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Preface

Hydropedology: Synergistic integration of soil science and hydrology in the Critical Zone

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Soil and water are the two critical components of the Earth's Critical Zone (Figure 1): Soil modulates the connection between bedrock and the atmospheric boundary layer and water is a major driving force and transport agent between these two zones. The interactions between soil and water are so intimate and complex that they cannot be effectively studied in a piecemeal manner; they require a systems approach. In this spirit, hydropedology has emerged in recent years as a synergistic integration of soil science and hydrology that offers a renewed perspective and an integrated approach to understanding interactive pedologic and hydrologic processes and their properties in the Critical Zone.

This special issue grew out of a special session at the 2013 AGU Fall Meeting sponsored by the technical committee on *Soil Systems and Critical Zone Processes* that is jointly associated with the Hydrology and Biogeosciences Sections, with co-sponsorship from Earth and Planetary Surface Processes, Global Environmental Change, Near Surface Geophysics, and Nonlinear Geophysics. It was an occasion to celebrate the 10 years of progress since the concept of hydropedology was first proposed in 2003. This special session brought together many experts from multiple disciplines to exchange views and to discuss future outlooks.

Six papers have been accepted into this special issue after peer-review. These papers highlight the field-based or model-based study of diverse topics such as preferential flow, hillslope hydrology, groundwater recharge, and the impacts soil structure, soil texture, and soil hydraulic parameters on hydrological modeling.

Gerke *et al.* (2015) presented field-staining experiments in Japan to improve the understanding of subsurface stormflow within organic layers of natural forested hillslopes (that they refer to as biomat flow). They developed a conceptual model for two key biomat flow mechanisms – one that considers lateral subsurface flow because of a permeability contrast between the much more porous and hence permeable biomat layer and the underlying mineral soil and the other that involves a hydrophobic soil layer between the biomat and the underlying mineral soil. Their study suggested that models of catchment hydrology should include lateral biomat flow when such layers are present in hillslope soils.

Geris *et al.* (2015) showed that hydropedological units are of critical importance in modulating catchment response in storage and flux under changing hydrological conditions. They examined short-term impacts of an extreme drought on the storage dynamics and runoff response in a headwater catchment in the Scottish Highlands. Their reported storage changes in histosols were remarkably small (<40 mm) compared with those in moorland (~100 mm) and forest (~200 mm) covered podzols. Their results suggested that during dry periods, large parts of the catchment were disconnected from the river network, and runoff was generated mainly from the wet histosols. However, during events, there was an intermittent connection of the hillslopes that contributed to strong recovery and resilience of the catchment in its runoff response.

Appels *et al.* (2015) investigated the spatial patterns of groundwater recharge on hillslopes with a thin soil mantle overlying bedrock. They used new measurements of spatially variable soil and bedrock hydraulic conductivity and a multi-event precipitation series to perform simulation of groundwater recharge with a new, simple,

