On the role of structure in PTFs

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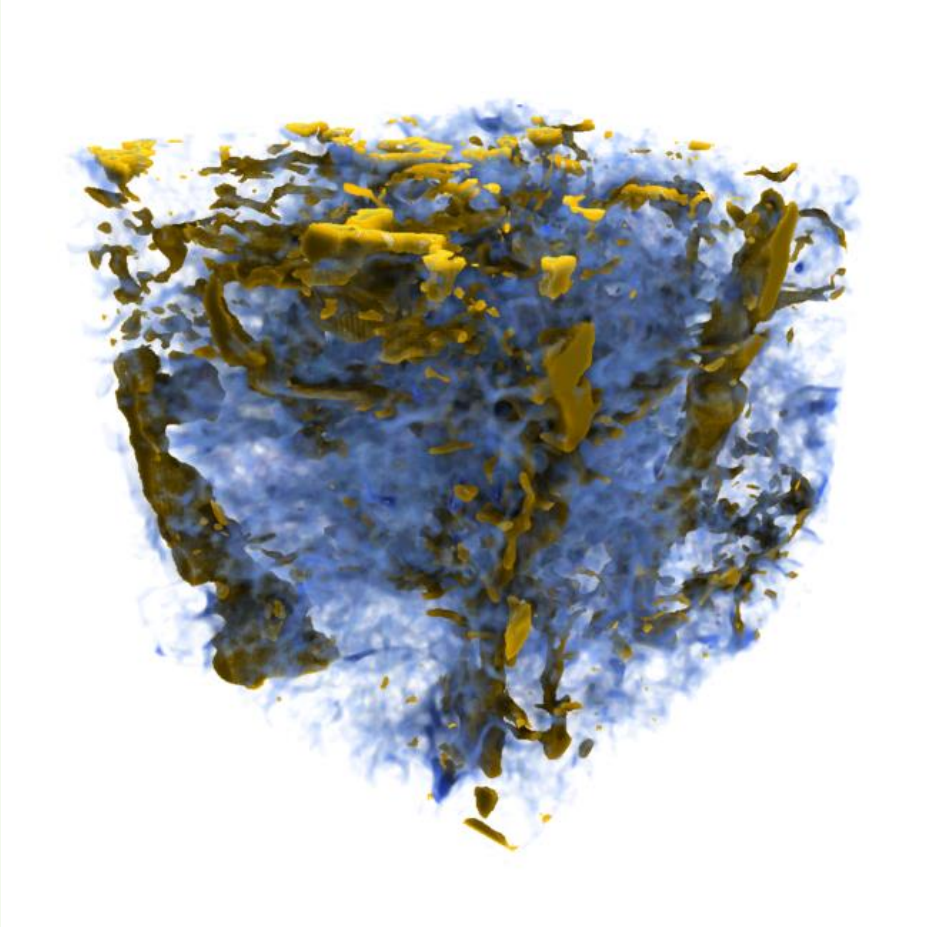

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Outline

Soil structure and soil function

Incorporating structural information into PTFs

- i) linking structure and function
- ii) identifying structure forming agents
- iii) finding proxies for inferring soil structure

PTFs, structure and scale

Rainer´s dilemma

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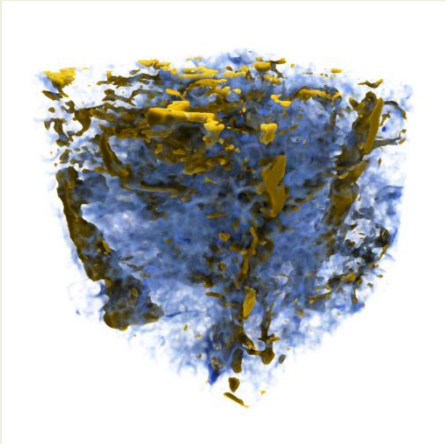
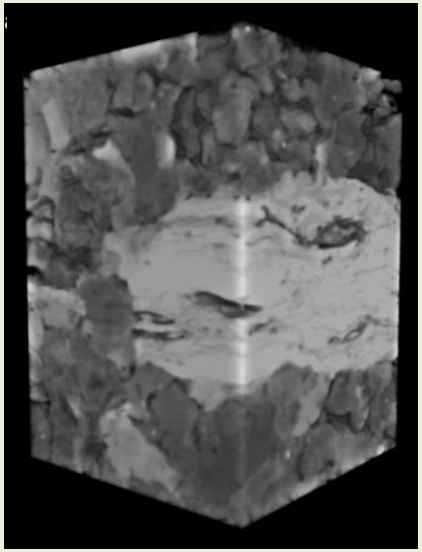
What kind of structure are we talking about?

