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JÜLICH
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Non-invasive characterization of biochar using geoelectrical measurements – A laboratory study

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Franz-Hubert Haegel[1], Odilia Esser[1], Nils Borchard[1], Nicolai D. Jablonowski[2], Santanu Mukherjee[1], Andreas Linden[1], Egon Zimmermann[3], Johan Alexander Huisman[1], Harry Vereecken[1]

[1] *Institute of Bio- und Geosciences – IBG-3 Agrosphere*
[2] *Institute of Bio- und Geosciences – IBG-2 Plant Sciences*
[3] *Central Institute of Engineering, Electronics and Analytics – ZEA-2 Systems of Electronics*

Task

Providing methods for monitoring the influence of biochar on soil properties at field scale

Idea

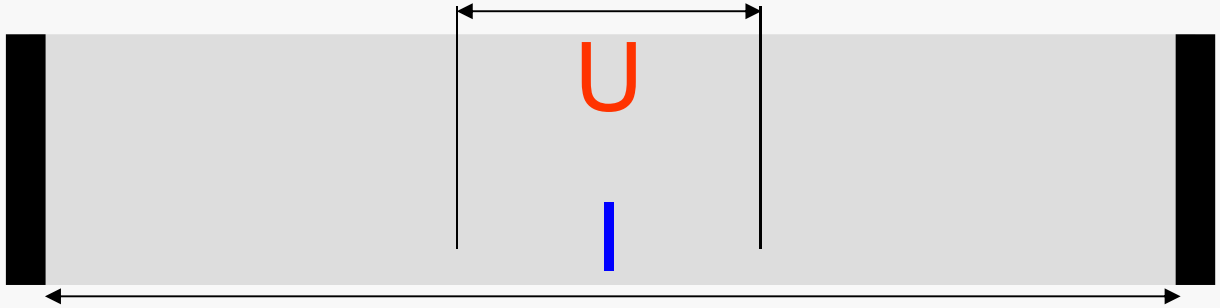
Using geoelectrical methods which are well known for field scale application in ore exploration, but recently also in environmental and hydrological research

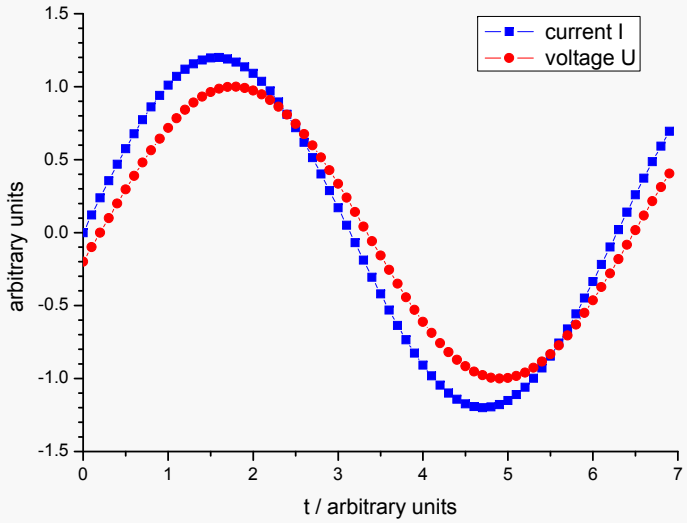
Objective of this work

Demonstration of the suitability of spectral induced polarization (SIP) and electrical impedance tomography (EIT) for the investigation of biochars

Spectral Induced Polarization (SIP)

Determination of the impedance Z and the complex electrical resistivity ρ*

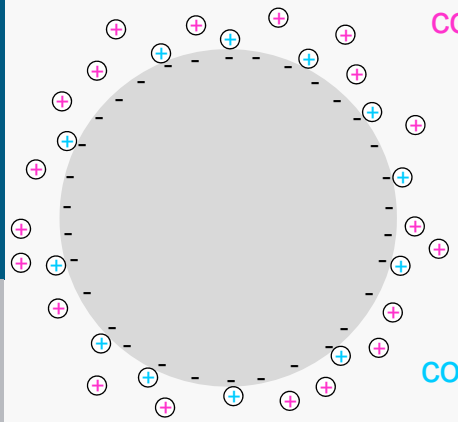




Polarizable media yield a phase shift between sinusoidal current and voltage.

