PEDOFRACT IX

El Barco de Ávila (Spain), July 9-12, 2019

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IX Seminario de Fractales Aplicados
a las Ciencias de la Naturaleza

International Workshop on Advances in Soil Scaling: Theories, Techniques and Applications

Organized by

PEDOFRACT
Group on Fractals and Applications in Soil and Environmental Sciences
(Universidad Politécnica de Madrid)

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3 Scientific program

Invited talks:

- John W. Crawford, Rothamsted Research (United Kingdom)

  "*Scaling and the Complexity Gap*".

- Patricia Garnier, INRA-AgroParisTech, Université Paris-Saclay (France)

  "*Upscaling biological and physical soil properties from 2D/3D multiscale images*".

- Kirill Gerke, Russian Academy of Sciences, Moscow (Russian Federation)

  "*From structure to soil physical properties: what and how do we want to upscale*".

- Alexandra N. Kravchenko, Dept. of Plant, Soil, and Microbial Sciences, Michigan State University (USA)

  "*Process-based physics is a missing piece in understanding of the plant/soil/microbe continuum* ".

- Hans-Jörg Vogel, Department Soil System Science, Helmholtz Centre for Environmental Research – UFZ (Germany)

  "*Scales in soil hydrology and the myth of hydraulic equilibrium*".

Oral Contributions:

- C. García-Gutiérrez: "*Is the available description of the PSD enough? And enough for what?*".
- A. Guber: "*Mass-balance approach to segmentation of water distribution in soil pores*".
- J.J. Ibáñez: "*Geodiversity at the crossroads: The two different sides of the same coin*".
- M.A. Martín: "*On the information content of coarse textural data respect to the particle size distribution and their predicting potential*".
- G. Martínez: "*Challenges in exploring the spatial variability of clay content at the field scale using electromagnetic induction and inversion modeling*".
- E. Nikooee: "*Random multifractal modeling of porous media: from soil structure to gas diffusion layer of PEM fuel cells*".
- Y. Pachepsky: "*Pattern and scale in soils*".
- A. Paz: "*Scaling heterogeneity of soil general properties at multiple depths*".
- E. Perfect: "*Fractal Characterization of Rock Fracture Surfaces*".
- L. Ren: "*Effects of soil wetness and tire pressure on soil physical quality and maize growth by a slurry spreader system*".
- F. Seaton: "*Soil textural heterogeneity impacts bacterial but not fungal diversity*".
- T. Vanwalleghem: "*Evaluation of drought stress through probabilistic modelling of soil moisture dynamics in SW Spain*".
- M.S. Zaid: "*The main chemical, rare earth and trace elements and minerals formation of mountain soil as an indicator of source and treatment pedogenetic in the Palestinian mountain soil*".

Posters session:

- D. Fomin, A. Yudina, K. Romanenko, K. Abrosimov, E. Skvortsova, K. Gerke and M. Karsanina: "*Soil structure dynamics with high saturation jumps*".
- A. Laguna, G. Guzmán, J.V. Giráldez, G. Martínez, K. Vanderlinden, A. Peña and T. Vanwalleghem: "*Revisiting the soil water retention equation, its equations and its properties for the evaluation of the agronomic properties*".
- M.C. Morató, M.T. Castellanos, P.L. Aguado and A.M. Tarquis: "*Topographic Surface Study Through MF-DFA*".
- A. Paz-González, R. da Silva Días, E. Vidal Vázquez, M. Lado Liñares, R. C. Hämmerly and A. Garcia Tomillo: "*Characterizing temporal trends of soil water content under Eucalyptus globulus using the multifractal approach*".
- E. Perrier, P. Baveye, P. Garnier, A. Tarquis, N. Bird and H. Laurie: "*An open discussion about the limits of multifractal models as regards porosity or mass spatial distributions*".
- M. Pfeiffer and J.J. Ibañez: "*Do Soil Forming Factors drive Pedodiversity in Central Chile?*"
- B. Ramírez-Rosario, L.F. Fernández-Pozo and J.J. Ibáñez: "*Diversity and Power Laws analyses of Pedo-environmental maps used for environmental assessment*".
- F. San José Martínez, C. García-Gutiérrez, J. Caniego and F. Peregrina: "*Preliminary research on long-range correlation of records of soil water retention for different soil managements and depths*".
- D.H.S. Souza, A. Paz-González, E.F.F. Silva and A. Garcia Tomillo: "*Multifractal and joint multifractal analysis of soil properties in an orthic Podzol at Pernambuco state, Brazil*".
- A. Urgilez-Clavijo, A.M. Tarquis, D. Rivas-Tabares and J. de la Riva: "*Deforestation transitions geometry patterns through shape metrics in the six continental Biosphere Reserves of Ecuador*".
- A. Yudina, D. Fomin, K. Romanenko, K. Abrosimov, E. Skvortsova, K. Gerke and M. Karsanina: "*Soil structure dynamics under steady state wetting-drying cycle*".

4 Schedule

	Monday	Tuesday	Wednesday	Thursday	Friday
9:30-10:30		J.W. Crawford	M.A. Martín	P. Garnier	K. Gerke
10:30-11:00 11:00-11:30		E. Perfect	C. García-Gutiérrez A. Guber	A.N. Kravchenko	Y. Pachepsky
11:30-12:00			COFFEE BREAK		
12:00-12:30 12:30-13:00		J.J. Ibáñez E. Nikooee	A. Paz G. Martínez	H.J. Vogel	**Closing session**
13:00-15:30			LUNCH		
15:30-16:00 16:00-16:30 16:30-17:00	**Trip to El Barco**	M.S. Zaid F. Seaton T. Vanwalleghem	**Excursion**	L. Ren Poster Session	**Trip to Madrid**
20:00 21:00	**Reception Wine**			**Social Dinner**	

5 Summaries

TUESDAY, 9:30-10:30
Title: *Scaling and the Complexity Gap.*
Authors: **John W. Crawford**.
Rothamsted Research, Harpenden, UK

Soil is connected to some of the most critical global risks we face in the next 10 years including water and food security, and climate change. The associated soil functions are a consequence of physical and chemical properties and the behaviour of the resident microbiome. There is a vast mismatch between the molecular scale at which the soil microbiome is usually characterised by 'omic technologies', the micrometre scale pore structures that regulate air/water balance, and the field scale at which impact is typically manifest and interventions are possible. We know that the biophysical properties of soil are an emergent consequence of dynamical interactions between genes, cells, communities, structure and the resource base. However, we lack an appropriate scientific methodology to bridge these scales.

