Geophysical Research Abstracts
Vol. 21, EGU2019-11891, 2019
EGU General Assembly 2019

Mass-balance approach to segmentation of water distribution in soil pores

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Visualization of water in soil pores is challenging due to uncertainty in defining the grayscale threshold between the solid and liquid phases on X-ray CT images. This problem could be partly resolved by using a dual energy combined with contrast solutions (e.g Ba, I, Sr). The use of Iodide as a contrast is preferable due to less interaction of anions with the solid phase of soil minerals, and thus more uniform distributing the contrast in soil pores as compared to the distribution of cations. The use of contrasts, however, does not resolve entirely the thresholding problem, since in unsaturated soil KI occupies mostly pores which are considerably smaller than the resolution of scanner. To resolve this problem we developed a procedure for segmentation of X-ray CT images based on mass attenuation of iodide and its saturation of voxels on images. Unlike other methods, the threshold was not obtained from the shape of image histograms, but was calculated based on total iodide saturation derived from X-ray CT images and mass of iodide applied to the system. To test the approach a 10% KI solution was applied to the three soil aggregate fractions (< 0.05, 0.10–0.50 and 1.00–2.00 mm) of Typic Hapludalf soil. For the first testing set we added the solution to the pipette tips inserted into the soil to avoid the partial volume effect, whereas for the second set we added solution to the same soil to achieve 3 water content levels. The soil micro-columns were scanned at 33.269 and 33. 069 keV at Argonne National Laboratory (GeoSoilEnviroCARS magnet beam-line 13-BM-D). For segmentation we used the 16 thresholding methods available in ImageJ software along with proposed mass-based procedure. Results demonstrated that reliable estimation of the threshold cannot be achieved with the standard methods. The error of mass for the developed procedure varied from 3% to 7% of applied solution, and generally increased with decreasing size of the soil fraction. This was attributed to increasing partial volume effect with increasing volume of fine pores.