Using math to significantly improve modeling of surface and subsurface water flow in complex landscapes

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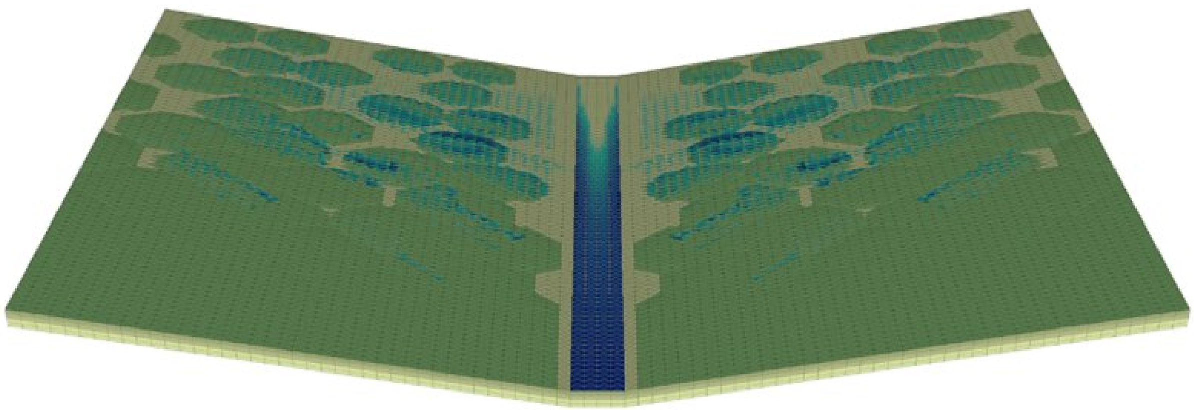

A sample simulation showing a polygonal landscape with variable vegetation cover (green) and surface water (blue) during a rainstorm. The porous, organic-rich soil beneath the vegetation can store a large amount of water, changing the flow of water. Credit: Ethan Coon, Oak Ridge National Laboratory

Understanding how surface and subsurface waters are affected by drought, fire, warming, and increased human demand requires computer models that can represent complex environments. Predictions are especially difficult for what scientists call patterned land cover. In Arctic permafrost landscapes, this patterning is caused by intense freezing and subsequent thawing. This can also overturn soil layers, resulting in a pattern of raised polygons of organic-rich soil and vegetation with surface water between the polygons. A team of scientists developed a new mathematical formulation that enables models to predict water runoff in these complex polygonal landscapes.

Most natural landscapes and their underlying soil structure are complex, and that complexity is hard to measure and hard to simulate. This new mathematical formulation appropriately captures the complexity of polygonal landscapes found in the Arctic environment and their underlying soil structure. This formulation will also advance researchers' ability to predict how surface and subsurface water flow will change over time in a given watershed. Researchers and local stakeholders can use these predictions to help make decisions about the use of water from a given watershed.

Watershed function, including capacity to provide clean, available water, is often significantly influenced by the local complexity of the land surface and underlying soils. Understanding that complexity requires models that can first represent the complexity and next solve for real-world scenarios of water conditions accurately and efficiently. A multi-institutional team of scientists developed a new mathematical formulation that appropriately captures that complexity and implemented it in the Department of Energy (DOE) Advanced Terrestrial Simulator (ATS) code.

This new feature of ATS allows scientists to accurately predict how water flows both below and on the surface of landscapes, including how it partitions between groundwater and surface runoff to streams. Researchers derived and tested this formulation against a series of benchmark problems and found it to be significantly more accurate in representing polygonal landscapes with convoluted soil structures than models previously used to represent these complex landscapes. This, and other advances in ATS, now allow scientists to more accurately simulate surface and subsurface water flow in complex landscapes, including cases of post-fire storms on patchy burn scars and variable depth of bedrock in a given spatial area. This new modeling capability provides a significant advance toward better predictions of water availability and quality in a watershed.

The research was published in *Advances in Water Resources*.

More information: Ethan T. Coon et al, Coupling surface flow and subsurface flow in complex soil structures using mimetic finite differences, *Advances in Water Resources* (2020). DOI: 10.1016/j.advwatres.2020.103701

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