days) that the pressure of 30 kPa was applied.



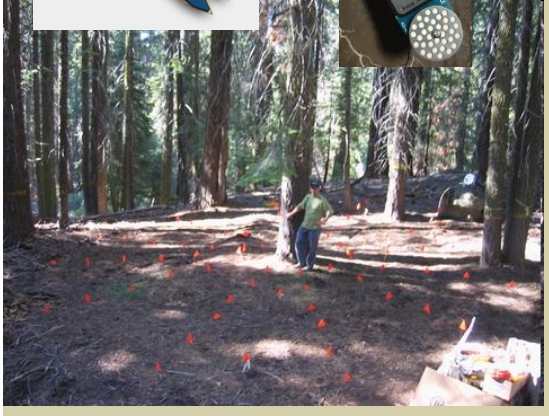
MPS-1 Evaluations - Field

One- point calibration

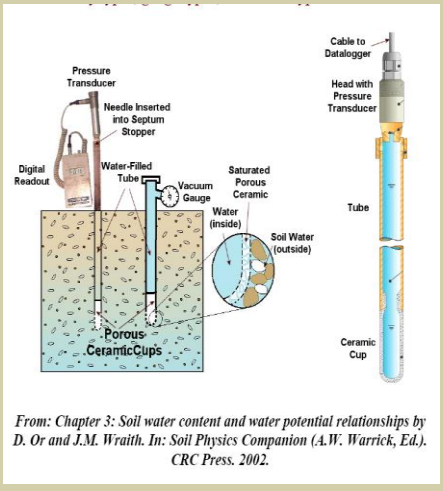


Comparison with CZO – tensiometer readings

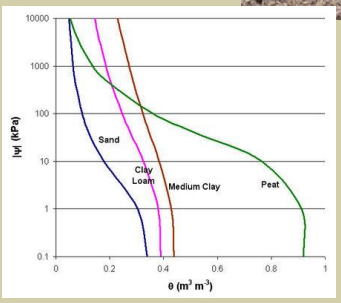
CZO – White Fir Tree Monitoring- KREW



Tensiometer- Soil moisture Tension



From: Chapter 3: Soil water content and water potential relationships by D. Or and J.M. Wraith. In: Soil Physics Companion (A.W. Warrick, Ed.). CRC Press. 2002.



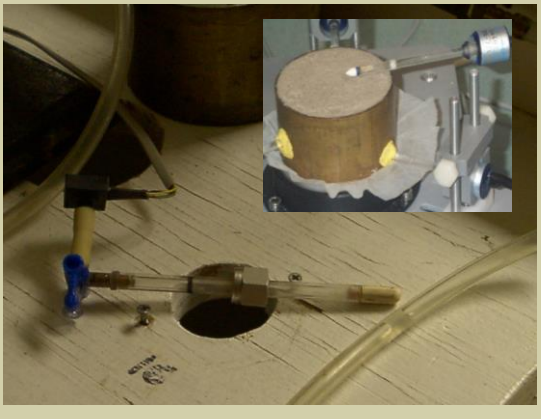
Soil moisture tension

Fixed Gauge

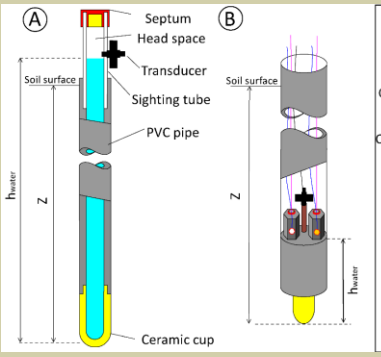
Soil Tensiometry

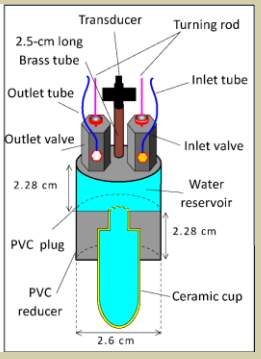
Dept Land, Air and Water Resources
University of California Davis