Pore network



Scales are in the range of 1 to 3 cm

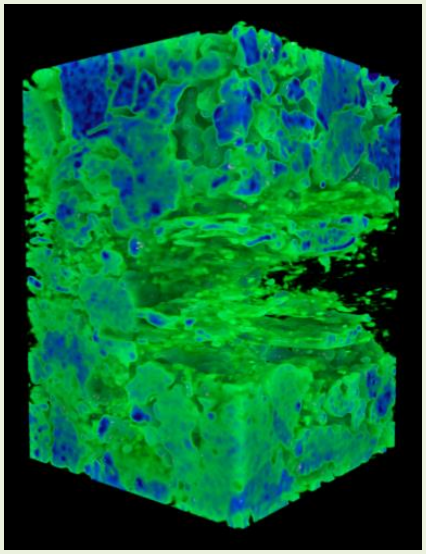
Material distr.



Keck et al. 2017

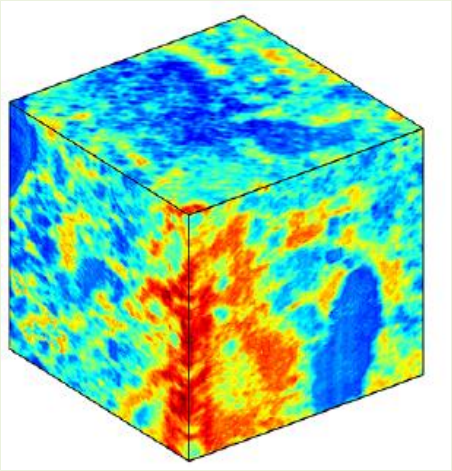
→ Chemical props.
for example:

Adsorption props.



Keck et al. 2017

Element distr.



Hapca et al. 2015

↓ Mechanical props.

→ Biology

etc…

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Structure and function

Soil functions influenced by soil structure listed in

Rabot et al. (2018):
"Soil structure as an indicator of soil functions: a review"

Are identical to the target properties of **all** the PTFs discussed in

Van Looy et al. (2017):
"Pedotransfer functions in Earth system science: …" !!!!!

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Structure and function

Mineralization

Soil fertility

Filtering properties

Nutrient accessibility

Root development

Solute/colloid transport

Soil ecology

Surface area

Hydraulic properties

Air diffusion/transport

Structure

Heat capacity/transport

Soil respiration

Mechanical stability

Redox potential

Erodibility

Trafficability

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Structure and function

It is known that soil structure plays a role for these functions…

But this knowledge is still mostly qualitative.

Future research needs to quantify importance of soil

Structure on the respective functions

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Incorporating structural information into PTFs