$|\rho^*|$ and φ $\sigma^* = \sigma' + i\cdot\sigma'' = 1/\rho^*$

Polarization mechanisms

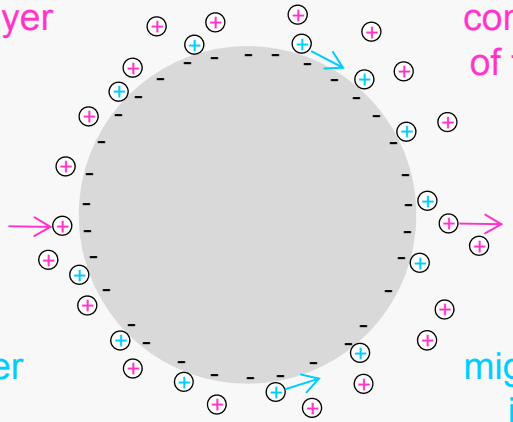


sand grain

excess charge
at the surface
of the grain

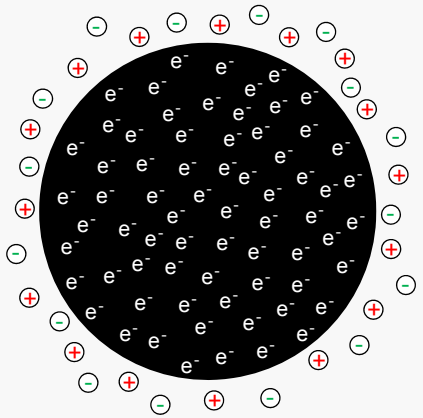
counter ions in the diffuse layer

counter ions in the Stern layer
adjacent to the surface



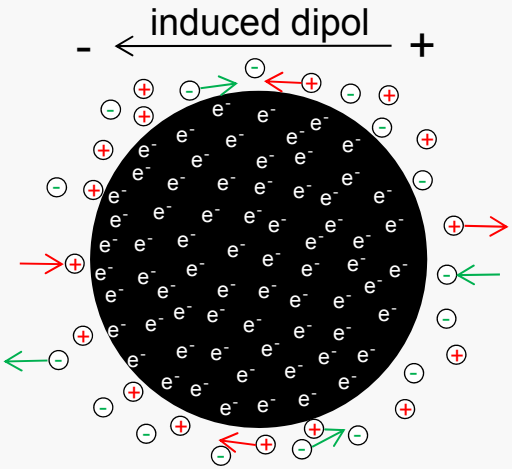
compression and dilation
of the diffuse layer (fast)

migration of the counter ions
in the Stern layer (slow)