The usual antidote is to collect ever more detailed data and to use empirical methodologies (e.g. statistics, AI) to seek patterns. Whilst certain functions may be amenable to this approach, it is not a general solution. This is a manifestation of perhaps the most fundamental challenge in the life sciences: understanding the origin of organised complexity. The source of the challenge is that living systems are intermediate between simple systems comprising a few interacting components (amenable to conventional analytic science), and disorganised complex systems that comprise billions of randomly interacting components (amenable to statistical thermodynamics). No generalised scientific method is currently available.

In this talk, I will present a series of experimental results derived from the Long Term Experiments at Rothamsted Research in the UK. I will show how we are trying to bridge the complexity gap by combining high resolution 3D imaging of soil micro- and meso-scale structure with deep sequencing of the soil metagenome. We use multi-scale and multi-phase modelling of convective and diffusive flow processes to link structure to physical and metabolic processes. The results can be usefully summarised on a three-dimensional state space that captures the trade-off between rate, efficiency and resilience of energy transduction through the soil system. I will show how both management and soil type have an impact on the state of the soil system, with consequences for water storage, nutrient flow, and the emission of greenhouse gasses. Finally, I will sketch some ideas about the direction of future work.

Tuesday, 10:30-11:30
Title: *Fractal Characterization of Rock Fracture Surfaces.*
Authors: **Ed Perfect**, Chris Gates, and Jared Brabazon.
University of Tennessee - Knoxville, USA

The roughness of rock fracture surfaces impacts flow and transport and is important in applications such as the deep disposal of hazardous wastes and hydraulic fracturing operations. In this laboratory study, several sedimentary and igneous rock cores were fractured using the Brazilian method and separated along their failure planes. Fragments of the exposed fracture surfaces were collected by further compressive loading of the fractured half-cores. The fragments were cleaned with compressed air to remove any fault gouge. They were then analyzed using a Phenom Pro X Scanning electron microscope at 30, 50, 100, 200, 400, and 600 μm length fields of view. The resulting 512 x 512 height maps were analyzed using multi-image variography. The method was validated using simulated fractal surfaces with known surface fractal dimensions (D_s). The measured D_s values for the fracture surfaces ranged from 2.00 to 2.16, and there were statistical differences between the various rock types. The measured D_s values were then used as inputs to a new analytical model for predicting spontaneous imbibition of a wetting fluid into a fracture bounded by opposing fractal surfaces.

Tuesday, 12:00-12:30
Title: *Geodiversity at the crossroads: The two different sides of the same coin.*
Authors: Nicolas Ferrer Valero[1] and **Juan José Ibáñez**[2].
[1]Department of Geography, Universidad de Las Palmas de Gran Canaria (ULPGC), Canary islands Spain
[2]National Museum of Natural History of Spain (MNCN), Spanish National Research Council (CSIC), Serrano 115 dpdo, 28006 Madrid, Spain

There has been considerable interest in geodiversity and pedodiversity studies in recent decades. Pedodiversity is considered part of geodiversity. However in practice they involved different experts and traditions. There are many common aspects that could be shared by all natural diversity studies, however, these common aspects have not been adequately studied and debated. Quantitative techniques that were developed and refined by biodiversity researchers along decades in the frame of biodiversity studies are

also be applicable to geodiversity and pedodiversity studies. Soil scientists studying pedodiversity followed the same techniques as mathematical ecologists, but geologists studying geodiversity focused on the implementation of proposals aimed at preserving geological heritage and popularising it among the general public for economic and social purposes (geosites, geoparks, geotourism). Therefore, pedodiversity and geodiversity diverged and it is not currently possible to compare the results of geodiversity and pedodiversity researches. To get this objective where biodiversity, geodiversity and pedodiversity results could be compared, it will be necessary to (i) follow uniform mathematical procedures in all natural resources disciplines to (ii) propose universal taxonomies that will be followed for each of the natural resources and (iii) to face the difficult task of investigating new indices that can integrate in a single value the diversity of all geodiversity resources with their idiosyncratic taxonomies. This contribution tries respond mainly to the item (iii) in order to reach a heuristic brainstorm among the assistants to the symposium.

TUESDAY, 12:30-13:00
Title: *Random multifractal modeling of porous media: from soil structure to gas diffusion layer of PEM fuel cells.*
Authors: **Ehsan Nikooee**.
Department of Civil and Environmental Engineering, Shiraz University, Shiraz, Iran
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In the absence of sophisticated imaging tools, one has to build mathematical models which can represent the porous structure of natural or man-made objects for modeling processes occurring therein. Born, coined and brought to us by late Benoit Mandelbrot, fractals have proved to be powerful tools in depicting the geometry of many objects, being capable of capturing details which each scale of observation discloses. When modeling a process occurring in an object, be it heat transfer in an industrial porous material, or moisture transport and retention properties of soils, we need a model of porous structure to simulate the process directly in its inside or to find effective properties of the medium based on the porous medium fractal indices. In the use of fractal analysis, one has to note that models of various complexity can be built to represent the targeted porous medium. A spectrum of various models from deterministic mono-fractals to random multifractals are available to be implemented based on the target porous media and the process whose simulation is aimed for.

While monofractals are quick to use and easy to interpret, multifractal match the intricate internal structure of various objects to a higher degree, and therefore, have attracted many researchers in recent decades.

In this contribution, different alternatives for modeling porous media using multifractal approach are introduced. The joint use of pore scale models such as pore network models and fractal analysis will also be explained in details.

Major/representative references:
Lehmann, P., Stähli, M., Papritz, A., Gygi, A., & Flühler, H. (2003). A fractal approach to model soil structure and to calculate thermal conductivity of soils. Transport in porous media, 52(3), 313-332.
Mandelbrot, B. (1967). How long is the coast of Britain? Statistical self-similarity and fractional dimension. science, 156(3775), 636-638.
Nikooee, E., Karimi, G., & Li, X. (2011). Determination of the effective thermal conductivity of gas diffusion layers in polymer electrolyte membrane fuel cells: a comprehensive fractal approach. International Journal of Energy Research, 35(15), 1351-1359.

TUESDAY, 15:30-16:00
Title: *The main chemical, rare earth and trace elements and minerals formation of mountain soil as an indicator of source and treatment pedogenetic in the Palestinian mountain soil.*
Authors: **Mahmoud Salahdeen Zaid**.