i) linking structure and function

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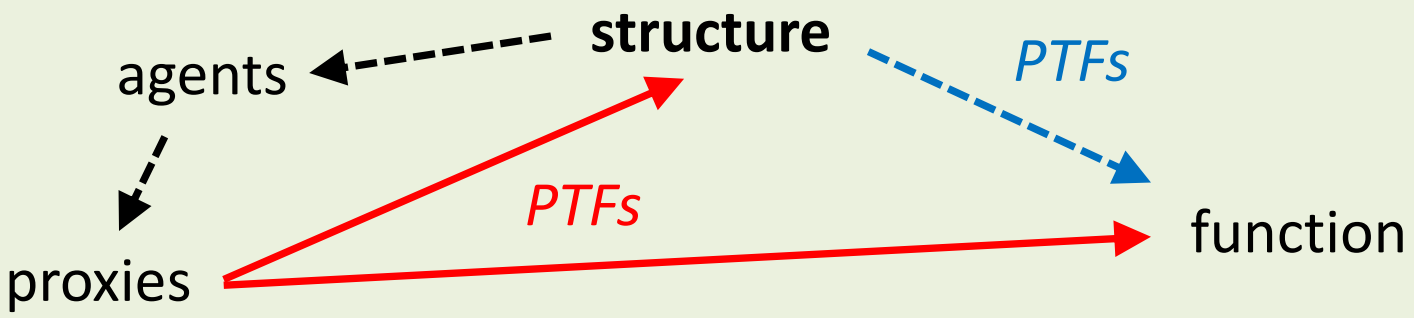

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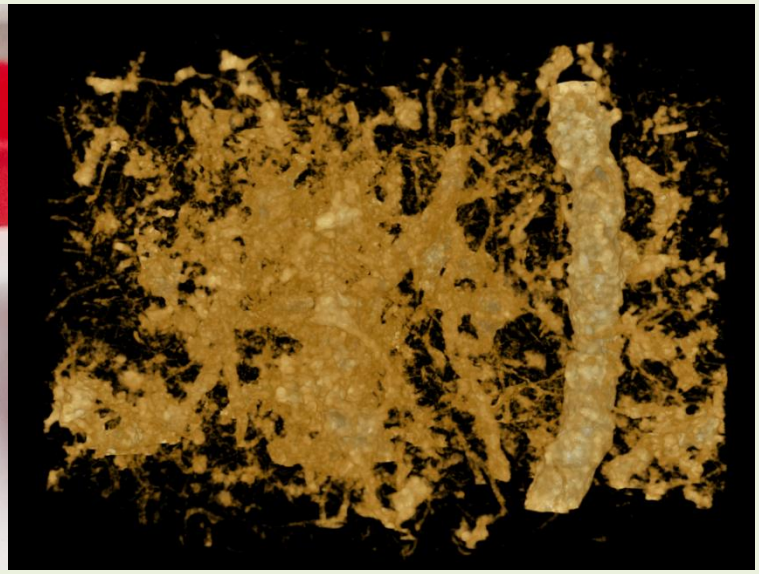
Linking structure and function

An example



95 undisturbed soil columns

X-ray imaging

Ks measurem.

