Contribution ID: **293** Type: **Oral Presentation**

Applications of Physics Informed Neural Networks for Modeling Soil Water Dynamics

Monday, 31 May 2021 20:20 (15 minutes)

The Richardson-Richards equation (RRE), a nonlinear partial differential equation (PDE), is commonly used to describe soil water dynamics. Analytical solutions of RRE are available only when simplifying assumptions are made. Therefore, numerical methods, such as the finite difference, finite element, and finite volume methods, are employed when solving practical problems. Here, we introduce an alternative numerical method known as physics-informed neural networks (PINNs), in which neural networks approximate the solution to the RRE. The PINN approach, which is rapidly gaining popularity in various fields of physics, is based on the universal approximation theorem that neural networks with at least one hidden layer with a finite number of weights can approximate any continuous function arbitrarily well. Furthermore, the automatic differentiation allows the evaluation of the residual of PDEs, which is incorporated into the loss function to be minimized. Although the forward solution of PDEs using PINNs is computationally more expensive than other numerical methods, the PINNs approach is expected to be more effective for the inverse problem because it does not require a repetitive solution of the forward problem as in other numerical methods. We will present a PINNs solver for the RRE and compare its approximations with analytical and conventional numerical solutions for homogeneous and layered soils. We also present a PINNs method for approximation of soil surface flux from only near-surface soil moisture measurements, which demonstrates the superior potential of PINNs for solving inverse problems.

Time Block Preference

Time Block C (18:00-21:00 CET)

References

Bandai, T. and T. A. Ghezzehei. "Physics-informed neural networks with monotonicity constraints for Richardson-Richards equation: Estimation of constitutive relationships and soil water flux density from volumetric water content measurements." Water Resources Research, 57(2): e2020WR027642, 2020. https://doi.org/10.1029/2020WR027642

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Session Classification: MS25

Track Classification: (MS25) Subsurface Water Flow and Contaminant Transport Processes –Special Session in Honor of Harry Vereecken