Hydrol. Earth Syst. Sci. Discuss., 6, C2200–C2205, 2009
www.hydrol-earth-syst-sci-discuss.net/6/C2200/2009/

Hydrology and Earth System Sciences Discussions

Interactive comment on "Examining the effect of pore size distribution and shape on flow through unsaturated peat using 3-D computed tomography" *by* F. Rezanezhad et al.

F. Rezanezhad et al.

frezanezhad@wlu.ca

Received and published: 29 September 2009

As the Anonymous Referee #3's comment, posted on 31 July 2009, we are thankful to the Referee for his/her valuable comments and thorough discussion of the materials presented in the paper. Below we provide the answers to the comments and questions raised from Referee and all modifications and improvements are incorporated in the final version of the paper.

The main concern in Referee#3's comments was that the work has been undertaken on just one sample where it was divided up into three samples but then only one sample

was focused on in this paper. The reason for this single-sample analysis is explained below:

The peat profile contains two layers, an upper layer containing living and lightly decomposed fibric material, and a lower layer containing darker and more humified peat. Although the physical and hydraulic properties vary greatly between the two layers, the detailed microscopic image analysis coupled with field and laboratory permeability measurements (Quinton et al., 2009), demonstrated that these properties are relatively uniform within each layer. This study was focused on the upper peat layer extending to 20 cm depth since the lower layer is below the relatively impermeable frost table for the first several weeks of soil thaw, and therefore does not conduct runoff during the time when the majority of the annual subsurface runoff is conveyed through the peat to the base of hill slopes. Due to the similarity among the physical and hydraulic properties and the air-filled pore size distribution between the three upper, middle and lower cores (taken from the upper peat layer) of the same sub-samples obtained with 2-D and 3-D CT images analyses and presented in Quinton et al., 2009, only the lower core sub-sample was analyzed in detail for this study. Therefore, all three sub-samples were scanned, but as the 3-D CT analysis is expensive and process of the images takes a lot of time, only one sub-sample was analyzed for hydraulic conductivity calculation.

Furthermore, the scientific merits of this manuscript focus on development of feasibility/suitability of analytical technique and concepts, as opposed to site (Scotty Creek) characterization. It is the author's hope that the methodology and application presented here will be taken and utilized by other researchers for expanded peat and earth material research. Finally, we should mention that the intention of this research is not to use the results somehow to be a parameter that describes runoff from Scotty Creek site. Rather, it is trying to explore the nature of hydraulic properties in peat, and understand more about the role of its structure on the way water moves in it.

Responses to Specific Comments:

- The style of writing is often excessively wordy and many of the more basic aspects of soil physics and CT measurement are covered in far too much detail. The paper could be quite heavily edited and would read better.

- We think the discussion of methodology and CT measurements and processing steps need to be included to make this section of the manuscript clear, particularly to non X-ray CT readers. The paper will be edited for the final version.

- To what extent is the data you present 2D or 3D. Please make this clear. Suggest you remove 3D from the title

- The data presented is all three dimensional, wherein a series of 'slices' of a particular thickness comprise a volume. It is for ease of comprehension that a single perpendicular view of a '2-D' slice is presented in the figure 1a, wherein fact the slice that is shown has a depth component equal to the imagery resolution of 45 micrometers. The development and implementation of 3-D image processing was one of the major tasks surrounding this manuscript, as it has been demonstrated in other works (Elliot and Heck, 2007) that processing 3-D imagery through 2-D methods produces dissimilar results from 3-D imagery processed in 3-D. In order to clearly indicate that the data is three dimensional from start to finish, the authors have changed page 3845 line 22 – 24 from: "The summary results of analysis of 3-D images of this sub-sample core at five levels of hydraulic head are shown in Table 2." to: "The summary results of 3-D analysis of 3-D images of this sub-sample core at five levels of hydraulic head are shown in Table 2."

As the common perception of CT is that is that CT is 3D in nature, we removed 3D from the title.

- P3842 L15 why not express BD in g cm3 as is the norm?

"kg/m3" was replaced by "g/cm3" for all bulk density's units.

- P3842 samples were removed from the pressure plates for scanning, hence were not

under pressure during scanning. Did this have any impact? What was the scan length?

