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Hydrology of Hillslopes in Global Change Research Modelling of the Earth System

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Editorial

Earth System Models (ESMs) are critical instruments for analyzing and forecasting global environmental change. Physical, chemical, and biogeochemical pathways must be used to model the multiplicity of interactions inside and among the atmosphere, land, and oceans. ESMs are based on huge model grid cells (0.2–2° latitude–longitude, 20–200 km), which cannot explicitly describe finer scaled yet basic processes in the atmosphere, oceans, and land alike. They are designed for global coverage and century-long simulations of fast atmospheric motion. Because of the pervasive role that water plays in controlling biogeochemistry and supporting ecosystems and societies, ESMs' capacity to predict terrestrial water stocks and fluxes becomes increasingly crucial as they incorporate ecosystem and biogeochemical processes. ESMs will need to develop their modelled hydrology along with their other characteristics as they move toward more mechanistic process representation and a wider range of processes that are represented. Many land model processes, such as vegetation water stress and plant distribution, organic matter decomposition, methane production and emissions, fire ignition and spread, soil thermodynamics, nutrient leaching, dissolved organic and inorganic carbon export, and irrigation, are dependent on the details of the hydrologic states. Furthermore, when large-scale models begin to focus more on societally important topics like water and land management and water security, the necessity of getting runoff and streamflow correctly (for the appropriate reasons) grows.

Hydrologic processes have typically been researched at scales ranging from hillslope to watershed (tens of metres to kilometres). Water, sediment, and biogeochemical fluxes are driven down the hillslopes and out of the catchments at this scale by topographic gradients from ridges to valleys. At this scale, the radiative, hydrologic, and biological conditions on the sunny and shaded sides of a ridge are very different. Field equipment are traditionally aligned with such fundamental gradients across the landscape, and hillslope and catchment scale models are constructed to capture them. Critical Zone (CZ) science, which studies the structure, function, and evolution of the soil and underlying regulate (the weathered mantle overlying fresh bedrock) that support terrestrial life, has recently catalysed an integrative, system-level approach to understanding the coevolution of the landscape and terrestrial life, bringing together diverse perspectives from the broader Earth Surface.

Hillslopes and catchments continue to be acknowledged as major organisers of water, energy, and biogeochemical states and fluxes over the landscape, therefore they remain the scales of instrumentation, conceptualization, and modelling in this new CZ science. Hillslope and catchment research has produced a wealth of field observations, theories, and models over the last six decades or so, both at individual research sites and across organised research networks such as the long-term ecological research network and the US Department of Agriculture Agricultural Research Service and Forest Service experimental watersheds. The embryonic international network Water Resources Research of Critical Zone Observatories (CZOs) is building the groundwork for global assessments of the most important structures and functions of hillslope processes that may affect large-scale flows in ESMs. As a community, catchment and CZ scientists can provide profound insights into the landscape, and we intend to draw into their collective wisdom to identify the most crucial processes to integrate in ESMs.

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