The purpose of this study was to explore the pedogenesis processes and to examine the source (parent material) of Mediterranean mountain soil; especially Terra Rossa, Rendzina and other associated soils through chemical (major, trace and Rare Earth Elements (REEs)), grain size and mineralogical compositions. Forty soil samples were collected form 13 pedons from different areas in Palestine that represent different soil types, lithology, elevation and precipitation along a climatic transect to demonstrate variability between south, north sections and west east transects. The north section around Nablus consists of: western and eastern transect. The western one in turn consists of Qusin pedon which was Terra Rossa, and Bait Eba pedon which was Rendzina. While the eastern one in turn consists of Tubas pedon which was Rendzina, and Tayaseer pedon which was Terra Rossa. The south section, which was Bethlehem and Jerusalem mountains, consists of: western

and eastern transect, the western one in turn consists of Battir1, Battir2 and AlQbu, which is Karstic, pedons which were Terra Rossa, while Ishwa and Ishwa (the road) pedons which were Rendzina soil. In other hand, the eastern one in turn consists of Teqo'a east and Teqo'a west pedons which were Terra Rossa, While Beit Sahour and Bayth Ta'amar pedons which were Rendzina. Two dust samples from Al-Quds University and seven rock samples from different pedons were collected also. From grain size, chemical compositions (major, trace and REEs), and mineralogical compositions results, dust was found to be the dominant parent material in studied soils. Leaching was dependent on rainfall amount and bedrock and soil permeability. Ca, Sr and U elements leached more than these trace elements Fe, K, Mg, Na, Al, Ba, Co, Cr, Cu, Mn, Ni, Rb, Sb, V, Zn and Zr and REEs. Some Terra Rossa samples were alike Typical Terra Rossa but with relatively high calcite content but mineralogical and chemical characteristics were similar to Pale Rendzina as in Qusin pedon. On the other hand, Brown Rendzina resembles Typical Terra Rossa as in Beit Sahour and Bayth Ta'amar pedons. The east transect samples leached less than the western, but the difference in leaching was low. Battir 2 profile has two soil layers deep layer, layers were composed of one on top of the other Dust samples were polluted with these trace elements Al, Cu, Pb, Sb and Zn, and this may be due to industrial or construction sources. Vanadium element found to be affected by rain and this is similar to Aluminum which considered to be well retained in soil. A baseline of grain size, major and trace elements, REEs and minerals was added to soil science in Palestine in general and Mediterranean virgin mountain soil (Terra Rossa and Rendzina).

Tuesday, 16:00-16:30

Title: *Soil textural heterogeneity impacts bacterial but not fungal diversity.*

Authors: **Fiona Seaton**, Paul George, Inma Lebron, Davey Jones, Simon Creer, David Robinson.
Centre for Ecology & Hydrology, Environment Centre Wales, Bangor, Gwynedd, LL57 2AW, UK
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Soil microbial diversity is incredibly high and as yet the factors driving this are not fully realised. The heterogeneity of the soil environment is often cited as a potential driver of high microbial diversity. Here we evaluate the impact of soil textural heterogeneity as represented through multifractal

analysis of particle size distributions upon soil bacterial and fungal diversities.

The Welsh national field survey GMEP created a powerful dataset that includes information on plant communities and soil properties. Over 1300 sites were examined for a range of soil properties and for a subset of these samples the soil fungal and bacterial communities were characterised using DNA sequencing of the 16S and ITS gene regions. Soil texture of over 400 of these samples was measured through laser granulometry, enabling detailed description of soil textural heterogeneity through multifractal analysis.

We have found that bacterial diversity was positively influenced by textural heterogeneity as represented by the D1 multifractal parameter, however fungal diversity was not. The extent to which microbial diversity is controlled by the soil structural environment is moderated by their life history strategies, ability to navigate the soil environment, and the influence of other biological groups in moderating soil structural influences.

TUESDAY, 16:30-17:00
Title: *Evaluation of drought stress through probabilistic modelling of soil moisture dynamics in SW Spain.*
Authors: Jiménez, M.P., Giráldez, J.V, **Vanwalleghem, T.**

Agricultural droughts are of critical importance in Mediterranean countries, and are likely to increase in a scenario of future climate change. An accurate characterization and prediction of droughts is necessary to improve the management of this natural hazard. Several indices have been proposed, such as the Standardized Precipitation Index (SPI), the Standardized Precipitation-Evapotranspiration Index (SPEI), or combined indices taking into account vegetation status through NDVI or fAPAR. However, the representation of soil moisture dynamics in these drought indicators up to date has been poor.

This study aims to improve the characterization of soil moisture dynamics in such drought indices. To this purpose, a probabilistic soil moisture model was applied to evaluate drought stress in rainfed cereal in Andalucia. The model followed the procedure used by Rodriguez-Iturbe et al. (1999) and the water balance model by Brocca et al. (2008).

The probability of soil water content was calculated at a daily basis for four different cereal growing regions, using the longest meteorological time series available at each site. The importance of soil depth, saturated hydraulic conductivity and of two parameters (λ and m) of the rainfall-runoff model was evaluated through a global sensitivity analysis. Finally, static and dynamical plant water stress was calculated based on soil moisture, following Porporato et al. (2002), and this stress is used to calculate the yield response to water deficit. This allowed to determine a critical threshold value for soil moisture that assured good yields. It is expected that this information will help to improve existing drought indices.

References

Brocca et al., 2007. On the estimation of antecedent wetness conditions in rainfall–runoff modelling. Hydr. Proc. 22(5), 629-642.
Rodríguez-Iturbe, I., 1999. Probabilistic modelling of water balance at a point: The role of climate, soil and vegetation, Proc. R. Soc. London, Ser. A, **455**(1990), 3789–3805.
Porporato et al., 2002. Ecohydrology of water-controlled ecosystems. Adv. Wat. Res. 25, 1335–1348.

Wednesday, 9:30-10:30

Title: *On the information content of coarse textural data respect to the particle size distribution and their predicting potential.*

Authors: **Miguel Ángel Martín**, Carlos García-Gutiérrez, and Yakov Pachepsky.

Soil and other complex granular media are formed by an enormous amount of size particles and, in fact, any particle size within the size interval might potentially be represented in a sample. In spite of this, the information reported on the particle size distribution (PSD), is usually very limited. In the case of soil, the distribution information is commonly reduced to three classical size fractions. A natural question is if there is a theoretical framework supporting the supposed information value of coarse textural data. The PSD reconstruction from this poor information, as well as their possible predicting potential, needs a rationale. The talk deals with theoretical aspects respect to this question.

Wednesday, 10:30-11:00
Title: *Is the available description of the PSD enough? And enough for what?*.
Authors: **Carlos García-Gutiérrez**[1], Miguel Ángel Martín[1] and Yakov Pachepsky[2].
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Soil particle size distribution (PSD) can be viewed as a mathematical measure supported in the interval of grain sizes. PSD not only describes soil, but it also is a useful predictor for many other soil physical properties, as bulk density or Ksat.

