Assessing soil hydraulic variability at the cm- to dm-scale using air permeameter measurements

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Background
Soils and surficial sediments are crucial elements in the hydrological cycle since they are the medium through which infiltrating precipitation percolates to the aquifer. At the same time, soil horizons and shallow stratigraphy may act as hydraulic barriers that can promote runoff or interflow and hamper deep infiltration. For most catchments little is known about the small-scale horizontal and vertical variability of soil hydraulic properties. Such information is however required to calculate detailed flow paths and estimate small-scale spatial variability in the water balance of the unsaturated zone.

Study area
- Interfluvie in the Nete catchment, northern Belgium, characterised by truncated and/or buried Podzols underneath historical drift sands with profile development (A/,E-)-horizon
- Strong vertical and horizontal soil property variability in these sandy soils due to strong horizon differentiation
- Study area for landscape evolution and soil hydraulic change

Conclusions
The hand-held air permeameter is a fast and reliable tool to assess small-scale hydraulic variability in complex vadose zones. Ksat variability of up to 4 orders of magnitude at the dm-scale are found in these sandy soils.

Air permeameter measurements
- Air permeameter measurements were done on a 10x10 cm grid, which results in 1 measurement point each 10 cm in x and y direction
- Ksat ranges up to 4 orders of magnitude, between 10⁻¹ m/s and 10⁻⁷ m/s
- Lower values found in A-horizons and lowest values in Bh-horizons
- Lateral variations highest in top drift sand between 10⁻¹ m/s and 10⁻⁴ m/s

Field air permeameter
Air permeability Ksa as measured with the Tiniyperm II air permeameter (New England Research & Vindum Engineering, 2011), is transformed to saturated hydraulic conductivity Ks (m/s) using pedotransfer functions, e.g. Iversen et al. (2003):

\[ K_s = \frac{2 \mu P_1 Q_1}{(P_1 - P_o_2) \alpha_0} \]

\[ K_s = \frac{10^{1.22 \times \log_{10} (U_c \times 9.892 \times 10^{-9}) + 13.93}}{86400} \]

\( l_0 = \) air permeability (m/s)
\( P_1 = \) injection pressure
\( P_o = \) outflow pressure
\( \mu = \) gas viscosity at atmospheric pressure
\( Q_1 = \) volumetric rate
\( \alpha_0 = \) dimensionless geometric factor
\( a = \) radius of the seal area

Comparision with laboratory measurements
- Sediments and soils were sampled for laboratory constant head measurements using Kopecky rings; one ring for each row of permeameter measurements
- Fair agreement within order of magnitude
- Degree of deviation from line of perfect agreement depends on type of pedotransfer function (Loll et al., 1999 or Iversen et al., 2003)
- Air temperature and soil moisture content may have a significant effect on the air permeameter results (Rogiers et al., this volume)

References
American Geophysical Union.
Rogiers, B., Winters, P., Huybens, M., Beerten, K., Mallants, D., Gedeen, M., Bakkeem, O., Cassargues, A., this volume. Centimeter-scale secondary information on hydraulic conductivity using a hand-held air permeameter on borehole cores.