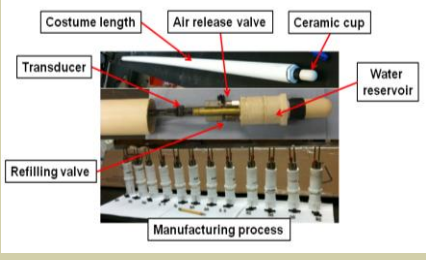
Soil Water Tension

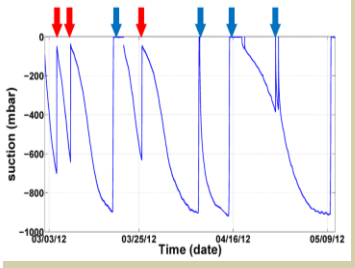


Advanced Tensiometer

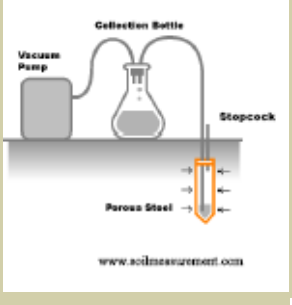


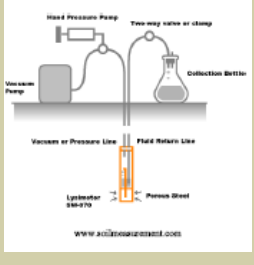


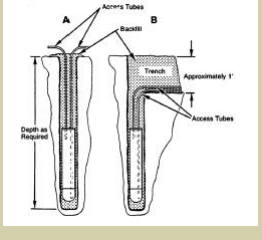




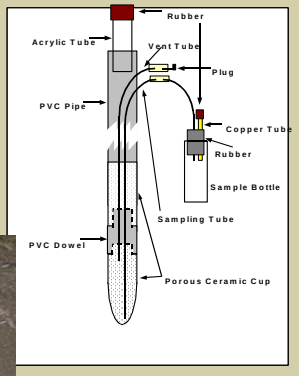
Soil water solution sampling



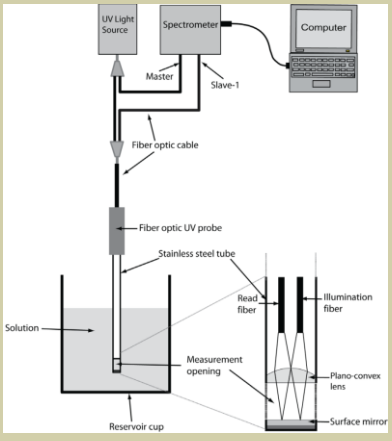




Soil Solution Sampling



In-situ soil solution nitrate measurement



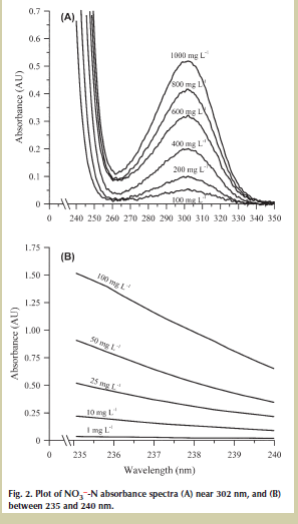
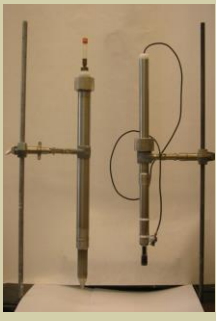


Fig. 2. Plot of NO_3^--N absorbance spectra (A) near 302 nm, and (B) between 235 and 240 nm.



