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Dynamic soil structure imaging experiments and their digital model representation

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It is now well recognized that soil structure is dynamic and changes due to numerous reasons, most notably due to saturation changes. In or study, we have sampled 15 soil samples and performed a detailed X-ray microtomography (XCT) imaging study of the full wetting-drying curve [1]. By analyzing the XCT images, we revealed the dynamics of soil pore structure under slow water changes. In total, our analysis is based on 135 3D tomography scans (9 soil moisture points for each sample). We were able not only to visualize structural dynamics (which showed significant changes within the soil at ~10 µm –3 mm pore sizes range) but also computed major classical morphological metrics. The analysis of these parameters and conceptual model of structural behavior revealed that after the wetting-drying cycle the studied soil degraded in general. This is contrary to the prevailing previous findings for mainly compacted soils where wetting-drying cycles led to structural improvements. We also found that classical metrics are not able to describe structural changes due to their low information content [2].

Now, we need something reliable to describe all structural changes and create model to describe the changes we observe din the experiments. Such a descriptor to create a digital structural model has to fully describe both geometry and topology of the soil sample and possess high information content. We shall argue that a set of directional correlation functions [3] is enough for this purpose. Compared to classical metrics they 1) contain all classical metrics within them and can also be extended to include topological measures such as persistent diagrams [4]; 2) allow to describe anisotropic structures [5]; 3), have measurable information content [2]; 4) if needed, the information content can be augmented with higher number of functions in the set and with higher-order functions [6,7]; 5) allow to establish stationarity and representativity of the structure itself [8,9]; 6) can collect dynamic structural information from different scales [10] –the very aim of the research in this area.

In this presentation we shall focus on:

- Experimental studies of soil structure dynamics by imaging with XCT;
- Description of dynamic soil structure without the use of classical approaches in the form of scalar characteristics;
- Creation of digital model of soil structure dynamics with high information content vector descriptors in the form of correlation functions.

In addition to experimental results and their interpretation, we discuss the major implications of our findings and outline a possibility to deepen our understanding of soil structure-function relationships, including dynamic hydraulic soil properties and 3D soil structure digital model based on correlation functions.

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Primary authors: Dr KARSANINA, Marina (Schmidt Institute of Physics of the Earth of Russian Academy of Sciences, Moscow, Russia); TOLSTYGIN, Kirill; ZUBOV, Andrey; FOMIN, Dmitry; YUDINA, Anna; ROMANENKO, Konstantin; ABROSIMOV, Konstantin; GERKE, Kirill (RAS)

Presenter: Dr KARSANINA, Marina (Schmidt Institute of Physics of the Earth of Russian Academy of Sciences, Moscow, Russia)

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