Soil Moisture and Soil Hydraulic Parameters Across Space and Time Scale: State-of-the-Knowledge and What is Next!

Binayak P. Mohanty
Texas A&M University

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Soil Moisture and Soil Hydraulics:
Spatial Resolution Where Typical Model Parameters Need to be Resolved for Various Applications!

- Coupled Physical-Chemical-Microbial Processes (mms to cms)
- Contaminant Fate and Transport (meters)
- Battleground Traffic (10s meter)
- Agricultural Water management (10s meter)
- Flood forecasting and Hydrology (10s to 100 meter)
- Weather Forecasting (100s meter to kilometers)
- Climate Prediction, RCM and GCM (1 to 100s kilometer)

...Other
POLARIS: A 30 meter soil properties map of the contiguous United States

SSURGO
100+ years of soil surveys

High resolution environmental data

Digital Soil Mapping

20000+ unique soil profiles

POLARIS
• 30 meter soil property maps
• Use in climate models, hydrologic models, precision agriculture, and remote sensing

Legacy Data; Courtesy: Nathaniel Chaney
Soil Hydraulic Properties

(a) Suction vs. Soil water contents, cm³ cm⁻³

(b) Hydraulic conductivity vs. Suction, cm d⁻¹
Objective: To develop cohesive multi-scale (saturated-to-unsaturated) soil hydraulic (soil water retention and hydraulic conductivity) parameters for various applications across continental USA (or even at global scale) assimilating Legacy (Static) soil survey and Novel (Dynamic) Soil Moisture, ET, Ground Water, and Stream Flow Data that are collected at different Extents, Spacing, and Resolutions by Remote Sensing and Insitu Networks!
Soil Hydrologic Processes at Local Scale…

- Upward flux
- Percolation
- Soil moisture observations
- Evapotranspiration
- Mostly Vertical Flow
- Heterogeneity of soil profile
- Infiltration
- Upward flux
- Percolation
- Free drainage

Ground Water:
- -100 cm
- -150 cm
- -200 cm
Soil Hydrology at Watershed Scale…
Both Lateral and Vertical Flow
Soil Hydrology at Pixel/Footprint Scale…
Depending on Landscape Configuration Soil Moisture Distribution Vary
Our Research Findings Suggest...

- Soil moisture variability is dominated by
Soil Hydrology for Complex Landscape Scale...

"Effective" Soil Hydraulic Parameters at Pixel/Footprint Scale
Soil Hydraulic Function Scaling Hypothesis

Using the information content of the soil moisture data collected at that particular SCALE, we can estimate the scale dependent soil hydraulic properties

\[ S_e = \frac{\theta(h) - \theta_{res}}{\theta_{sat} - \theta_{res}} = \left[ \frac{1}{1 + |\alpha h|^n} \right]^m \]

\[ K(h) = K_{sat} S_e^\lambda \left[ 1 - \left( 1 - S_e^{1/m} \right)^m \right]^2 \]
Genetic Algorithm Implementation

Soil Parameter Chromosomes!
Unique Soil Hydraulic Fingerprints Across the Globe!

• Can we use near-surface soil moisture data to quantify the effective soil hydraulic properties of the soil profile?

• Chromosomal representation of parameter combinations, e.g.

\[
\begin{align*}
\alpha & \quad n & \quad \theta_{\text{res}} & \quad \theta_{\text{sat}} & \quad K_{\text{sat}} \\
00101 & \quad 110010 & \quad 000111 & \quad 00001 & \quad 0101000101
\end{align*}
\]
Remote Sensing Soil Moisture Time Series Data

- Airborne: **ESTAR** (SGP97) 800mX 800 m in Little Washita Watershed, Oklahoma
Validation on $\theta(h)$, Oklahoma

Soil water, cm$^3$ cm$^{-3}$

Suction, cm
Future Direction: Estimating Multi-Scale Effective Soil Hydraulic Parameters with New Generation Data!

Challenges:
- Heterogeneity
- Irregular Domains
- Linked in Space + Time
- Scale Up or Down
- Complex Process Modeling!

Opportunities:
Assimilate/Fuse Time Series Soil Moisture, ET, Streamflow, Groundwater Data from Various Platforms and Scales & Develop Multi-Scale Soil Hydraulic Parameters across Continental USA!
Thank You

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