graphite grain

mobile electrons
inside the grain

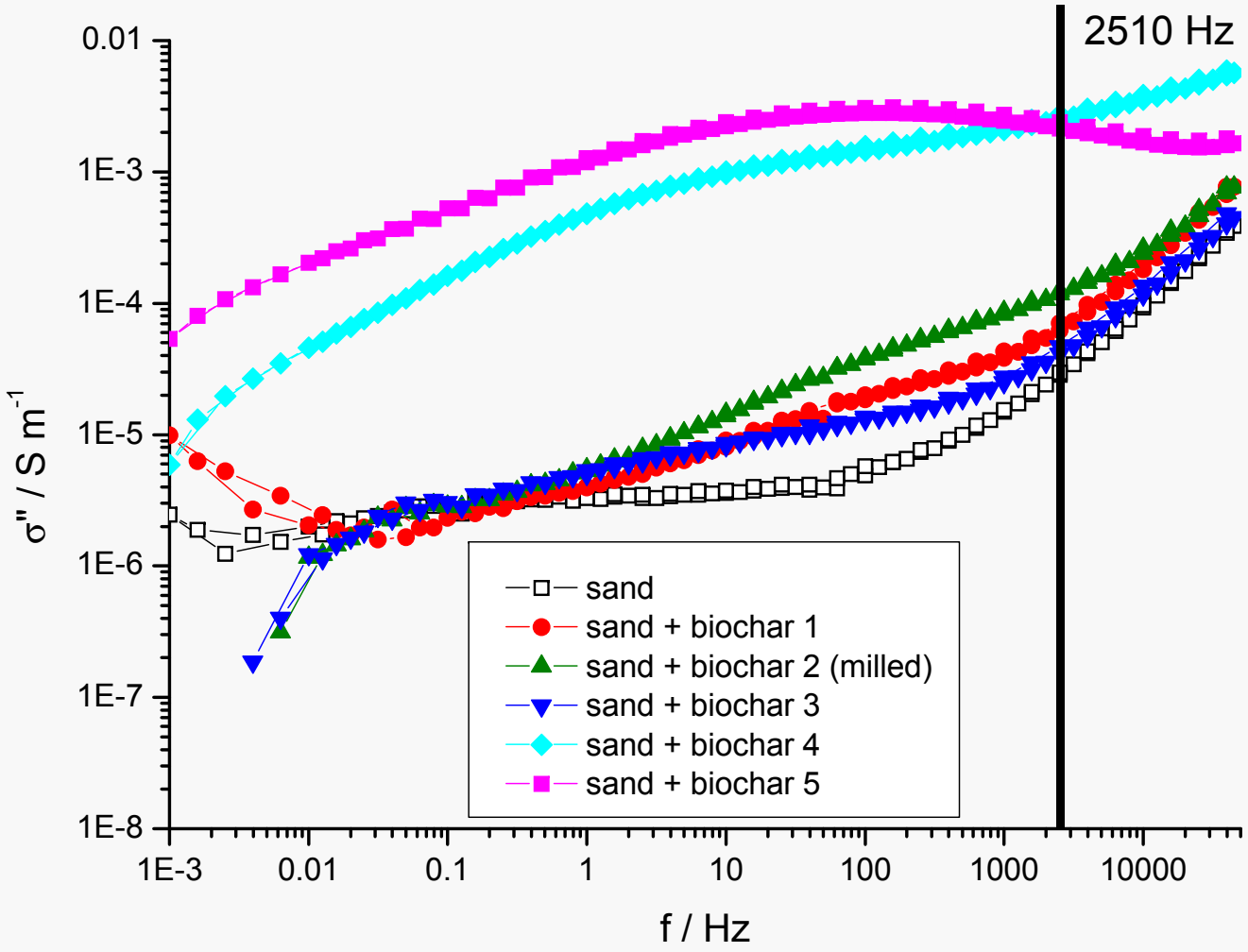


enrichment of electrons
at the positive side followed
by the redistribution
of ions around the particle
including the migration
of ions around the grain