In the case of soil, available information about this distribution is usually very scarce, and given in form of triplets, i.e., the mass of three different size intervals, e.g. the USDA clay, silt and sand percentages. The size of these intervals has changed over time for different reasons; nowadays triplet limits seem to be arbitrary.

Without any more assumptions, this limited knowledge would not suffice to recover the whole distribution. However, the Information Entropy (IE) approach models the PSD as a selfsimilar measure. In this setting, the PSD is the solution of a differential equation that uses the coarse triplet measurements as initial condition. In this sense, the information contained in the input triplet, i.e., the available information of the PSD, entirely determines the final distribution.

This poses a problem: which size intervals should we measure? Indeed, different input triplets -different initial conditions- will lead to different distributions. So one can speak about how much “information” a triplet stores based on its potential to correctly reconstruct the actual PSD.

Results indicate that the information contained in certain soil triplets is sufficient to rebuild the PSD: for each soil sample tested there is always at least a triplet that contains enough information to simulate the whole distribution.

Furthermore, this conceptual approach provides us with a useful parameter, which is also triplet-dependant: the “coarse-entropy”. In the spirit of the pedofransfer functions, that use the PSD to estimate difficult to measure soil physical properties, we investigate which triplets store greater capability of predicting some of these properties -Ksat and packing- by means of the IE parametrization. Overall, the textural triplet selection appears to be application specific.

WEDNESDAY, 11:00-11:30
Title: *Mass-balance approach to segmentation of water distribution in soil pores.*
Authors: **Andrey Guber** and Alexandra Kravchenko.
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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 disturbing of the contrast in soil pores as compare 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 to 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 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 should that reliable estimating 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 soil fraction. This was attributed to increasing partial volume effect with increasing volume of fine pores.

Wednesday, 12:00-12:30

Title: *Scaling heterogeneity of soil general properties at multiple depth.*

Authors: E. Vidal Vázquez[2], S.R. Vieria[1], O. Camargo[1], **A. Paz González**[2], and A. García Tomillo[2].
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Measurements of soil properties of the uppermost soil layer along transects have established that the spatial variability of the data sets obtained can be described using the principles of fractal and/ or multifractal theory. However there is a lack of knowledge about the scaling heterogeneity of soil properties of sib-surface layers. If the surface scaling properties are kept at deep layers, information gathered from the former can be used in determining land management practices. The current work examines the scaling properties of soil properties measured at successive layers. The study site was located at the experimental field (Santa Eliza Farm) of the Agronomic Institute of (IAC), São Paulo, Brazil, (22º53' S, 47º04' W), with an average altitude of 600 m above sea level. Soil samples were taken down to 1.0 m depth at five equal intervals, namely 0-20, 20-40, 40-60, 60-80 and 80-100 cm along a transect. The following soil properties were analysed: textural fractions (sand, silt, and clay), pH, organic carbon (OC), available P, exchangeable cations (Ca, Mg, K), exchangeable acidity (H and Al), sum of bases (SB), cation exchange capacity (CEC) and percent base saturation (V). Mass exponent function, τq, generalized dimension, D_q, and singularity strength, $f(\alpha) - \alpha$ curves, showed the spatial distributions of the studied soil attributes, at the particular sampling scale, behaved as multifractal measures for all the five studied depths. Irrespective of sampling depth, the slightest heterogeneity corresponded to the spatial distributions of soil pH. The remainder variables studied showed in general a strong multifractality, but there were differences in the degree of scaling heterogeneity of the studied attributes between soil depths. Not all the studied soil attributes showed highest scaling heterogeneity at the 0-20 cm layer; in other words, the degree of multifractality wasn't a function of soil depth. Notwithstanding, the scaling properties of the soil analyzed at the surface layer were highly correlated with those of the deep layers, which indicated a highly similar scaling behavior in the soil profile. In general, the strong similarity between the scaling properties of the soil properties at the surface layer and deep layers provides the possibility of inferring about the spatial distributions for whole profile using the scaling properties of the easy-to-sample surface data.

WEDNESDAY, 12:30-13:00

Title: *Challenges in exploring the spatial variability of clay content at the field scale using electromagnetic induction and inversion modeling.*

Authors: **G. Martínez**[1], K. Vanderlinden[2], L. Mateos[3], A.M. Laguna[1], J.V. Giráldez[3,4], F.A. Monteiro-Santos[5].
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[5]Faculdade de Ciencias, Universidade de Lisboa, Portugal

Soils are by nature heterogeneous. This heterogeneity manifests itself in the scale-dependent spatial and temporal variability of the soil properties. Generally, soil texture, and more specifically clay content and type, is considered as one of the most important factors of soil variability as it influences greatly the hydrological response of the landscape. While traditional soil sampling and laboratory analysis are quite inefficient, electromagnetic induction (EMI), which measures the soil apparent conductivity (ECa), provides valuable and cost-effective information on soil spatial and temporal variability. In this study, we evaluated the relation between multidepth soil texture and EMI data in an olive orchard and the interaction between soil features and properties. A quasi-3D analysis of inverted EMI data (σ_a) at the studied depths was performed using the EMTOMO inversion algorithm. We found a large similarity both in terms of median values and variability for each soil property (e.g. ECa, clay and sand) at different depths. Correlation analysis showed that clay content correlated significantly ($p<0.05$) but weakly ($r<0.5$) with depth-weighted measurements of ECa. Spatial patters of the different soil properties were different. This was corroborated by a cluster analysis of clay content and σ_a, allowing the identification of 3 homogeneous groups . Finally, a non-linear analysis performed with regression trees highlighted the importance of topographical features (e.g. slope, elevation) in explaining either clay content and σ_a. The relevance of these factors reflects the important role of soil moisture in the relation between clay content and σ_a. Our results show the importance of soil moisture effects on the spatial relationship between soil texture and EMI patterns, which, in a site-specific context, may mask the frequently found relation in numerous studies between EMI and clay conducted at different scales.