Noninvasive soil salinity

Dennis Corwin

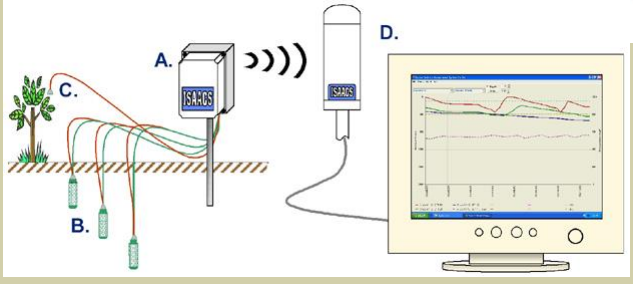
US Salinity Laboratory

Riverside, CA

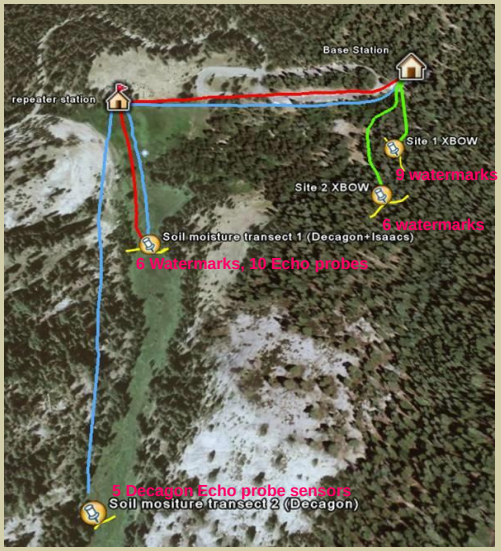
Telemetry: groundwater level

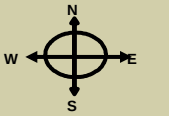
Telemetry: rain gauge

Telemetry: Soil moisture



Wireless Networks-Wolverton



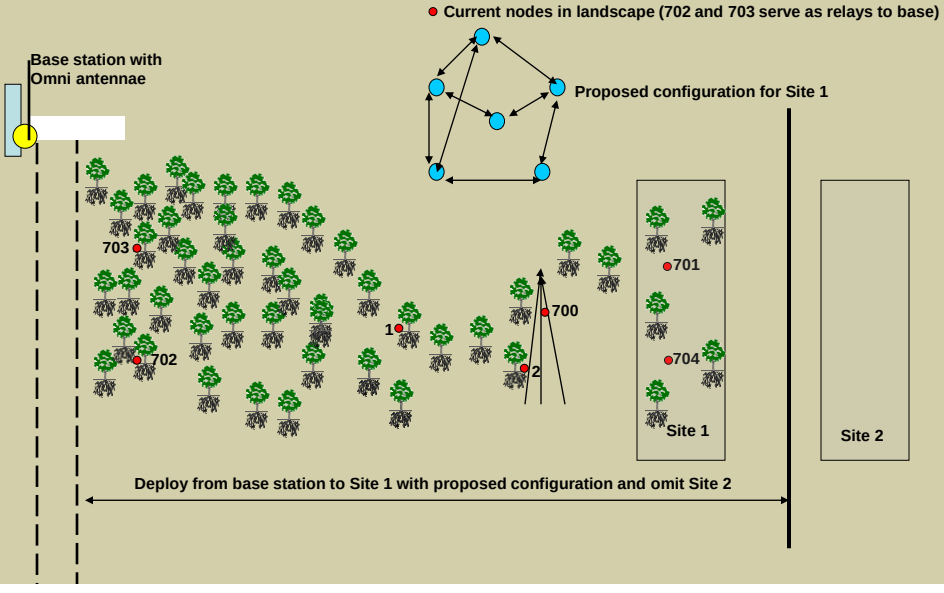


Isaacs link

Decagon link

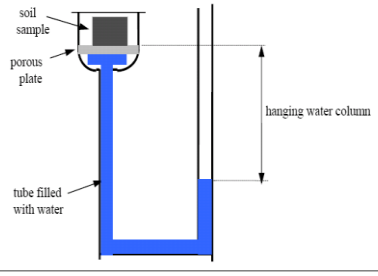
Crossbow link

Crossbow Mote Network – 100 yards between nodes



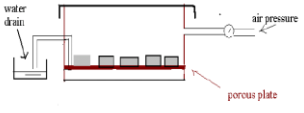
Soil Water Retention

1. **Buchner funnels** can be used up to about -300 cm



If the length of the hanging water column is X and the system is in hydraulic equilibrium, what is the pressure potential in the soil?

Pressure plate apparatus

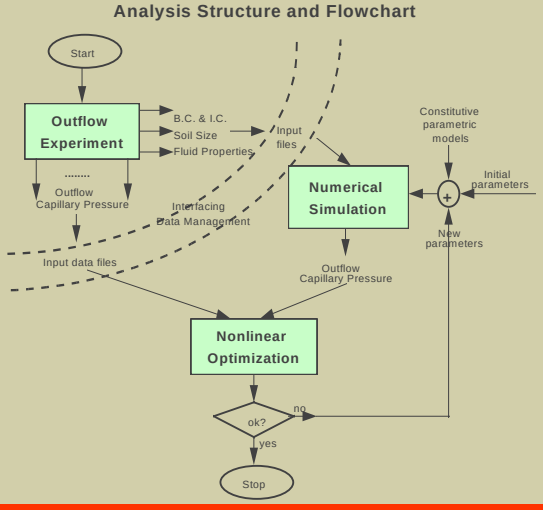


If 1 bar gauge pressure is applied to the pressure plate apparatus, and water drainage has stopped, then what is the pressure potential of the soil water in the cores?