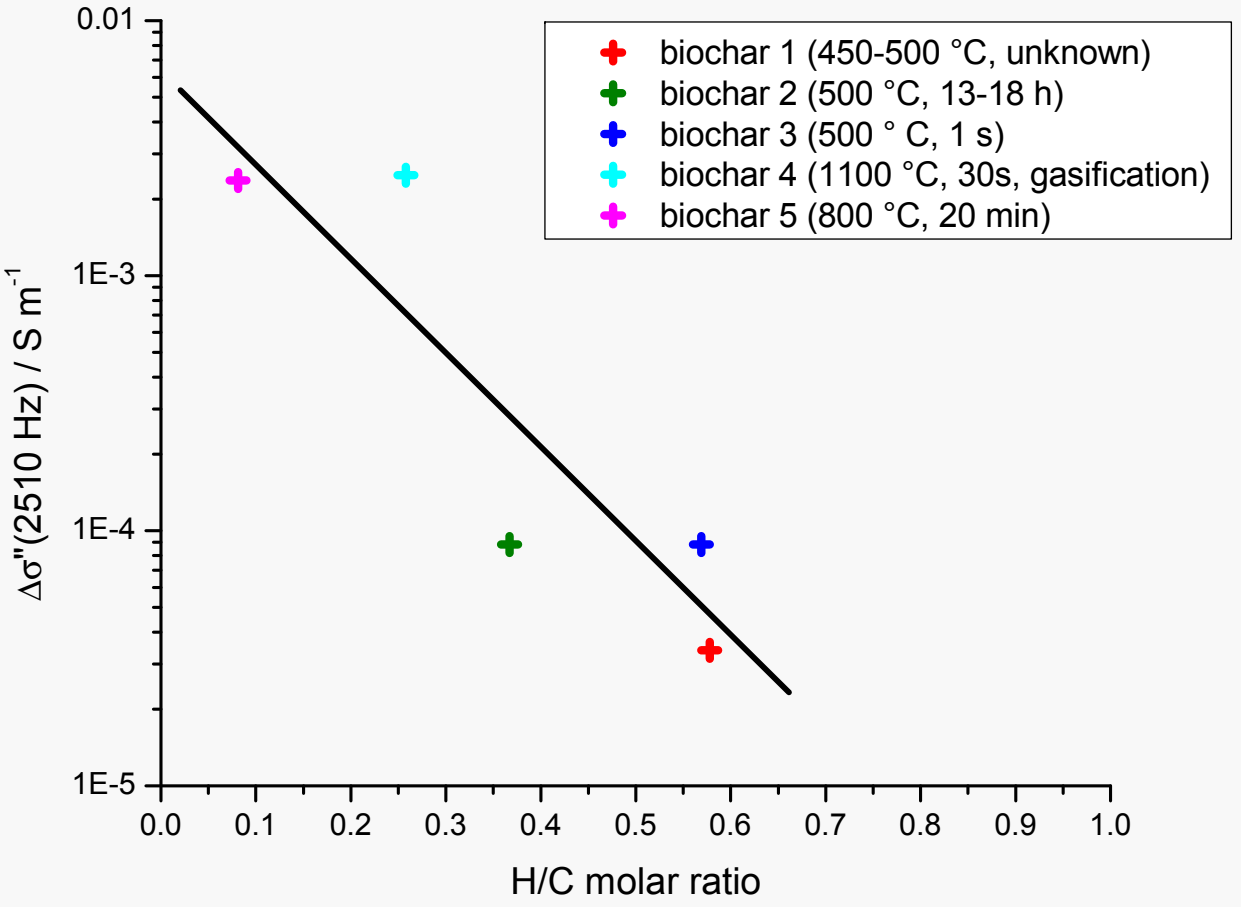
no external field

external field

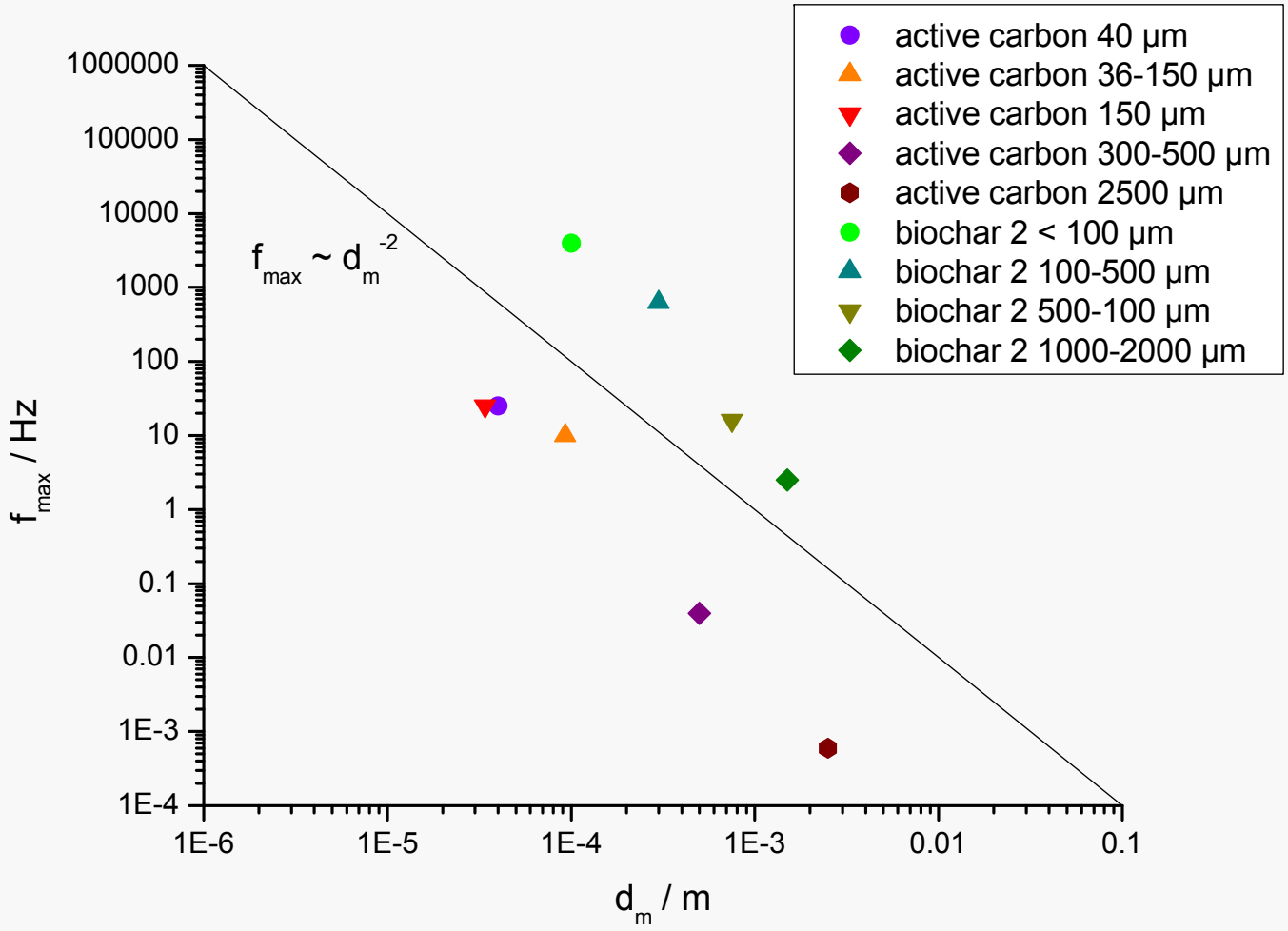
Imaginary part σ“ for several biochars (2 % w/w in sand)



