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Extended multistep outflow method for the accurate determination of soil hydraulic properties close to water saturation

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Multistep outflow experiments are a well-established method to determine soil hydraulic properties. In the medium pressure head range where the specific water capacity is sufficiently high, the method yields reliable results. However, in the pressure head range corresponding to conditions close to and at water saturation, the method suffers from considerable uncertainties, in particular with respect to the determination of the hydraulic conductivity function. This is caused by the insensitivity of the experimental design with respect to the saturated hydraulic conductivity K_s. It is therefore generally recommended to perform an additional percolation experiment in order to determine K_s. The disadvantages resulting from this are an increased experimental cost and the necessity to combine information from two different experiments. In the case treated in this study the latter bears the risk of data inconsistency. We present a new experimental design which combines a water saturated percolation with an unsaturated multistep outflow experiment in a consecutive manner. The saturated percolation resembles a falling-head experiment with an initial ponding of 2-4 cm of water at the soil surface. The onset of unsaturated flow can be identified unambiguously by pressure head measurements inside the sample. We test this extended multistep outflow method (XMSO) by inversions using synthetic and real laboratory data. The soil hydraulic properties are parameterized with free-form functions in order to avoid model errors in the constitutive relationships and to quantify robustly the uncertainties of determination close to water saturation. Our results confirm that the XMSO method allows to identify correctly the soil hydraulic properties in the pressure head range near and at water saturation. In particular, the saturated hydraulic conductivity can be determined without bias and with great accuracy. Because of the improved information content and since the experiment is quick to perform and evaluated easily by inverse modelling, it can replace the MSO design in future applications.