SoilSpace project, NFR2013/668, PI: Attila Nemes

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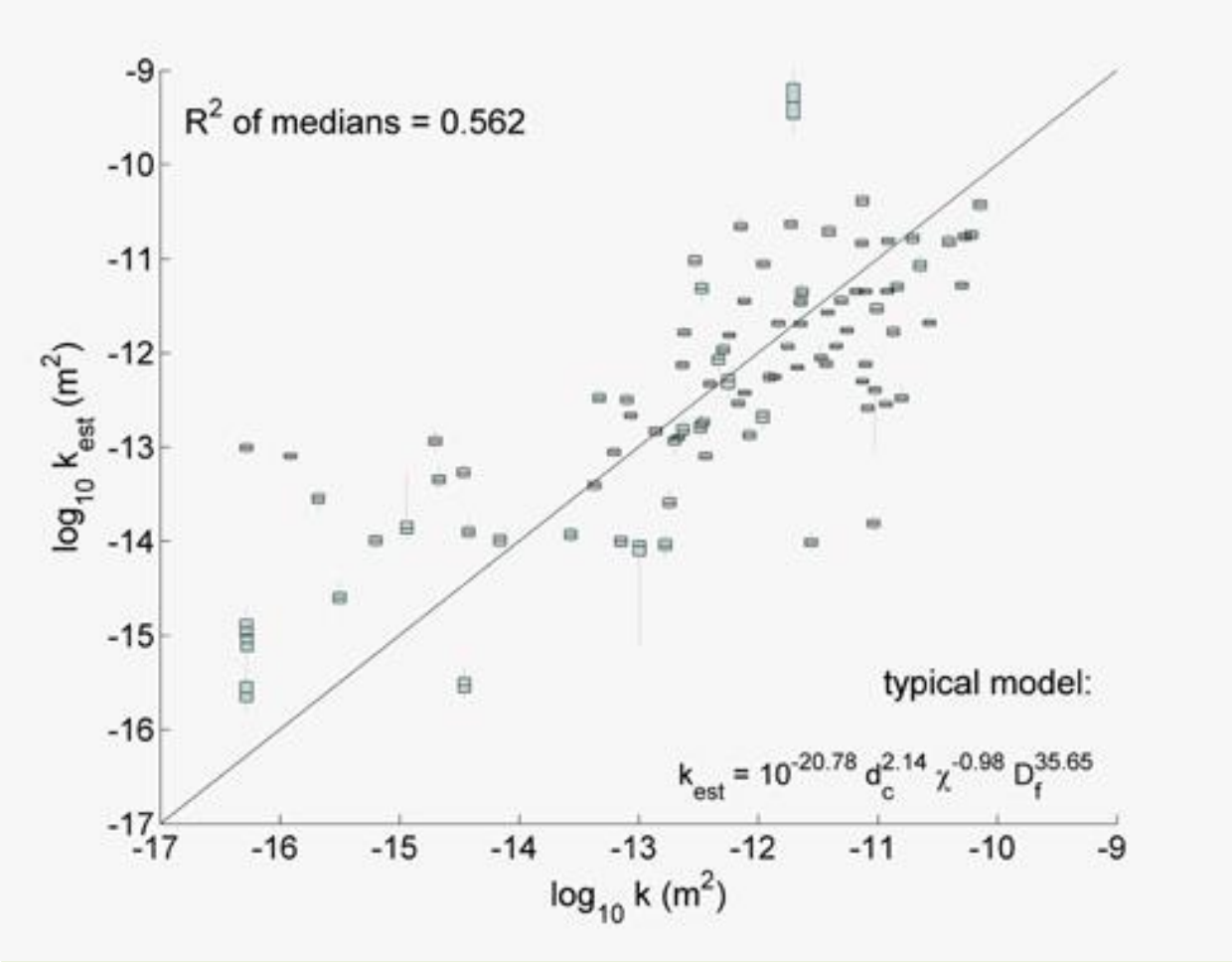

Predicting permeability from pore network properties

Linear, stepwise regression on log values of bootstrap samples

Out-Of-Bag validation

Most important predictors:

Critical pore diameter
Euler number
Fractal dimension

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Ok, this was quite promising…

But a PTF that requires X-ray imaging is a step forward albeit

Sample and image acquisition and analyses takes time and effort

Another step forward would it be to find proxy variables

That allow PTFs for soil structure

In the optimal case these would be derivable from
remote sensing data or digital soil maps
or similar

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Suitable proxy variables for PTFs for soil structure require

Research on agents that are responsible for soil structural

Properties, e.g. the critical pore diameter.

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What are candidates for such agents?

It is known that at least 10% of clay are needed for a stable structure
(but that does not mean that other structural features are homogeneously distributed, e.g. soil water repellency)

Prime candidates for such agents are soil macrofauna like earthworms

or vegetation (roots and their exudates)

In turn these will be subject to variables like local climate, geology, etc..

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Why should proxy variables be derivable from
remote sensing data or digital (3D) soil maps
or similar?

Because scale matters and such maps deliver structural information

that can be used for upscaling!

