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The cosmic module for hydrus-1d: modifications of the hydrus-1d code to simulate cosmic-ray neutron fluxes

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Among the ground-based remote sensing techniques, the Cosmic-Ray Neutron Sensing has shown good promise to capture soil moisture at relevant scales. Briefly, fast neutrons are produced by nuclear interactions between the incoming cosmic rays and elements of the Earth's atmosphere. When they reach the soil surface, they penetrate to a certain depth and are scattered back into the atmosphere. Since fast neutrons are mainly moderated by hydrogen, the fast neutron intensity at a near-ground-level is negatively correlated with the near-surface soil moisture. For this reason, soil moisture can be inferred from the fast neutron intensity measured by Cosmic-Ray Neutron Probes (CRNPs). The CRNP measures integral soil moisture in a circular footprint centered on a detector. This radius varies between 130 and 240 m depending on the site conditions, which is significantly larger than the typical spatial correlation length of soil moisture patterns. Due to this large sample volume, the information content of CRNP data could potentially improve the estimation of effective SHPs for land-surface models because the scale mismatch between sample volume and model resolution is much smaller. For this, the physically-based COsmic-ray Soil Moisture Interaction Code (COSMIC) (Shuttleworth et al., 2013) is now implemented in HYDRUS to calculate the aboveground neutron intensity for a given soil moisture profile. The developed model, which can be freely downloaded from the HYDRUS website, has been used successfully by Brunetti et al. (2018) to inversely estimate effective SHPs from synthetic and measured aboveground neutron fluxes, thus opening new perspectives in the use of CRNP data in land-surface models.

Brunetti, G., Simunek, J., Bogena, H.R., Baatz, R., Huisman, J.A., Dahlke, H., Vereecken, H., 2018. On the Information Content of Cosmic-Ray Neutron Data in the Inverse Estimation of Soil Hydraulic Properties. Vadose Zo. J. https://doi.org/10.2136/vzj2018.06.0123

Shuttleworth, J., Rosolem, R., Zreda, M., Franz, T., 2013. The COsmic-ray Soil Moisture Interaction Code (COSMIC) for use in data assimilation. Hydrol. Earth Syst. Sci. 17, 3205–3217. https://doi.org/10.5194/hess-17-3205-2013.