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Hochfrequente Spektrale Induzierte Polarisation zur Charakterisierung von Permafrostböden

High-frequency induced polarization for the characterisation of permafrost soil

Jan Mudler, Andreas Hördt, Dennis Kreith, TU Braunschweig

Motivation

- Ice content is essential parameter in permafrost research
- Geophysical methods based on combination (DC resistivity and seismics)
- Potential of HFIP to estimate ice content

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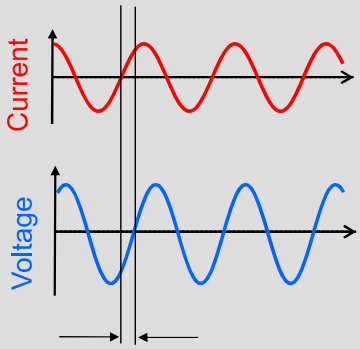
High-frequency induced polarisation



Phase shift

1Hz < f < 230 kHz

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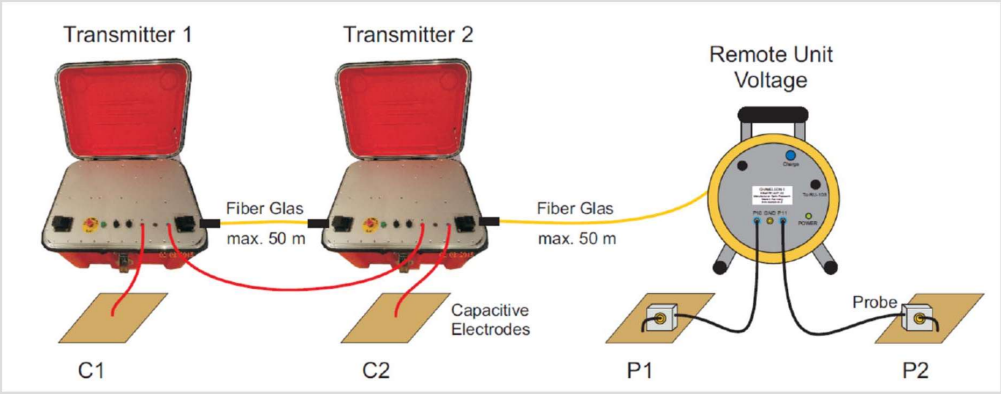
The Chameleon II equipment



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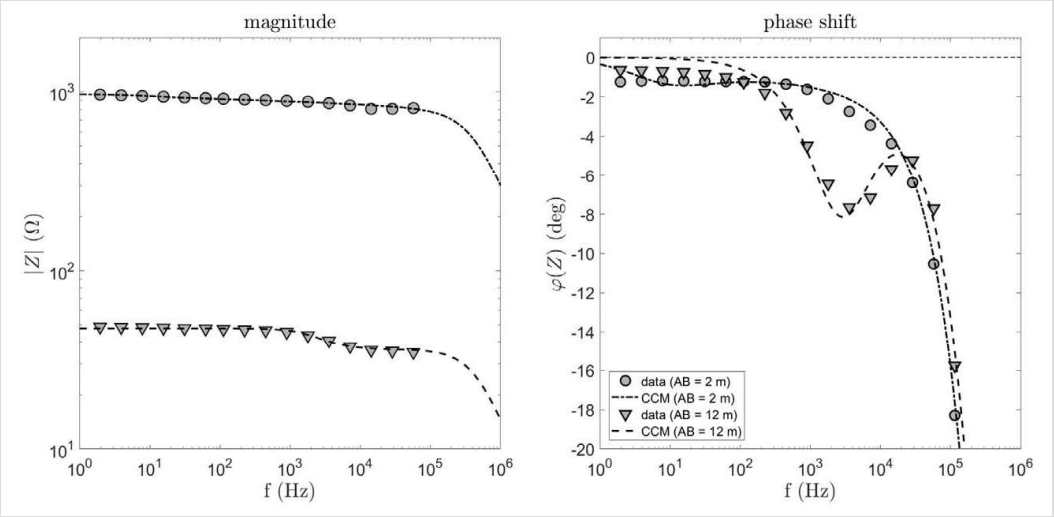
Measured data