Thurdsday, 9:30-10:30
Title: *Upscaling biological and physical soil properties from 2D/3D multiscale images.*
Authors: **Patricia Garnier**[1], Edith Perrier[2], Valérie Pot[1], Philippe Baveye[1].
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Greenhouse gas emissions are generated in the soil at a very fine scale by microorganisms. Many experimental studies have shown that emissions are very dependent on local conditions and on the organization of the soil at this small scale. Our presentation describes a complete approach that would make it possible to use all the new modeling or visualization techniques developed in soil science to take into account the processes at the fine scales and make them accessible in a simple way at larger scales. At different stages of our approach, we will discuss the interest of using fractals or multifractals. Recent visualizing techniques make possible to obtain in 2D or 3D small-scale distribution in soils, such as solid/air/water/organic matter and microorganisms in the soil structure using different methods. From these images, indicators of the structure such as porosity, tortuosity, Euler number, fractal dimension, etc... can be calculated. Other indicators can quantify the spatial relationships between microorganisms and organic matter such as accessibility. Moreover, some 2D or 3D models have been developed to explicitly take into account the distribution in the soil structure using 2D or 2D images of soil as inputs. These models can simulate a set of physical and/or biological processes, for example the microbial degradation of soil organic matter. From these models, the simulation of many scenarios also highlighted the importance of spatial organization. Some studies are trying to relate simulated microbial activities to spatial indicators. These relationships would make possible to identify indicators of the microscopic organization that explain the macroscopic emissions that could then be the inputs of models operating at higher scales. However, some limitations of these approaches can be identified. They are related to the size of the images and their resolution which are necessarily finite. An extrapolation to smaller scales could be considered but would involve problems of memory size and computing time. The question then arises of using modelled or measured distributions of the variables at lower scales, that could be incorporated into the images in order to try to integrate the effect of the porosity which cannot be seen at a given image resolution using multiscale modeling approaches.

Thursday, 10:30-11:30
Title: *Process-based physics is a missing piece in understanding of the plant/soil/microbe continuum.*
Authors: **Alexandra N. Kravchenko**.
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Soil is a key component of terrestrial ecosystems that contains almost twice as much carbon (C) as atmosphere; and it is the C which can be easily lost under right environmental settings or, alternatively, can be increased by appropriate management. International research community has achieved substantial progress in decifering the mechanisms driving soil C gains. However, abundant unexplained examples of unexpected outcomes signal that our understanding is incomplete. For example, some soils accumulate C even in the presence of aggressive tillage, while soils of some perennial systems can be slow to gain it despite the lack of soil disturbance and large belowground C inputs. Such discrepancies suggest a significant knowledge gap with respect to the plant-soil-microbial interactions that drive soil C accretion. This deficiency is especially unfortunate given globally changing climate, since soil C accrual strategies effective under new future environments can be efficiently developed only with a full understanding of underlying drivers.

There is always been, and is now growing, a view that complete process-based understanding of mechanisms driving C protection can be achieved only through understanding of soil flow, transport, and movement processes, all of which take place within soil pores. By serving as conduits for gases, water, nutrients, and dissolved organic C, pores define microbial habitats, thus have a major effect on microbs' ability to function, access, and decompose soil organics.

In my talk I will present a review of past results of my research team exploring various routes by which presence and characteristics of pores contribute to creation of contrasting habitats for microorganisms and pores' contribution to C processes. These will include the roles of pore sizes, connectivity, and origins (biological vs. non-biological) in defining the type of micro-environmental conditions they create; how these micro-habitat differences affect compositions of microbial communities; and how they are further expressed in differences in extracellular enzyme patterns, and resulting soil organic matter decomposition products.

Thursday, 12:00-13:00
Title: *Scales in soil hydrology and the myth of hydraulic equilibrium.*
Authors: **Hans-Jörg Vogel**.
Helmholtz Centre for Environmental Research - UFZ, Halle, Germany

Soil hydrology is a key control for the functioning of the terrestrial environment. Many environmental issues that we need to tackle today are directly linked to soil water dynamics. This includes agricultural production and food security, nutrient cycling and carbon storage, prevention of soil degradation and erosion, and last but not least clean water resources and flood protection. However, these problems need to be addressed at scales of fields, regions and landscapes while soil water dynamics and soil hydraulic properties are well understood and typically measured at much smaller scales – the comfort zone of soil physics. An obvious problem is how to link these vastly different scales and how to profit from small scale understanding to improve our capability to predict what is going on at the large scale.

In this presentation the phenomenology of soil water dynamics along the cascade of scales is discussed with special emphasize on "effective" properties and the assumption of hydraulic equilibrium which is typically required but rarely met in real soil. As a synthesis, a two-step scaling approach is proposed for modelling soil water dynamics from local to landscape scales where the scale of the soil profile is the stepping stone.

Thursday, 15:30-16:00
Title: *Effects of soil wetness and tire pressure on soil physical quality and maize growth by a slurry spreader system.*
Authors: **Lidong Ren**[a], Tommy D'Hose[b], Greet Ruysschaert[b], Jan De Pue[a], Redouane Meftah[c], Veerle Cnudde[c], Wim M. Cornelis[a].

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The effects of soil wetness and tire pressure on physical soil properties was evaluated by using a ∼5 Mg wheel load slurry spreader mounted on a tractor. The impacts were also compared with Terranimo® model predictions of soil

stress and X-ray micro-computed tomography (micro-CT) results. In the consecutive maize growing season, soil physical properties, total nitrogen content and maize above biomass was evaluated between in and out track position. Just after traffic, penetration resistance was significantly higher ($p<0.05$) under moist condition and in track positions compared with dry and out track for the top 10 cm. Tyre pressure did not affect PR at in or out track position. At 10 cm depth, bulk density and macroporosity ($d > 30$ μm) of soil trafficked under moist conditions differed ($p<0.10$) as compared with dry trafficked conditions.

Macroporosity showed also a clear response ($p<0.10$) to tire pressure and the four treatments. Deeper in the profile, there were no significant differences in these soil physical quality indicators. X-ray micro-CT results agreed well with the soil physical quality indicators and more precisely to detect slight changes in degree of compaction. Terranimo® could well predict the contact area and mean ground pressure (RMSE=0.06 m^2) and indicated considerable compaction risks from the tractor's rear wheels. In the maize growing season, soil physical properties and nitrogen content had no difference between in and out track position while maize dry biomass was significant smaller at in track position.

Keywords: soil compaction; Terranimo®; X-ray micro-CT; wetness; tire inflation pressure

Poster Session
Thursday, 16:00
Title: *Soil structure dynamics with high saturation jumps.*

Authors: **Dmitriy Fomin**[1], Anna Yudina[1], Konstantin Romanenko[1], Konstantin Abrosimov[1], Elena Skvortsova[1], Kirill Gerke[2], Marina Karsanina[2].
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Soil structure defines most of soil functions: water and air transport, carbon and water storage, habitat of microorganisms and fauna, nutrient availability for plants and many other. In this work we are mainly focused on hydrological soil function as affected by its structure. To date there has been little research about dynamic of soil structure under different moisture regimes. Aim of this study is characterization of soil structure dynamics under fast soil moisture jumps. The experiment site is natural coniferous

forest near Zelenogradskaya Research Station of V.V. Dokuchaev Soil Institute, Moscow region, Russian Federation (56°05'58.6"N, 37°49'13.5"E). The soil is Silt Loam Eutric Retisol, developed on clay loam mantle. The undisturbed soil samples (cylinders of D=2 cm, H=5 cm) were collected from genetic horizons (A, E, B) in five replicates. Contrast stationary conditions of water pressure were studies – such setup differs from our another poster by the pronounced soil moisture jumps. The experiment design included 5 steps: 1 – field moisture condition, 2 – plant wilting point, 3 – full water saturation condition, 4 – plant wilting point again, 5 – very dry condition. At each saturation step μCT imaging, 3D image analysis and quantification including structure properties characterization were performed.