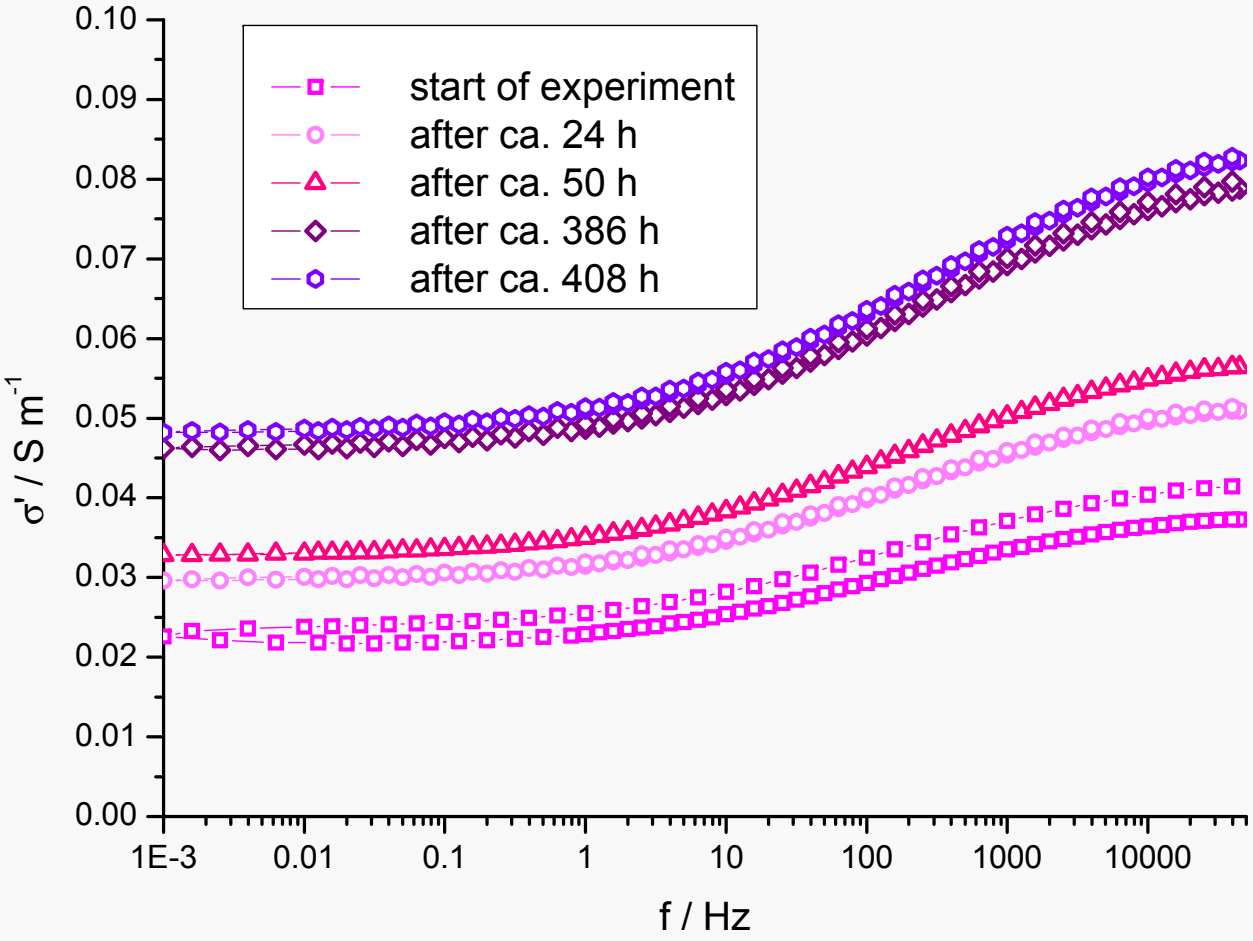
Correlation of hydrogen/carbon ratio and Δσ” at 2510 Hz