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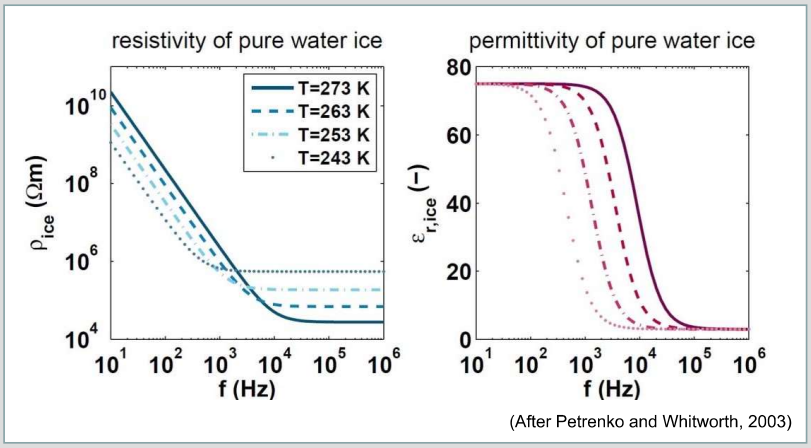
Electrical permittivity of ice



(After Petrenko and Whitworth, 2003)

$$\varepsilon_r^* = \varepsilon_{HF} + \frac{\varepsilon_{DC} - \varepsilon_{HF}}{1 + (i\omega\tau)} + \frac{1}{i\omega\varepsilon_0\rho_{DC}}$$

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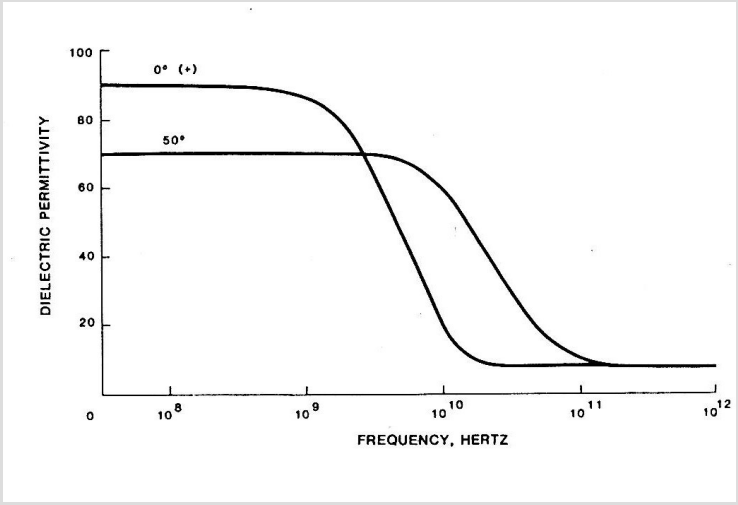
Electrical permittivity of fluid water



Eisenberg and Kauzmann, 1969

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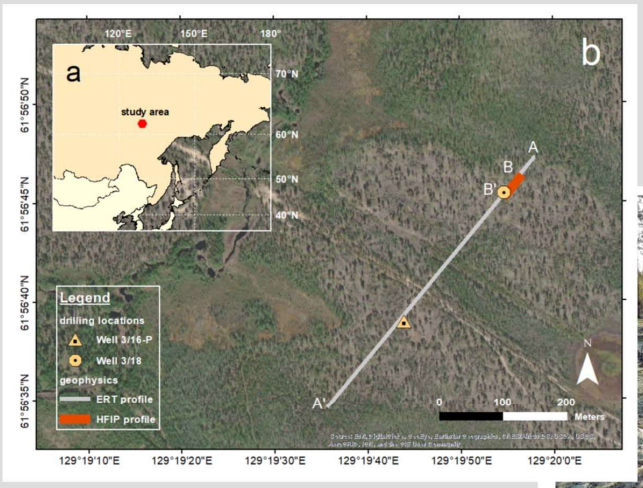
Survey area: Shestakovska River, Yakutia