- The negative pressure exerted by the pressure plates was not present during the scanning process. However, upon removal from the pressure plate the samples were placed in sealed acrylic cylinders with no moisture source (atmospheric or otherwise) and kept in the identical gravitational orientation to ensure that no force greater than the pressure level exerted by the pressure plates were acting on any remaining pore-water within the sample. No 'leakage' or evaporation (i.e. moisture accumulation on the cylinder wall) was observed. There was no observable redistribution or evacuation of soil moisture from the Peat samples. With no moisture source, no significant external force being exerted, and no observable redistribution of pore-water the authors believe that there was no impact of having the sample removed from the pressure plate for the duration of the scan. Scan length was 1.5 hours.

-P3842 L42 Too much detail of established methodology here.

See above explanation (first Specific Comment).

- P3845 L1 - did you try to segment the solid material from the water manually? What were the HU for these materials? Did they overlap?

- Because of the close relationship of water and cellular plant material, there is currently no lab-based bench-top X-ray CT imaging system commercially available, to which this author is aware, that could segment out the organic peat (inclusive of hyaline cells) from the surrounding water with a degree of verisimilitude that would suffice for consideration in a scientific paper, which is ultimately dependent upon the highly integrated nature of vascular peat and water. The only systems capable of accomplishing such a separation would be extremely low energy (which have an inherently high signal-noise ratio that would mask the desired separation even with increased imaging times), or a monochromatic source (i.e. synchrotron, which have limitations to sample sizes) x-ray units. We used a procedure that is based on the grey-level histogram, where the user applies a threshold value developed by the Elliot and Heck (2007) method, which operates on the equiprobability point that separate the grey level classes associated with solid and voids. For more details of the applied threshold algorithm, please see Elliot and Heck (2007).

The relative densities of sample constituents are expressed using the Hounsfield unit (HU) which assigns to each voxel an intensity value between -1500 and 1000, the former of which results from preferential attenuation of low energy X-rays emitted from the polychromatic source. Air space typically is assigned an HU of -1000, although it was found to be as low as -1500 in the sample imagery, whereas water retained a HU of approximately 0. The large density difference between air (HU = -1000), represented by void voxels (i.e. air), and the remaining constituents of water and organic solids (HU = $\sim$0) represented by the non-void voxels, results in a bi-modal distribution on a histogram of relative density for the peat samples (Figure 2).

- P3847 - given the importance of the single continuous pore you dont include any images of this? This is precisely the benefit of CT!

In our previous paper (Quinton et al., 2009), we found that the distribution of pore size in 3-D measurements is dominated by a single large pore-, whose volume and surface area is 3-orders of magnitude larger than the next largest pore (see Figure 3 and Figure 4 in Quinton et al., 2009). This single large pore is readily observed as the interconnected pore space that extends throughout the peat sub-sample. In the present paper, the dominance of this single large pore-space was found at all five head levels, where it accounted for > 94-99% of the air-filled porosity (see Table 2).

In Quinton et al., 2009, using 2D and 3D analysis, we showed that the distributions of pore size derived from the 3D CT measurements are starkly different from those derived in 2D. The 2D view of peat indicates a more gradual transition from large to small pores; while in 3D CT images, the distribution is dominated by a single large pore space, whose volume and surface area are 3-orders of magnitude larger than the next largest pore.

- Do Table 3 and Figure 3 show the same data? if so please just use one or the other.

The authors would like to keep both Table 3 and Figure 3 in this paper as the reader can have a better comparison of the data from the values that are presented in Table 3 for unsaturated hydraulic conductivity, especially for the low values.

-P3851 L24-26. Going back to my comment above, how can you make a statement such as this on the basis of analysing just 1 sample?

Please see above explanation for response to main comment by Referee #3.

References:

Elliot, T. R. and Heck, R. J.: A comparison between 2-D vs. 3-D thresholding of X-ray CT iimagery, Can. J. Soil Sci., 84(4), 405–412, 2007.

Quinton, W. L., Elliot, T., Price, J. S., Rezanezhad, F., and Heck, R.: Measuring Physical and Hydraulic Properties of Peat from X-ray Tomography, Geoderma, 153, 269-277, 2009.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 6, 3835, 2009.