The reported study was funded by RFBR according to the research project No 18-34-20131.

Poster Session
Thursday, 16:00

Title: *Revisiting the soil water retention equation, its equations and its properties for the evaluation of the agronomic properties.*

Authors: A. Laguna[1], G. Guzmán[1], **J.V. Giráldez**[2,3], G. Martínez[1], K. Vanderlinden[4], A. Peña[5], T. Vanwalleghem[2].
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The water retention curve is one of most relevant physical characteristics of a soil. Many models have been proposed in the last fifty years to describe it. Nevertheless, there is not a universal equation, valid for all types of soils. In this report several of the main equations are discussed attempting to find a connection between them.

Some properties related to the soil water retention curve like the soil water retention curve like the soil quality indices, the air entry states and the field capacity.

Poster Session
Thursday, 16:00
Title: *Topographic Surface Study Through MF-DFA.*
Authors: **M.C. Morató**[a], M.T. Castellanos[a], P.L. Aguado[b], A.M. Tarquis[a,c].
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Digital elevation models (DEMs) provide the information basis in many geographic applications, for example, topographic studies and landscape analysis. The information obtained from those models has been combined with powerful mathematical methods such as fractal and multifractal analysis.

This work evaluates the multifractality of altitude data points along transects that are obtained in several directions using Detrended Fluctuation Analysis (DFA) in three different areas in Spain: a protected area adjacent to Madrid (El Pardo) and two cultivated areas with fields of vineyards and olive trees in Toledo. The study data sets consist of a matrix 1003_1003 pixels obtained at a 1m resolution and extracted from a digital terrain model (DTM) using a Geographic Information System (GIS).

The analysis of the directionality by means of a generalised Hurst rose plot showed differences in the scaling characteristics both along and across rivers and croplands indicating a clear anisotropy. Comparison between the three sites is analyzed according to the land use and the topography of the land.

Poster Session
Thursday, 16:00
Title: *Characterizing temporal trends of soil water content under Eucalyptus globulus using the multifractal approach.*
Authors: **A. Paz-González**[1], R. da Silva Días[1], E. Vidal Vázquez[1], M. Lado Liñares[1], R.C. Hämmerly[2], and A. Garcia Tomillo[1].
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Temporal behavior of soil water content as a function of depth is essential to understand soil hydrodynamics. Frequency domain reflectometry (FDR) was used to continuously monitor soil water content under Eucalyptus globulus in Atlantic climatic conditions. In this work, we analysed a data set measured at five depths (10, 20, 40, 60, 90 and 140 cm) on an hourly basis during successive years. Data gathered with FDR sensors provided a detailed description of the soil water regime and soil water use by Eucalyptus during the dry and the wet seasons of the year and also were useful to determine the depth to which the root system is active. Also multifractal and joint multifractal analysis of yearly data sets measured at successive depths was performed. The scaling properties of soil water content series under Eucalyptus could be fitted reasonably well with multifractal models. However, the scaling heterogeneity of soil water content decreased as a function of soil depth. Several multifractal parameters cropped from the generalized dimension, D_q, and singularity, $f(\alpha) - \alpha$, spectra were sensitive in characterizing soil water content time series at different layers and all of these parameters showed a correlation with soil depth. For example, the widths of D_q and $f(\alpha) - \alpha$, or the entropy dimension, D_1, steadily decreased as a function of soil depth. Therefore, multifractal analysis allowed discriminations between different patterns of yearly soil water content series. This multifractal nature of soil water content time series indicated that the transformation of information from one scale to another at the surface layer during the wet period requires multiple scaling indices. In addition, joint multifractal analysis showed the scaling properties of the surface layer were highly correlated with those of the deep layers, which indicated a highly similar scaling behavior of soil water temporal trends in the soil profile. It was concluded that multiple scale analysis significantly improved characterization of spatial variability in the temporal distribution of soil water content. Moreover, the observations carried out at the field scale in the studied landscape and climate may be generalized in similar landscapes and climatic situations.

Poster Session
Thursday, 16:00
Title: *An open discussion about the limits of multifractal models as regards porosity or mass spatial distributions.*
Authors: **E. Perrier**, P. Baveye, P. Garnier, A. Tarquis, N. Bird, H. Laurie.

This poster presents theoretical and technical problems concerning the use of multifractal models to represent plausible distributions of either the solid or pore mass in soils.

The main issue to be discussed is that physical limits occurring on the maximum concentration of mass in a given space area lead to constraints about the porosity that can be actually represented by a multifractal model. These constraints are presented here as a function of the number of iterations and of the degree of multifractality for a given multifractal model. This may have also lead to discussions on the tuning of multifractal algorithms on real images.

Poster Session
Thursday, 16:00
Title: *Do Soil Forming Factors drive Pedodiversity in Central Chile?*
Authors: Marco Pfeiffer[1], **Juan José Ibañez**[2].
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Central Chile is characterized by having a mosaic of ecosystems that reflect the transition between one of the driest deserts on the planet and the humid climate that characterizes the Patagonian fjords. This ecological complex is located in a geography that is modeled by its location on a convergent tectonic margin. This has created a relief with physiographic units that run parallel from north to south, rich in lithologies of different origin and age, whose climatic gradient and geographical isolation have created a unique landscape and a particular flora. The hypothesis of this work is that like the vegetation, the geography of Soils of Chile presents a diversity and spatial variability that are intimately related to the conformation of the territory

and its recent geological history. For this, the database of the official cartography of soils of Chile, which covers between 32ºS and 43ºS, was analyzed, applying the tools of pedodiversity to the taxonomy of soils, such as wealth, entropy (Shannon index) and equality (eveness). When comparing the soil diversity indexes with the vegetation diversity indexes of this region of Chile, it is observed that the soil diversity indexes present a pattern of variation similar to the diversity of vascular flora. This pattern of diversity was observed at different levels of the Soil Taxonomy. The results of this study allow us to propose that there are many similarities between the factors that explain the diversity of both soils and plant species in Central Chile. This study is a contribution to the discussion about whether soil diversity drives plant diversity, or both are explained by similar environmental factors and that they co-evolve in the landscape over time.