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PTFs, structure and scale

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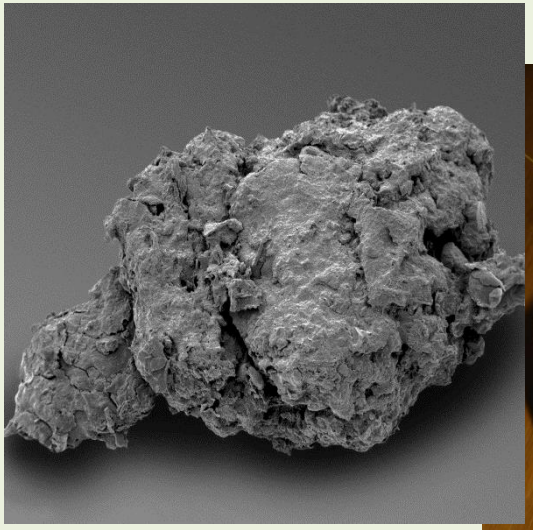

www.microped.uni-bremen.de

Different scale means **different structures and associated processes and functions**

Scale needs to be considered in PTFs or when applying them (see also Pachepsky and Hill, 2017)

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Small columns scale is the classical scale at which PTFs are derived

Why?
Because at this scale we can measure the soil properties relatively easily!!

Possible future developments

Development of PTFs at larger scales?

Upscaling of PTFs by including structural information?

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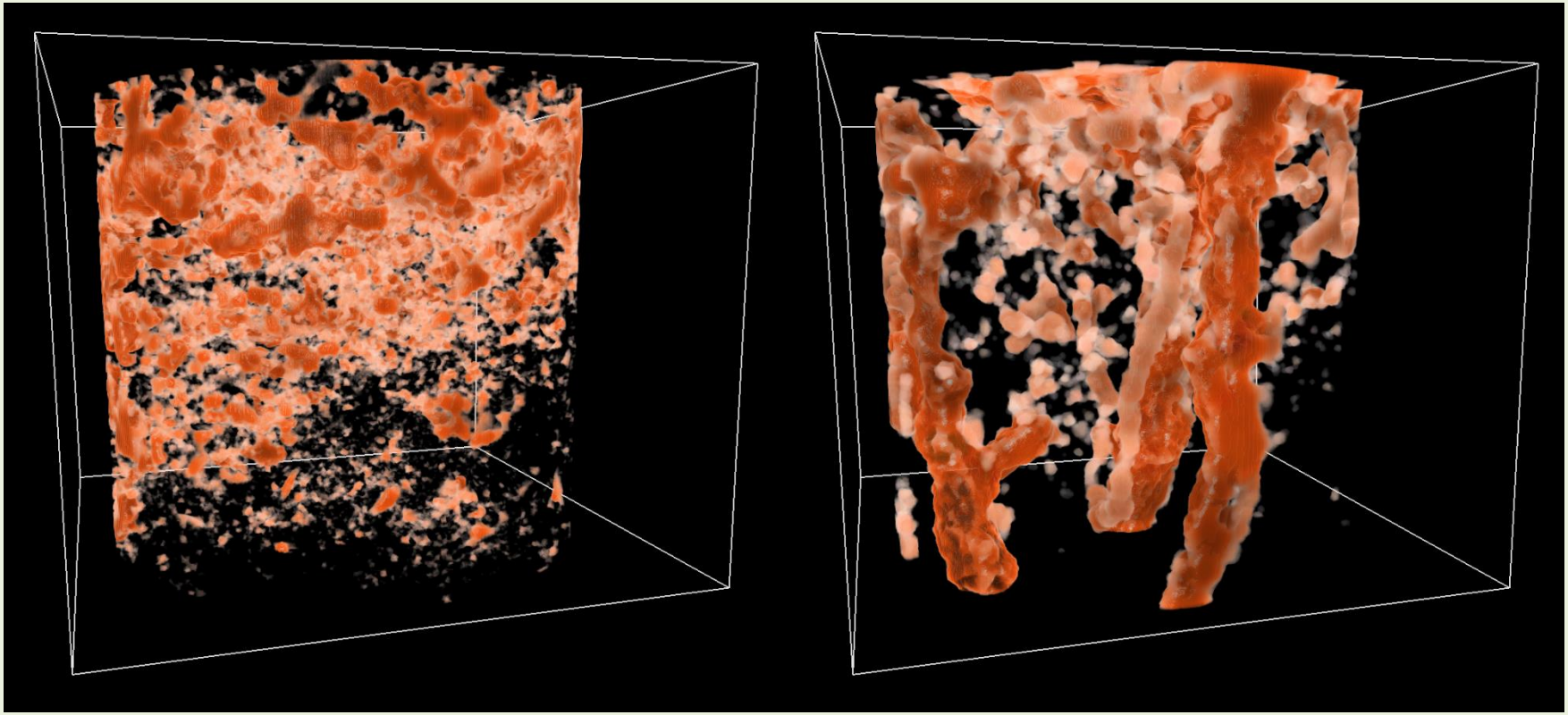
Rainer´s dilemma