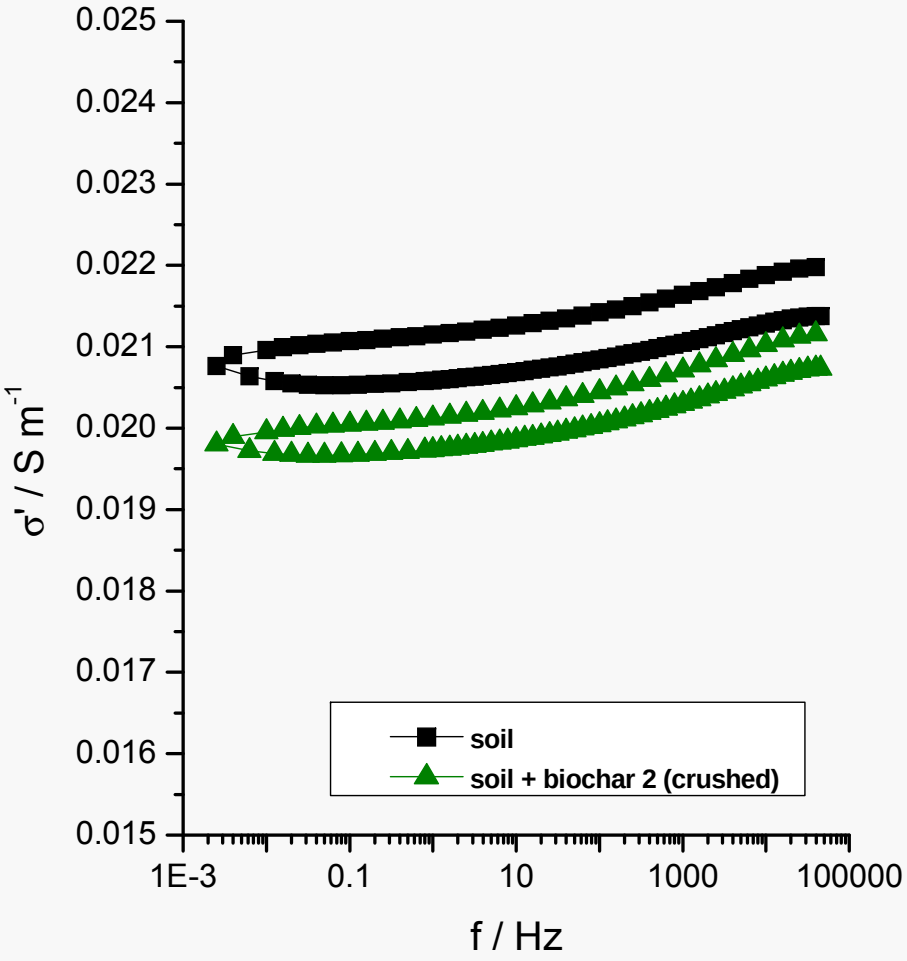
Size dependence of the maxima of σ“

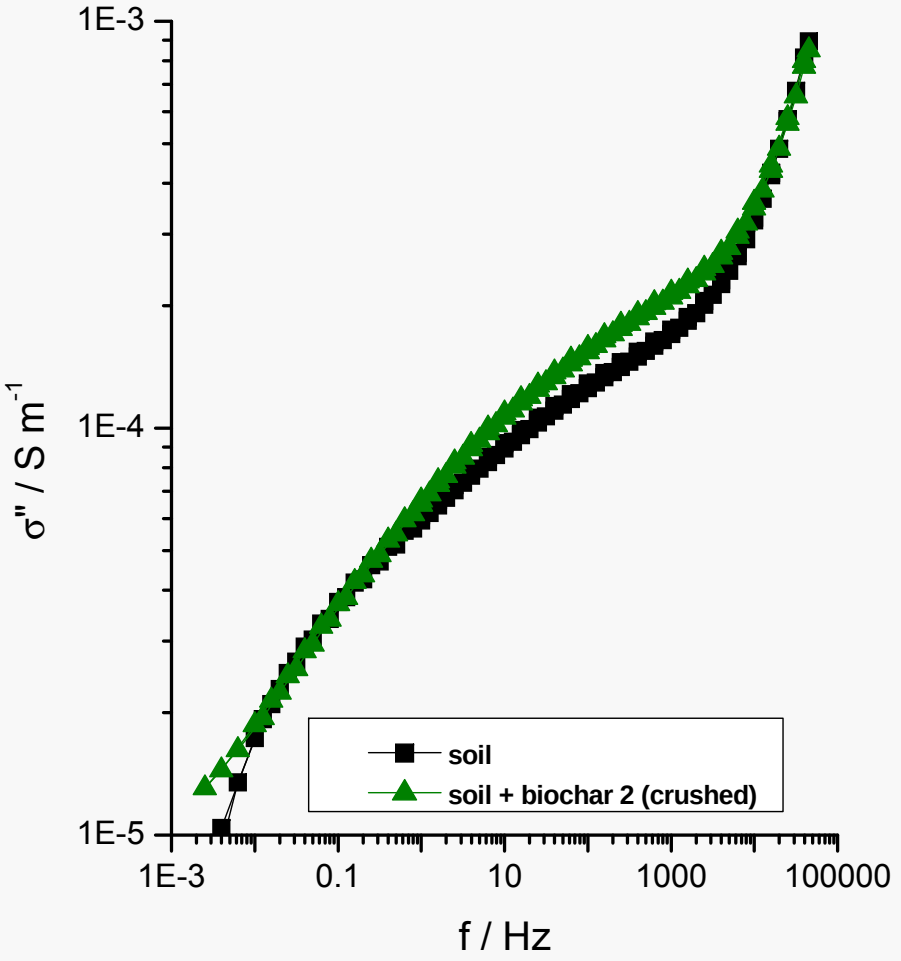


Time series of the real part σ' for biochar 5 in sand

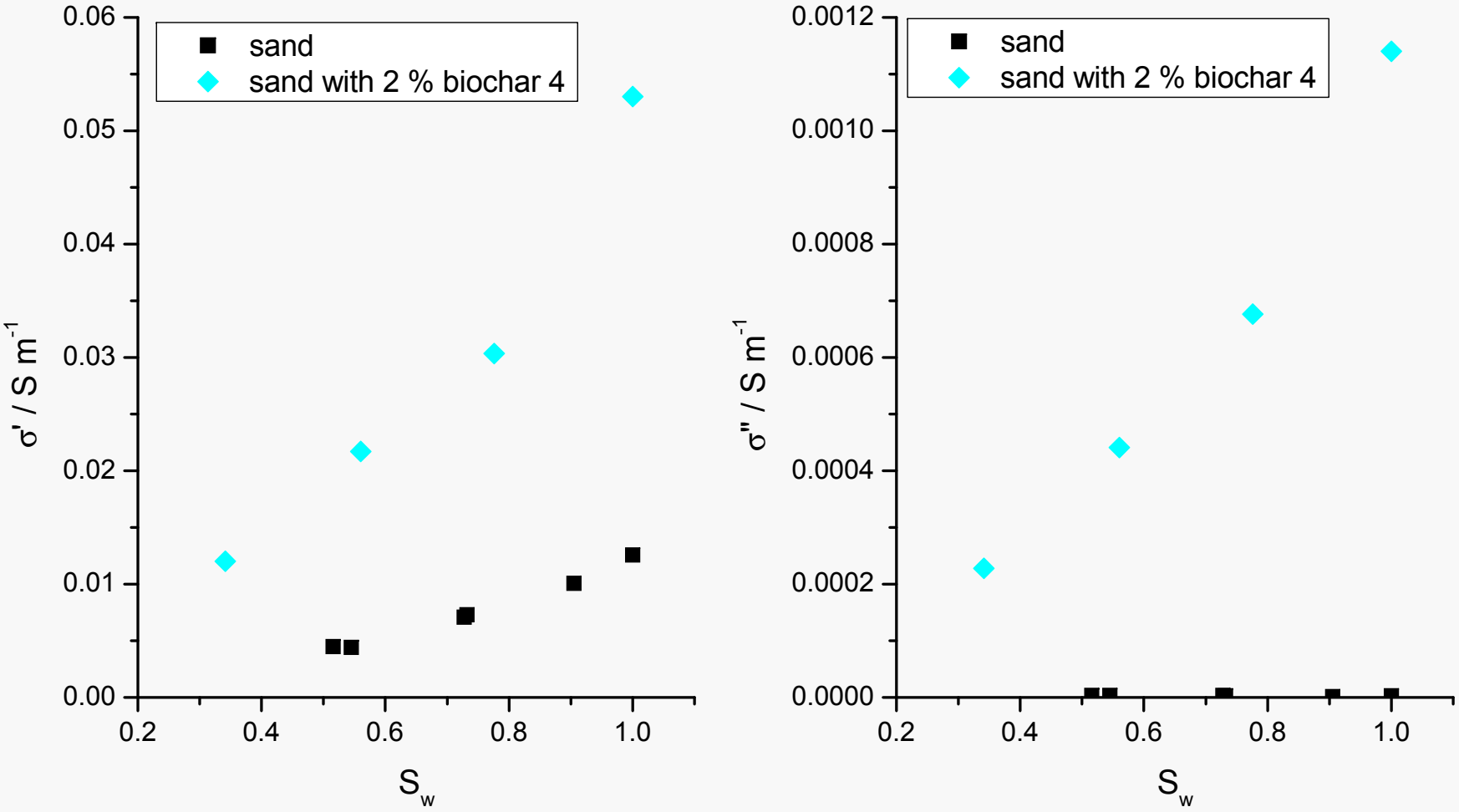


Spectra for 1.5 % crushed biochar 2 in a soil





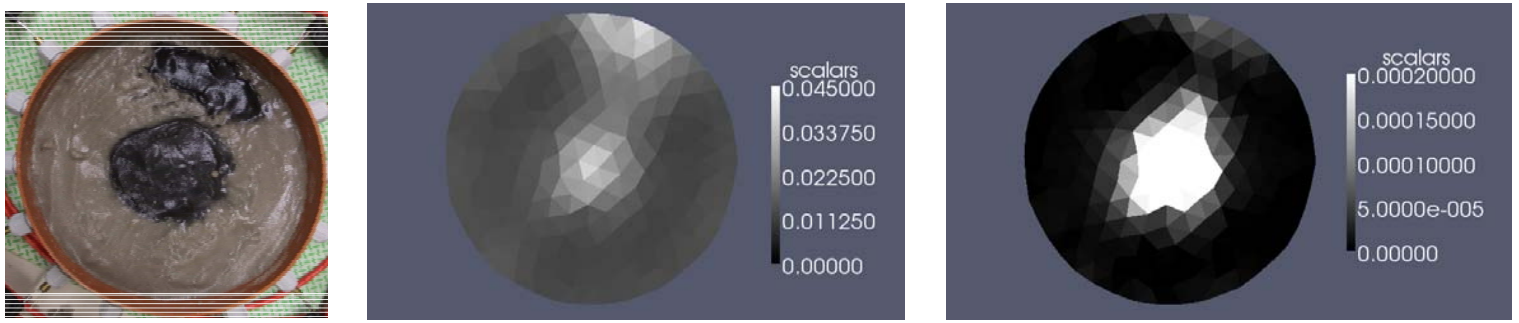
Values of σ‘ and σ“ at 10 Hz for different water saturation



Electrical Impedance Tomography

Based on the SIP signal, the local distribution of the complex electrical conductivity can be determined by multi-electrode arrays.

This imaging technique is called electrical impedance tomography (EIT)



Biochar 4 with high values of σ‘ and σ“ in the center and an active carbon with high σ‘ and low σ“ at the margin can well be detected and discriminated bei EIT.

Conclusions

The addition of biochars to soil yields

- an increase of the real part of the complex conductivity with time due to the release of ions
- an increase of the imaginary part of the complex conductivity depending on the chemical structure and the particle size

The complex conductivity of sand-biochar mixtures is dependent on the water saturation. Desaturation can well be determined.

Biochars can be localized by electrical impedance tomography (EIT).

EIT seems to be suitable for monitoring the influence of biochar on the ion and the water content in soil.

EIT may be used to investigate the potential use of biochar for optimizing the effectivity of fertilizer addition and irrigation.

Outlook

- Investigation on further biochars
- Studies on the interaction with compost, digestates and fertilizer
- Scale-up of EIT in the laboratory
- EIT on processes (evaporation, irrigation, fertilizing) in the lab
- EIT on field scale

Partners for cooperation are welcome!

Thanks to all colleagues who contributed to this work
and thanks to the audience for the attention.