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Empirical confirmation of the sub-kilometer footprint of cosmic-ray soil moisture probes

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The Cosmic Ray Soil Moisture Observing System (COSMOS, http://cosmos.hwr.arizona.edu) is a continental-scale network of in situ soil moisture sensors that aims to obtain coverage of the United States by 2015. The COSMOS network utilizes the cosmic-ray neutron technique to measure average soil moisture over a horizontal scale of ca. 600 meters and depths from the surface to 15 cm (for wet soils) and 70 cm (dry soils) using hydrogen-moderated cosmic-ray neutrons as a proxy for soil wetness. The large horizontal scale is a function of the distance that neutrons travel between being moderated in soil and detected somewhere above the land surface, which is in turn related to the collision mean free path in air and the number of collisions in air.
The footprint has been derived theoretically but is difficult to confirm empirically with controlled experiments due to the large scale. Here we present the results of field experiments and numerical modeling designed to verify the COSMOS probe footprint. Field experiments were conducted near and over large water masses to determine the upper limit of fast neutron moderation, and to provide scenarios with which to verify our Monte Carlo particle transport simulations. Having demonstrated that the model is capable of reproducing the observed spatial distributions of neutron fluxes, we apply it using simplified geometries to empirically estimate the probe footprint. Based on the combined results from field experiments and neutron transport modeling, our best estimate of the horizontal footprint is 600 m, which agrees with theory.