NOTE:
In both soil core and at drain outlet: $H = H_p + H_g + H_s$

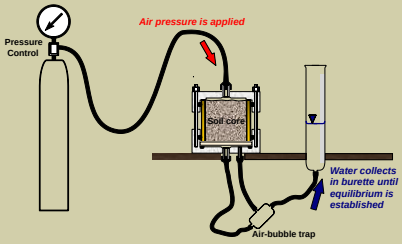
Soil Water Retention

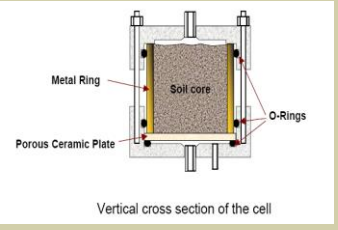
Parameter Optimization by Inverse Modeling

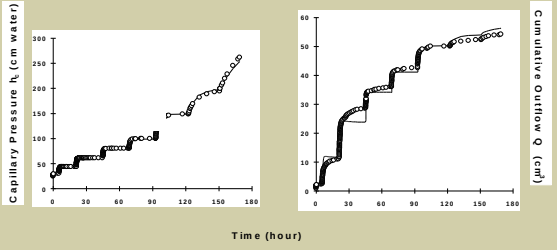


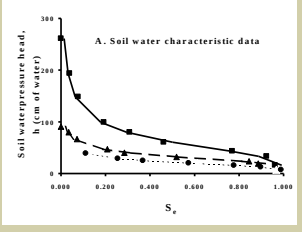
- Combines experiment with modeling
- Yields both soil water retention and unsaturated hydraulic conductivity functions

Multi-step Outflow Experiment









Dept Land, Air and Water Resources
University of California Davis

Soil Water Retention

$$S_e = \left[\frac{1}{1 + (\alpha h)^n} \right]$$

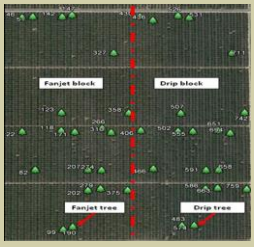
$$K_r = S_e^l \left[1 - \left(1 - S_e^{1/m} \right)^m \right]^2$$

Efficient irrigation and fertigation practices across California

UCDAVIS UNIVERSITY OF CALIFORNIA

Objectives:

- Develop improved irrigation water & nitrate management guidelines in **almonds**
- Focus on reduced leaching practices
- Establish field-scale soil water monitoring protocol



Paramount Farms, Lost Hills

Tomato field: Effect of winter fallow and cover crop in nitrate leaching under drip irrigation

Walnut orchard: Plant nutrition and nitrate leaching under sprinkler irrigation

Almond orchard: Nitrate leaching under fanjet and drip irrigation

Almond orchard: Nitrate leaching under fanjet irrigation, pump and fertigate

Citrus orchards: Irrigation efficiency and nitrate leaching in oranges and mandarin orchards under fanjet ation

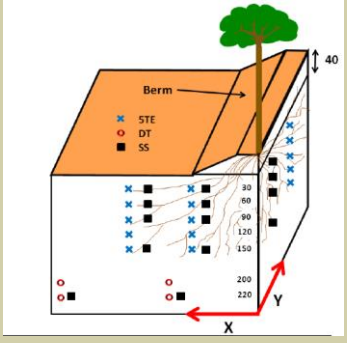
Wireless Sensor Networks

Instruments list and functions:

1. **Tensiometers**: measures soil matric potential, range: 850 - 0 mbar, individually-calibrated pressure transducers
2. **Decagon 5TE sensors**: measures soil water content, electrical conductivity, temperature
3. **Decagon MPS-2 sensors**: measures soil matric potentials, range -4000 mbar – 0
4. **Neutron Probe**: measures soil water content, large representative soil volume
5. **Suction lysimeters** : is used to collect soil solution for nitrate analysis
6. **Equilibrium-Tension Lysimeters**: measures drainage below the root zone and collect soil solution samples for nitrate analysis

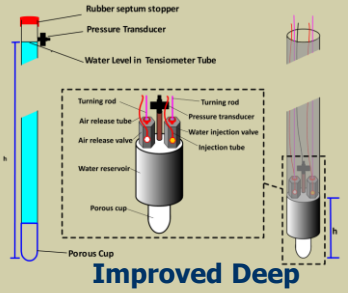
Multiple sensors at various depths and locations for each treatment plot