Soil macropore structure of an individual column

in June 2013 in September 2013

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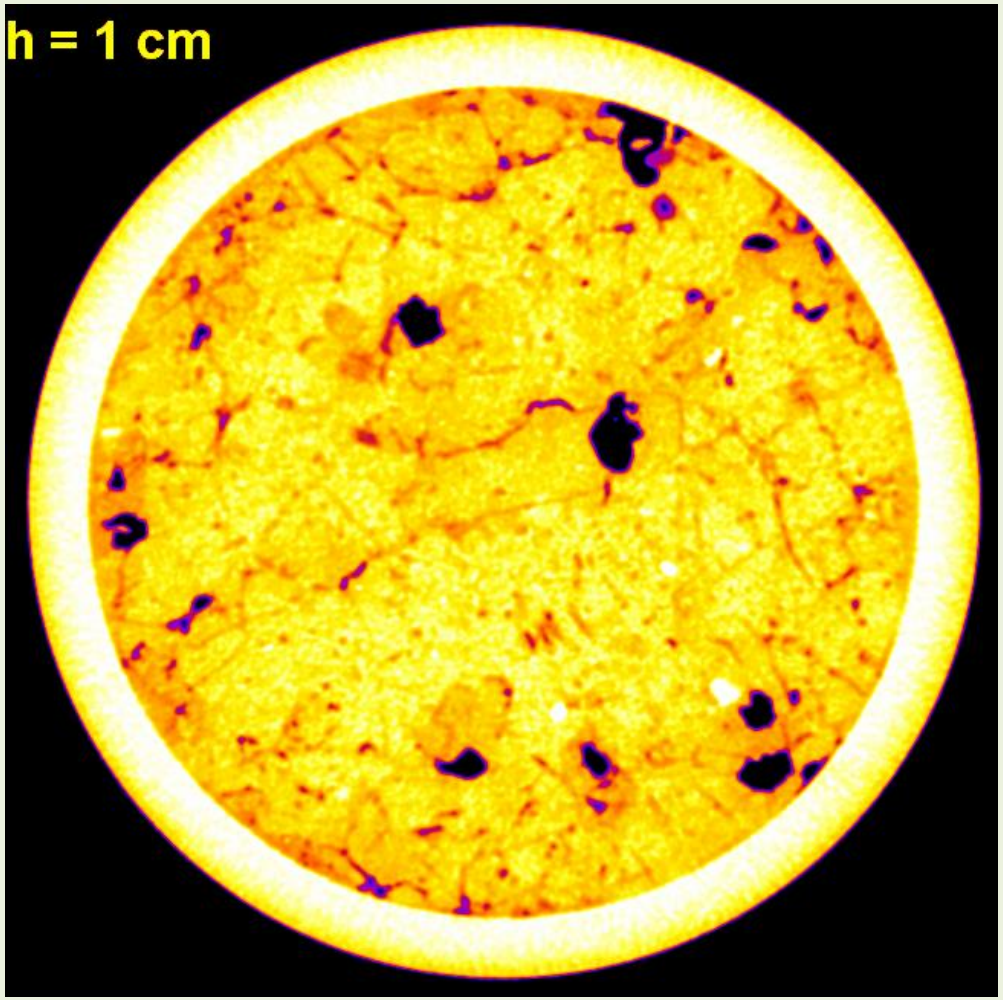

