Mesoscopes for Hydropedology in the Critical Zone

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Understanding Soils – Their Architecture & Functional Manifestations

• **Heterogeneity differs from randomness**: the former is associated with order while the latter is linked to disorder.

• **Organized heterogeneity** reflects underlying structure that governs the direction and efficiency of energy and matter transfer.

• **Evolutionary processes** have been made possible because of heterogeneity of all kinds leading to the flow of energy and mass that are driven by various gradients at different scales.
Organized complexity: too complex for analytical treatment and too organized for statistics

Large number systems
( aggregates)
→ Statistical treatment

Microscope ↔ Mesoscope ↔ Telescope

Small number systems

I. Organized simplicity
(machines)
→ Analytical treatment

II. Unorganized complexity
→ Scientific treatment?

(Modeled from: Weinberg, 1975)
Soil Architecture

Preferential Flow

Lin, 2012, Hydropedology
Subsoil Moisture Clusters of the Monitoring Sites

Automatic soil monitoring stations
Site 53 right (Berks)

Volumetric water content ($m^3/m^3$)

13:52

13:53

Transient saturation

Response time

(Lin and Zhou, 2008, EJSS)
Controls and Frequency of Preferential Flow Occurrence: A 175-Event Analysis

- Preferential flow was common throughout the catchment, occurring during 17 to 54% of the 175 events at each of the 10 monitored sites along a hillslope. Preferential flow occurred in at least one site during 90% of the 175 events. While the frequency of preferential flow appeared insensitive to topographic position, the controls on preferential flow initiation varied with landscape position. While the frequency of preferential flow can be determined from 1 yr of real-time monitoring, the controls on preferential flow require much longer (≥ 3 yr) monitoring to be reliably identified.

(Graham and Lin, VZJ, 2011)
Preferential flow occurred during <1% to 70% (overall average 26%) of 323 events over 5.5 years (2006-2012) at each of 35 monitored sites, with 90% of the events generating preferential flow in at least one site.
Seasonal profiles show strong isotopic attenuation with depth. In winter, preferential flow occurs along soil-horizon and soil-bedrock interfaces. In summer, preferential flow occurs vertically through macropores. 

(Thomas et al., VZJ, 2013)
A) Complex slope
B) Planar slope
C) Swale cross-section

(Lin, Hydropedology, 2012)
Time-lapsed GPR in combination with real-time soil water monitoring have revealed flow paths in fractured shales and the impacts of soil layering on subsurface lateral flow.

(Zhang et al., 2014)
Time-Lapsed GPR Radargram Interpretation
After Water Infiltration into Soils

Oe and A: 0-12 cm
BW: 12-45 cm
BC: 45-90 cm
C: 90-135 cm

Near-surface lateral macropore flow and vertical finger flow
Subsurface flow network
Vertical macropore flow
Deep lateral macropore flow

(Guo et al., WRR, in revision)
Green water: Essential in combating looming global freshwater crisis (P. Rogers, 2008)
Biogeochemical hot spots and hot moments in the landscape

(Modified from McClain et al., 2003)
While landform and vegetation can now be mapped with high resolution, we lack adequate tools and techniques for in situ, precision, continuous, and noninvasive mapping and sensing of the complex subsurface. Improved mesoscopes (i.e., devices or techniques that are between microscopes and telescopes) are needed to shed better light on the complex subsurface in the Critical Zone.