Paramount Farms (Lost Hills):
Fanjet versus Surface Drip

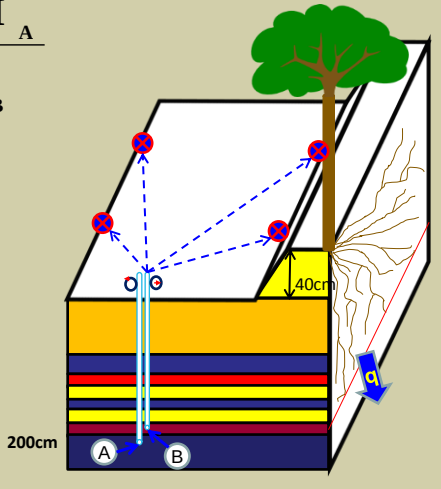


Darcy Flow Approach : Tensiometers below root zone
Tree plot scale

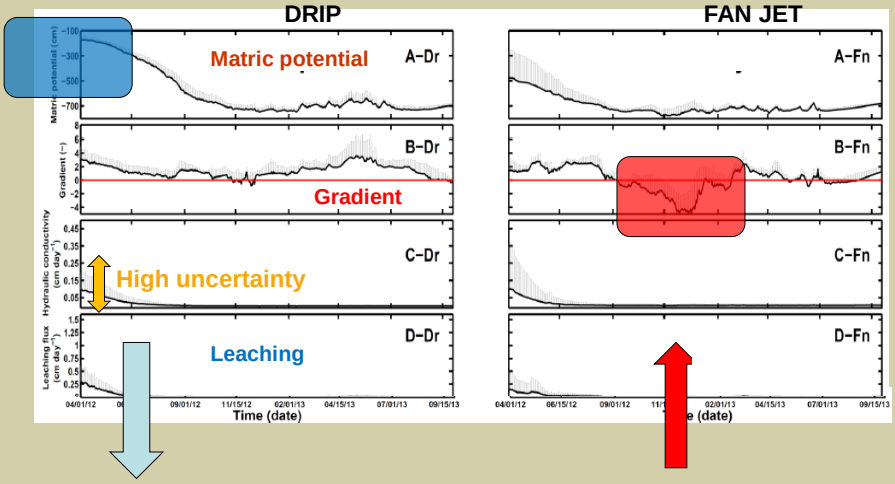
$$q_{A-B} = -K(\theta)\frac{H_B - H_A}{\Delta z_{A-B}}$$



Improved Deep Tensiometer



LEACHING RATES COMPUTED FROM TENSIOMETERS



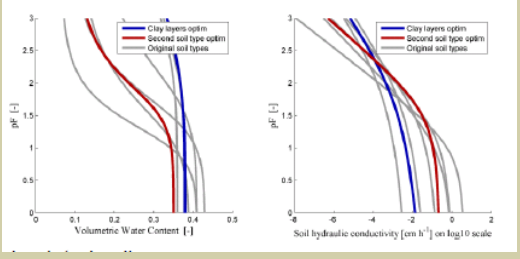
Leaching only significant when deep soil is wet, with possible upwards capillary flow in the late summer

Inverse Modeling

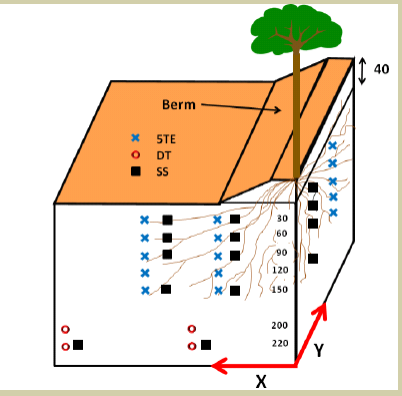
Improve soil hydraulic characterization

Fan Jet	Clay (%)	Silt (%)	Sand (%)	Depth (cm)
Sandy clay loam	21	18	61	10
				20
				30
	27	26	47	40
				50
				60
	21	26	53	70
				80
				90
Loam	28	27	45	100
				110
				120
Clay	54	27	19	130
				140
Sandy loam	19	25	56	150
				160
loam	23	32	45	170
Sandy loam	14	12	74	180
				190
Silt clay	44	47	6	200
				210
Clay loam	29	37	34	220
				230
				240
				250
				260
				270

Typically, field-scale variations in soil texture and soil layering are huge



Soil Layering – Inverse Modeling
Field-scale effective Hydraulic Conductivity



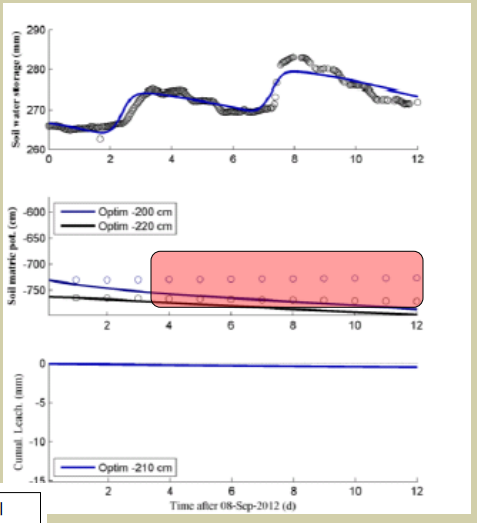


Figure 19. Observed (circle), and simulated (line) soil water storage (top plot), soil matric potential (middle plot), and leaching (bottom plot) below the root zone.