Time-series
from a 3-D water retention experiments…

Large pores are growing on the expense of smaller ones during drying

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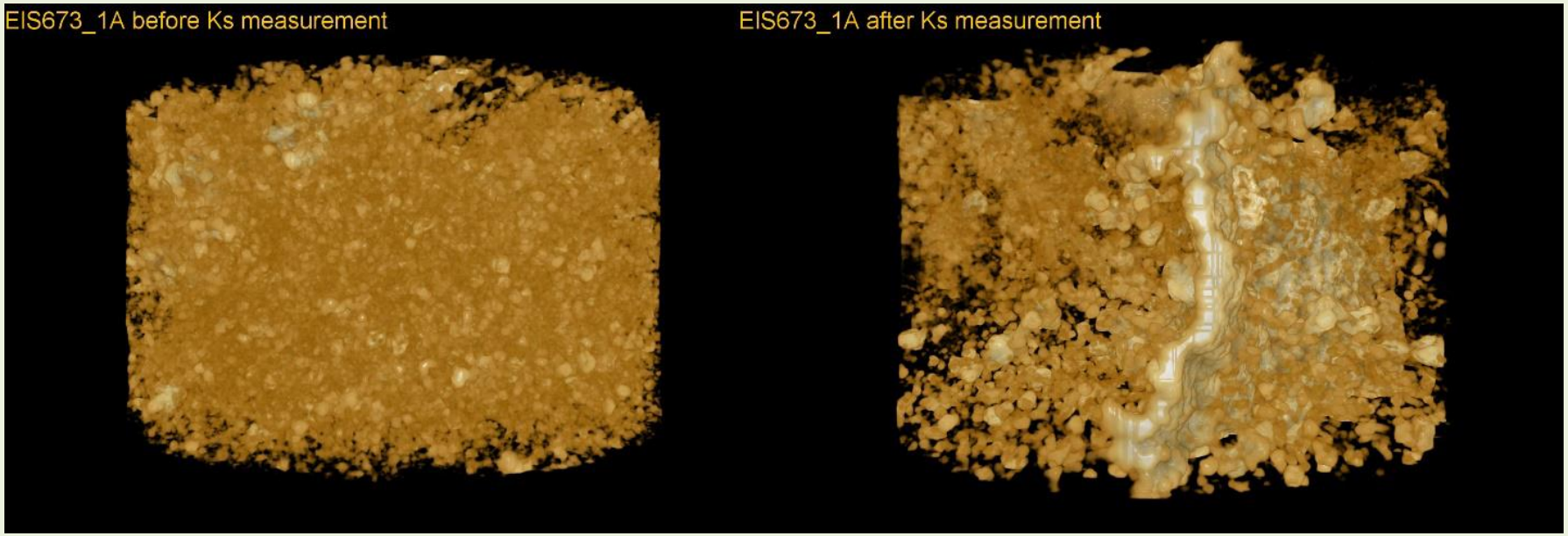
Worst case example of an imaged pore network before and after K_{sat} measurement



