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Spatial and Temporal Patterns of Soil and Bedrock Groundwater Age and Age Tracer Concentration on Soil-Mantled Mountainous Hillslopes

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The volume and scale of mountain-block groundwater circulation plays an important role in watershed hydrologic function; carbon, geochemical and nutrient budgets; and response to climate change. However, mountain block groundwater remains one of the least understood components of the hydrologic cycle. In this project, we investigate the role of bedrock groundwater circulation on groundwater age and isotopic tracer concentration on soil-mantled mountainous hillslopes. We perform numerical modeling of variably saturated soil, saprolite and bedrock groundwater flow, groundwater age, and transport of a suite of environmental tracers including stable isotopes of water, tritium, dissolved CFC's and SF_6. We use these models to investigate patterns of bed-rock groundwater circulation, and the distribution as well as integrated discharge of groundwater age and tracer concentration. We identify first order processes controlling the spatial distribution and volume of groundwater circulation on hillslopes, the partitioning between slope parallel through-flow versus bedrock recharge, and the resulting hillslope age and tracer dynamics. Monte-Carlo simulations are used to evaluate the relative role of topography, soil characteristics, underlying lithology and antecedent moisture conditions in governing the age and tracer distribution. The basic relationships derived provide new insight into the role of bedrock groundwater recharge and discharge on hillslope age and tracer distribution. Model results are compared with observed patterns of water level and stable isotopes measured in soil and bedrock groundwater on hillslopes in west-central Montana, United States. These results can be used to help hydrogeologists develop better conceptual models and estimates of bedrock groundwater circulation in upland catchments and its role in watershed hydrologic and biogeochemical function.