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Natural neutrons in near surface hydrology: a narrative encompassing new advances and niggling conundrums

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Over the past twenty years, and particularly over the past decade, progress has been made in utilizing cosmic rays to better observe states and processes in near surface hydrology. In particular, cosmic rays have proved useful in monitoring soil moisture at a unique spatial scale, but they also hold promise for sensing changes in biomass and for making non-invasive measurements of snow water equivalent (SWE). Some of what is old is new again, in that there has been a resurgence in the use of cosmic rays for invasive measurements of SWE, with applications now extended to monitoring SWE on glaciers in some of the most formidable places on Earth. As these terrestrial applications advance, new technical questions continue to arise, and previously unanswered questions become increasingly exigent. Some particular issues relate to the spatial scale of non-invasive measurements, methods of correcting data for solar activity in real time, relationships between neutron monitor measurements and low energy terrestrial neutron measurements, the behavior and modeling of thermal neutrons, and attenuation lengths in rock and ice. Such questions underscore the need to draw upon expertise from the several distinct disciplines that have cosmic rays and neutrons at their nexus.