Poster Session
Thursday, 16:00
Title: *Diversity and Power Laws analyses of Pedo-environmental maps used for environmental assessment.*
Authors: Ramírez-Rosario, B[1], Fernández-Pozo, L.F.[1], **Ibáñez J.J**[2].
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Pedodiversity analysis at landscape level has been carried out mainly using maps of some natural features of physical geography (e.g. landmass units such as continents, islands of selected archipelagoes, drainage basins in a given territory, river cross sections, etc.), climatic and bioclimatic zonation maps and administrative units (States, Regions, etc.). However, it is frequent those policy makers to demand synthetic environmental maps for applied purposes such as environmental assessment and protection. The latter spatial products have been carried out by overlapping spatial data layers of different sources (some natural usually and others artificial), and at different scales, using GIS technologies. Thus these purpose-oriented environmental maps consist of (i) decisions of experts that select natural resources to be considered (ii) manipulation of these maps to obtain others conforming to the intended targets (e.g. merging categories to reduce the number of objects, merging pixels spatially for the units to be used, etc.). Thus these maps turn out to be quite artificial products. In this contribution the authors analyse, making

use of pedodiversity tools, a spatial data set of this kind that represent pedo-environmental units of a southwestern territory in the Iberian Peninsula. This Pedo-environmental map is a product that should be included in the category of the so-called "Land System Approach". The spatial data layers correspond to several soil forming factors such as lithology (seven types after being grouped the types of lithologies of previous lithological maps), land use (ten types after grouping the most numerous classes of the UE CORINE Landcover map), relief (6 classes according to FAO, 2009) as well as the soil association presents in this area from the Digital Soil Map of Europe –V 1.0.). A total of 251 different Pedo-Environmental units (UEAs) were obtained.

Thus, (UEAs) are basic units of sampling and cartography, elaborated from the soil forming factors, among them lithology, vegetation/soil use and relief with the objective of obtaining parametric and/or edaphic maps, whose study will allow us to carry out multiple comparisons to analyze the state of the soils and their role in the conservation of the ecosystems.

In comparison with classical analysis of pedodiversity, in this study case the results obtained show many similarities and some differences: (i) in all analysis Rank Abundance Plots dataset are conforms to the termed Hollow Curves; (ii) power fits of each natural resource studied (lithology, land use, relief, soils) with the area or number of polygons reach significant R2 values in many instances, but the trend is reversed in 20% of them However it seems surprising that when same statistical test is carried out with the UEAs in all cases the adjustment to the power law was considerably better than linear regression. The spatial distribution pattern of UEAs does not differ from the results obtained in previous pedodiversity analyses. What are the conclusions?

Poster Session
Thursday, 16:00
Title: *Preliminary research on long-range correlation of records of soil water retention for different soil managements and depths.*
Authors: **F. San José Martínez**, C. García-Gutiérrez, J. Caniego, F. Peregrina.

The aim of the current research were to describe the dynamic of soil water content in a vineyard where three different soil managements practices were undertaken. We also considered data from three depths. For this study we had access to a rich database. The records that were examined span nineteen months and data were recorded every 30 minutes.

Due to the nonlinear processes that affect soil water content, studies based on traditional statistical analysis may provide a limited description of this kind records where high variability is related to complex dynamics. But also, standard multiracial tools, well suited to analyses data that show complex behavior, have limitations when analyzing stationary time series.

In this preliminary research we explore the suitability of multifractal detrended fluctuation analysis to characterize the dynamics of soil water content and how it is affected by different soil management and depths thought the detection of long range correlations.

Poster Session
Thursday, 16:00
Title: *Multifractal and joint multifractal analysis of soil properties in an orthic Podzol at Pernambuco state, Brazil.*
Authors: D.H.S. Souza[1], **A. Paz-González**[2], E.F.F. Silva[1] and A. Garcia Tomillo.
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[2] Faculty of Science, University of A Coruña, Spain

Spatial variability of soil properties has been demonstrated to occur at different scales. Multifractal characterisation of soil heterogeneity may contribute to a better understanding of the patterns soil spatial variability and to improved resource management. This study aimed to assess the scaling heterogeneity and multiple scale relationships of soil general properties using multifractal and joint multifractal techniques. We collected 144 soil samples at the 0.20 m depth at equal intervals of 20 m along a 2880 m transect. The sampling was performed in an orthic Podzol at Pernambuco state, Brazil. The following soil properties were analysed: textural fractions (sand, silt, and clay), pH, organic carbon (OC), available P, exchangeable cations (Ca, Mg, K), exchangeable acidity (H and Al), sum of bases (SB), cation exchange capacity (CEC) and percent base saturation (V). The spatial distribution of soil general properties, characterised through generalised dimension, Dq, and singularity spectra, $f(\alpha) - \alpha$, showed a well-defined multifractal structure. This multifractal nature indicated that the transformation of information from one scale to another at the surface layer during the wet period requires multiple scaling indices. Notwithstanding, these variables displayed several degrees of scaling heterogeneity, which was lowest for pH and sand content and highest for available P an exchangeable cations and. Joint multifractals showed that correlations between pairs of variables may be stronger at multiple scales than at the observation scale across a range of spatial scales. Multifractal and joint multifractal analysis provided new insights to characterise the spatial patterns and the relationships between soil properties at multiple scales, and to evaluate heterogeneity of soil spatial variability.

Poster Session
Thursday, 16:00
Title: *Deforestation transitions geometry patterns through shape metrics in the six continental Biosphere Reserves of Ecuador.*
Authors: Andrea Urgilez-Clavijo[1,2], **Ana M. Tarquis**[3,4], David Rivas-Tabares[3], Juan de la Riva[2].
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Forest landscapes in the six Continental Biosphere Reserves of Ecuador are complex systems exposed to a very dynamic Land Use Land Change (LULC), in most of the cases related to human activities. Natural forestation and deforestation were identified as the most common land use changes in the last 26 years. The aim of this study is to identify and analyze the deforestation transitions geometry patterns through shape metrics at different scales (patch, classes and landscape).

For this, classified images from Environmental Ministry of Ecuador were used for the years 1990, 2000, 2008, 2014 and 2016 at a resolution of 30m and, deforestation areas were identified in space and time. A global comparison revealed that 9.3% of the Biosphere Reserves of Ecuador were deforest from 1990 to 2016. Those areas were later exploited for agriculture 85% and 15% for pastures in special, for extensive livestock activities.

The results suggest that the assessment of the landscape through shape metrics shows the outstanding dependency of perimeter-area relationships in deforested areas. This situation was point out through the use of fractal dimension (FD) metric of a set of deforested patches. The FD, in this case, is influenced with anthropogenic agricultural activities affecting patches across a wide range of scales, and differences between landscapes can suggest differences in the underlying pattern-generating process. Thus the analysis in other deforested scales of Ecuador landscapes could be reasonable done with shape metrics as FD of deforested patches. Mapping the patches at different scales could be a reasonable strategy for the Ecosystem Services assessment.