SoilSpace project, NFR2013/668, PI: Attila Nemes

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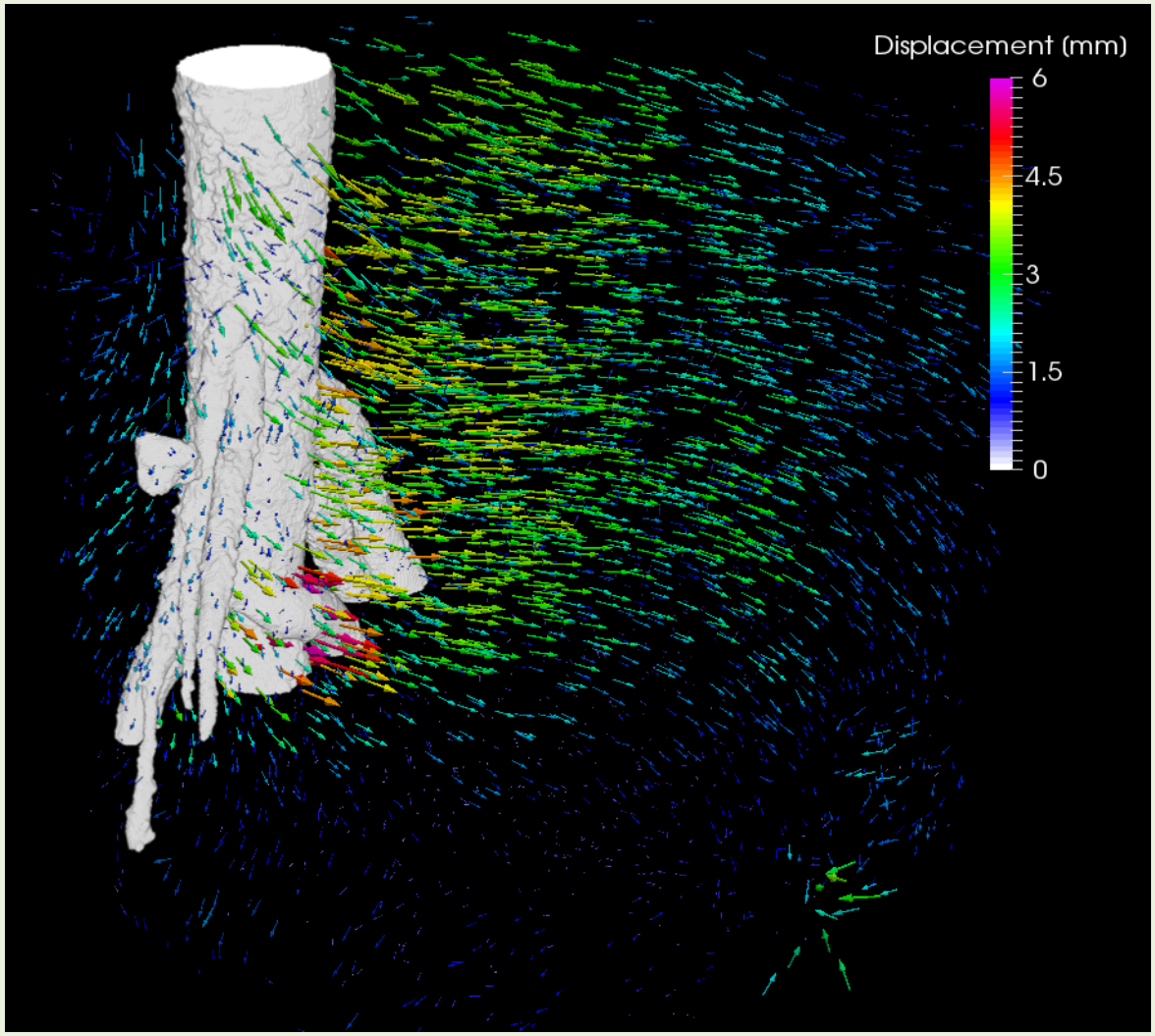

Soil matrix displacement caused by a growing dandelion root

Courtesy to Steffen Schlüter

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Soil structure seems to be not overly time-stable!!

… which poses a large challenge for the

Development of future PTFs!

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Conclusion

By using non-invasive imaging techniques it becomes possible to investigate relationships between soil structure and soil function in unprecedented detail

Development of PTFs including structural information that are applicable at a global scale is related with large challenges,

i.e. i) how to upscale and ground-truth cm-scale relationships
ii) how to deal with the temporal evolution of soil structure

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Thank you for your attention!