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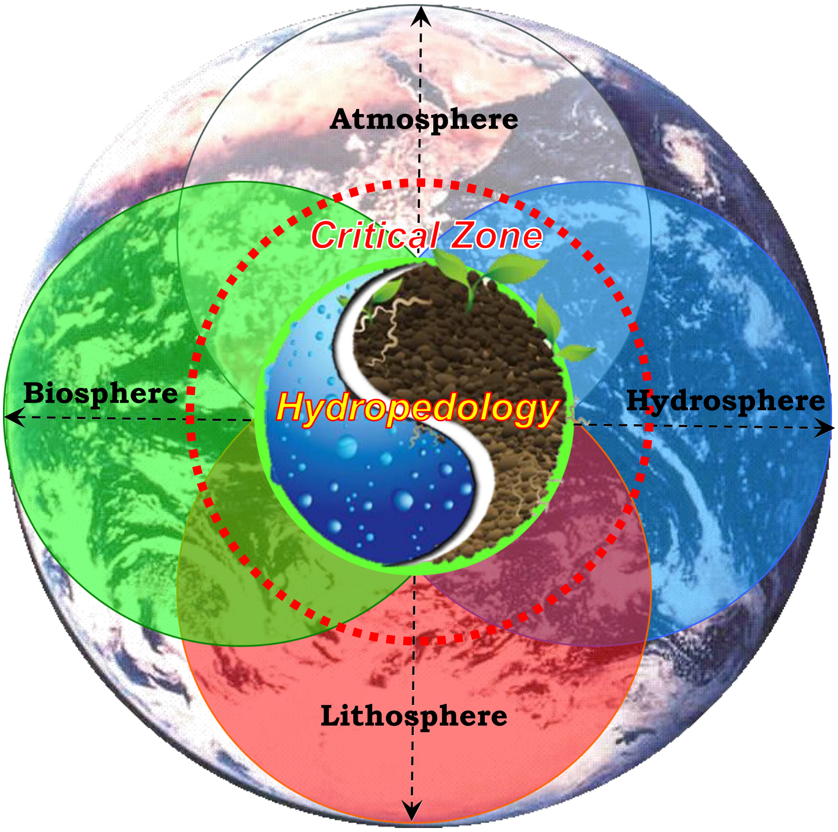

Figure 1. The relationship of hydropedology with the Critical Zone and the Earth system

spatially distributed model. Their simulations showed that unsaturated drainage from soil into bedrock was the prevailing recharge mechanism (accounting for 60% of annual groundwater recharge). Thus, soil depth, through its correlation with available storage capacity and influence on vertical flux, is a major control on recharge. The other 40% of recharge occurred during storms that generate transient saturation at the soil-bedrock interface. Under these conditions, locations that can sustain increased subsurface saturation (because of their topographical characteristics or high permeability of the underlying bedrock) will act as hotspots of groundwater recharge when they receive lateral flow from upslope areas.

Mirus (2015) used a distributed physics-based model (Integrated Hydrology Model or InHM) to assess the influence of soil horizons and structure on effective parameterization in the R-5 catchment and the Tarrawarra catchment. He tested the viability of two established and widely used methods for simulating runoff and variably saturated flow through layered soils: (1) accounting for vertical heterogeneity by combining hydrostratigraphic units with contrasting hydraulic properties into homogeneous, anisotropic units and (2) use of established pedotransfer functions based on soil texture alone to estimate water retention and conductivity, without accounting for the influence of pedon structures and hysteresis. He suggested that identifying a dominant hydropedological unit provided the most acceptable simplification of subsurface layering and that modified pedotransfer functions with steeper soil–water retention curves might adequately capture the influence of soil structure and hysteresis on hydrologic response in headwater catchments.

Shi *et al.* (2015) tested the ability of a land surface hydrologic model (Flux-Penn State Integrated Hydrologic Model or PIHM) to simulate high-resolution soil moisture patterns in the Shale Hills watershed. Calibrated using only watershed-scale observations and a few point-based measurements, and driven by spatially uniform meteorological forcing, Flux-PIHM was able to simulate the observed macro spatial pattern of soil moisture at ~10-m resolution. It was also able to simulate the day-to-day variation of soil moisture pattern, although it underestimated the amplitude of the spatial variability and the mean soil moisture. Shi *et al.* (2015) showed that the spatial distribution of soil hydraulic parameters had the dominant effect on the simulated soil moisture spatial pattern, followed by surface topography and depth to bedrock. Field-measured soil type maps and soil type specific hydraulic parameters significantly improved the predicted soil moisture pattern as compared with the most detailed national soils database.

