Geophysical Research Abstracts
Vol. 15, EGU2013-1723, 2013
EGU General Assembly 2013

The effect of horizontal soil moisture heterogeneity on the cosmic-ray neutron probe

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Given the horizontal measurement area of a cosmic-ray neutron probe at ∼35 ha, the probe has the potential to fill a critical measurement gap for validating and calibrating hyper-resolution land surface models. Because the relationship between neutron counts and average soil moisture is nonlinear, previous work has shown that averaging over vertical profiles during wetting and drying states may potentially result in non-uniqueness. Here we investigate the effect of horizontal heterogeneity on the relationship between neutron counts and average soil moisture. Observations from a distributed sensor network at a study site in southern Arizona indicate that the horizontal component of the total standard deviation of the soil moisture field is nearly constant in time. In addition, electromagnetic induction surveys at the site suggest that the soil moisture has a Gaussian or bimodal distribution following a rain event. Using neutron particle transport simulations we demonstrate that 1-dimensional binary distributions of soil moisture may result in different mean neutron counts and standard deviation of neutron counts for a randomly placed detector in a soil moisture field. However, simulations of 1 and 2-dimensional Gaussian soil moisture fields indicate consistent mean and standard deviations of a randomly placed detector with short correlation length scales. Based on soil moisture observations from this study site and numerical simulations of the detector response we conclude that horizontal heterogeneity does not greatly affect the relationship between mean neutron counts and average soil moisture for horizontal soil moisture fields with near Gaussian distributions.