Key words: Transition matrices, shape metrics, deforestation, fractal dimension, LULC.

Poster Session
Thursday, 16:00
Title: *Soil structure dynamics under steady state wetting-drying cycle.*
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Soil structure controls a number of functions such as water flow and its retention, transport of nutrients and related processes. While we all understand that the structure is dynamic for most structured soils and is affected by wetting-drying, freezing-thawing, and swelling-shrinkage cycles, such processes are usually "left out" of consideration in majority of soil physical models. In this contribution we try to address at least one of these pillars by asking two questions: to what extent wetting-drying cycles affect soil structure and how does it influence soil hydraulic functions. To make such analysis meaningful, we further limit our study to steady state wetting-drying cycles. We characterise structure dynamics within conventional soil cores in wetting-drying cycle using a combination of water retention curve (WRC)

and μCT measurements. Soil cores from A, E, and Bt horizons from Eutric Albic Retisol (Moscow region, Russia) were used in 3 replicates for such parallel experiments. At first, soil cores were scanned using X-ray μCT under field conditions. Then cores were slowly saturated and dried with the help of sand and sand-kaolin box method at a wide range of pFs: 0.4-0-0.4-1-1.5-1.8-2.0-2.3-2.7 and by oven-drying (3 days + 3 days under T=50°C; 7 days under T=105°C), underlined conditions were scanned using μCT. Pore and solid structural changes in the form of morphological characteristics were computed and analized through the whole wetting-drying cycle and will be presented at our poster.

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Friday, 9:30-10:30
Title: *From structure to soil physical properties: what and how do we want to upscale.*
Authors: **K. Gerke**.

Soil is known to be the most complex natural porous media we know about. This is mainly due to the fact that it is dynamic and consists of numerous components, including organic matter and living organisms. Modelling the processes within soil is crucial for understanding soil fertility, water resources and irrigation strategies, climate change effects mitigation, to name just a few critical applications. Such modelling was conventionally performed using continuum media approximations which does not account for real processes taking place at all different scale from nanometers to meters and above. More physical modelling of processes of interest such as flow and transport or microbial activity requires a detailed knowledge on soil structure. If soil structure is known, one can utilize direct or, sometimes referred to as pore-scale modelling, approaches to simulate aforementioned processes of interest without utilizing any inconsistent assumptions. While recent years saw a huge boom in soil structural studies, thanks to abundance of X-ray tomography devices, we still have very fragmented information.

We shall start by discussing the possibility of building a multi-scale soil structure digital model: what tools do we have, what is still lacking, what could we do to improve our knowledge? To address these questions we shall consider existing and emerging techniques. By doing so we shall discuss some important topics related to soil structure, such as representativity, statistical homogeneity and information content. Moreover, we shall consider some examples then soil physical properties are close to impossible to be defined without structural information. Finally, structural-property relationships for soils will be considered through the prism of upscaling. Expect to dive into diverse waters spanning from small angle scattering and deep learning to tensorial properties and super-resolution. Unlike my usually lousy presentations, this one will contain less formulas and the goal will be to share complex concepts through simple schemes, figures and visual examples.

Friday, 10:30-11:30
Title: *Pattern and scale in soils.*
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The interest in patterns as related to scales grows exponentially. Both scale and pattern are useful yet vague notions. Scales can be defined via hierarchical levels of organization, via measurement metrics, or just via geometric similitude. Patterns have been defined as discernible arrangements of component parts, as a form or model that is proposed to be or actually is replicated, or reliable sample of observable characteristics found in a large number of objects. One working definition is: patterns are defined as recurrent features in systems' behavior or appearance that can be observed in space, over time, or across scales.

The interest in patterns has deep epistemological roots. A set of mechanisms should exist that enable patterns. Pattern discovery advances the knowledge. If all known fine-scale processes do not produce the pattern at the coarser sale, self-organization and emergence are possible and are of the great interest. One philosophical aside here is that the dialectic relationships between form and content in interactions of patterns and underlying processes serves a driver of knowledge creation. In applications, patterns signify and embody repeatability, therefore knowledge about patterns appears to be invaluable for diagnostics, monitoring, prediction and management of environmental systems.

Soil science came into existence with the discovery of major patterns of genetic horizons and soil zones. Eventually, patterns have been established at different scales defined in terms of hierarchical nature of soil. Different soil forming factors had the leading role in explanation of the patterns at different scales: zonality, soil combinations, polypedon, horizon, aggregate, and pore. Pattern discovery in soils has been followed by the formulation of competing hypotheses about underlying processes, and thus stimulated the efforts to understand the soil functioning.

Significant developments in soil physics happened when scales were defined using measurement metrics, such as support, spacing, and extent. The pattern of scale invariance brought in action the fractal geometry. Physical, chemical, and biological mechanisms for this pattern have been hypothesized and studied. Breaks in patterns were shown to provide a signal of change in underlying mechanisms. Highly irregular behavior in soil processes has been observed, amongst others, in soil respiration and soil moisture dynamics. Suitable techniques are needed for detecting and parameterizing patterns in these signals. Developments in multi-fractal analysis, lacunarity analysis and similar techniques can be explored.

Role of patterns is significant in creating and evaluating the predictive instruments n soils science. It is important that models reproduce patterns. Comparing spatial patterns in maps of soil variables may provide better insight into the relationship between these variables than non-spatial correlation analysis. Creating synthetic soil datasets can benefits from Including patterns. Accounting for patterns can substantially reduce uncertainty in predicting states and fluxes. Finally, patterns provide essential information for several upscaling and downscaling procedures with data-rich inputs. Pattern recognition allows to upscale the knowledge from the underlying process scale to the scale where the pattern is present.

Opportunities of pattern discovery and applications continue to present themselves. New types of measurements became available at various scales, and large volumes of data call for detection of patterns in the 'big data' observations. Relatively little attention is paid to patterns in variability of soil variables. Knowledge of variability becomes more and more important as ensemble modeling and data assimilation become more popular and risk assessment replaces rigid standard-based assessments. Patterns represent empirical information about non-random variations in soils at various scales, and their detection and parameterization creates the opportunity for better understanding and decision making.

6 Social program

- Monday, July 8th, 20h: Reception Wine at El Barco de Ávila.
- Wednesday, July 10th, 16h: Field trip to La Nave del Barco and BBQ at La Galamperna.
- Thursday, July 11th, 21h: Social Dinner.