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Finally, Livneh *et al.* (2015) quantified the impact of soil texture on the uncertainty of hydrologic states and fluxes, including major historical flood and drought events, in the Mississippi river basin. Mesoscale hydrologic model simulations driven by the digital general soil map of the USA soil database (1 : 250 000) were compared with those using the Food and Agriculture Organization-based harmonized world soil database (1 : 5 000 000). The choice of soil database altered the partitioning of precipitation between evapotranspiration and runoff, and affected the correlation structure between forcing and modeled fluxes. As compared with other decisions needed to make hydrologic predictions, this analysis demonstrated that the choice of soil textural properties for a large river basin simulation can be an appreciable source of uncertainty and therefore warrants careful consideration.

Looking forward, we feel that we need to attack several frontiers in soil-hydrology interactions, including:

- The issue of ecohydrological separation (McDonnell, 2014) where recent work (Evaristo *et al.*, 2015; Good *et al.*, 2015) has shown widespread compartmentalization of portions of the soil water balance into mobile and immobile zones with little interaction;
- The need to quantify and understand soil architecture and preferential flow across space and time in diverse soils and landscapes. In particular, the relative roles of soil structure versus soil texture and the fundamental scaling relations from the pedon to the catchment scales;
- Soil water controls on pedogenesis and how to use hydrologic information to inform and enhance the understanding, mapping, and modeling of the complexity of soil formation and soil functioning processes;
- Advancement of collaborations between those studying hydropedology and related sub-disciplines focused on Earth's Critical Zone, including soil chemistry, soil ecology, hydrogeophysics, and soil geomorphology.

We would like to dedicate this special issue of *Hydrological Processes* to the celebration of the International Year of Soils. As 2015 is also a decisive year for setting sustainable development goals for the global community (http://sustainabledevelopment.un.org/), we hope that the integration of soil science and hydrology via hydropedology focus can make significant contributions to our sustainable future. Trying to understand the linkages between soil science and hydrology can be a good framework for helping pry loose new understanding of complex processes.

REFERENCES

Appels WM, Graham CB, Freer JE, McDonnell1 JJ. 2015. Factors affecting the spatial pattern of bedrock groundwater recharge at the hillslope scale. *Hydrological Processes* **29**: 4594–4610. DOI:10.1002/hyp.10481.

Evaristo J, Jasechko S, McDonnell JJ. 2015. Global separation of plant transpiration from groundwater recharge and streamflow. *Nature*, **525**. 91–94. DOI:10.1038/nature14983.

Geris J, Tetzlaff D, Soulsby C. 2015. Resistance and resilience to droughts: hydropedological controls on catchment storage and run-off response. *Hydrological Processes* **29**: 4579–4593. DOI:10.1002/hyp.10480.

Gerke KM, Sidle RC, Mallants D. 2015. Preferential flow mechanisms identified from staining experiments in forested hillslopes. *Hydrological Processes* **29**: 4562–4578. DOI:10.1002/hyp.10468.

Good S, Noone D, Bowen G. 2015. *Hydrologic connectivity constrains partitioning of global terrestrial water fluxes*. Science *10 July 2015*. **349**(6244): pp. 175–177. DOI:10.1126/science.aaa5931.

Livneh B, Kumar R, Samaniego L. 2015. Influence of soil textural properties on hydrologic fluxes in the Mississippi river basin. *Hydrological Processes* **29**: 4638–4655. DOI:10.1002/hyp.10601.

McDonnell JJ. 2014. The two water worlds hypothesis: Ecohydrological separation of water between streams and trees? *Wires Water*. DOI:10.1002/water2.1027.

Mirus BB. 2015. Evaluating the importance of characterizing soil structure and horizons in parameterizing a hydrologic process model. *Hydrological Processes* **29**: 4611–4623. DOI:10.1002/hyp.10592.

Shi Y, Baldwin DC, Davis KJ, Yu X, Duffy CJ, Lin H. 2015. Simulating high-resolution soil moisture patterns in the Shale Hills watershed using a land surface hydrologic model. *Hydrological Processes* **29**: 4624–4637. DOI:10.1002/hyp.10593.

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