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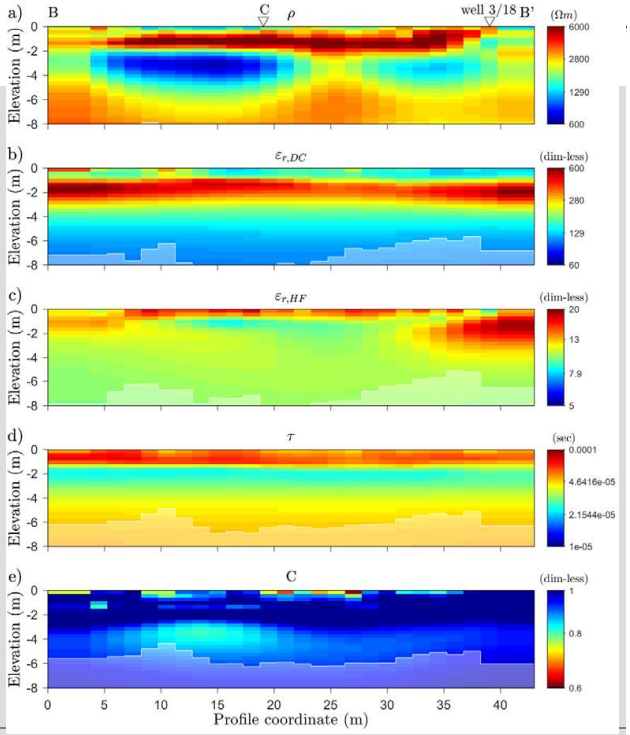
Results, 2D inversion

$$\varepsilon_r^* = \varepsilon_{HF} + \frac{\varepsilon_{DC} - \varepsilon_{HF}}{1 + (i\omega\tau)^c} + \frac{1}{i\omega\varepsilon_0\rho_{DC}}$$

Cole-Cole model (CC)



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Ice content estimation

Electric conductivity of ice-containing material (Zorin and Ageev, 2017)

$$\tilde{\sigma}_b^k(\omega) = (1-\alpha)\,\tilde{\sigma}_m^k(\omega) + \alpha\,\tilde{\sigma}_i^k(\omega)$$

α = ice content

k = structural parameter

σ_i = electrical conductivity of ice:

$$\tilde{\sigma}_i(\omega) = \sigma_{i,DC} + i\omega\varepsilon_0\left(\varepsilon_{i,HF} + \frac{\varepsilon_{i,DC} - \varepsilon_{i,HF}}{1 + i\omega\tau_i}\right)$$

σ_m = electrical conductivity of „matrix“ (=non-ice)

$$\tilde{\sigma}_m(\omega) = \sigma_m + i\omega\varepsilon_0\varepsilon_m$$

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Ice content estimation

Remember: from 2-D inversion (CC)

$$\varepsilon_r^* = \varepsilon_{HF} + \frac{\varepsilon_{DC} - \varepsilon_{HF}}{1 + (i\omega\tau)^c} + \frac{1}{i\omega\varepsilon_0\rho_{DC}}$$

Zorin-Ageev model (ZA)

$$\tilde{\sigma}_b^k(\omega) = (1-\alpha)\,\tilde{\sigma}_m^k(\omega) + \alpha\,\tilde{\sigma}_i^k(\omega)$$

Remember: $\sigma_{eff}^*(\omega) = i\omega\varepsilon_0\varepsilon_{r,eff}^*(\omega)$

Inversion:

Find parameters of ZA-model to fit CC-model
underdetermined: Fix 3 known parameters of pure ice → 5 parameters remain

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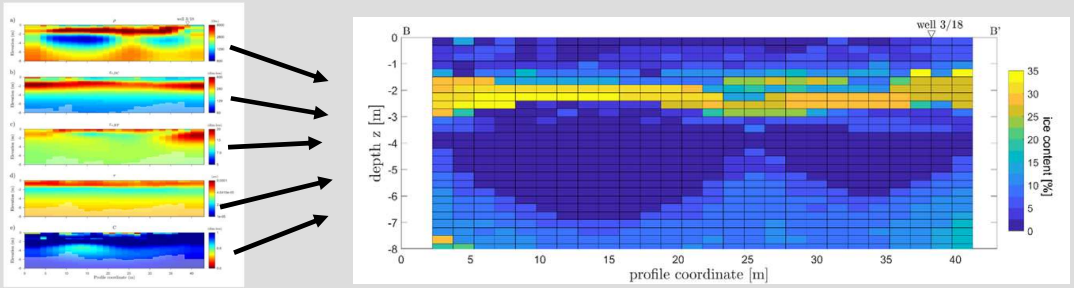
Results from Shestakovska River



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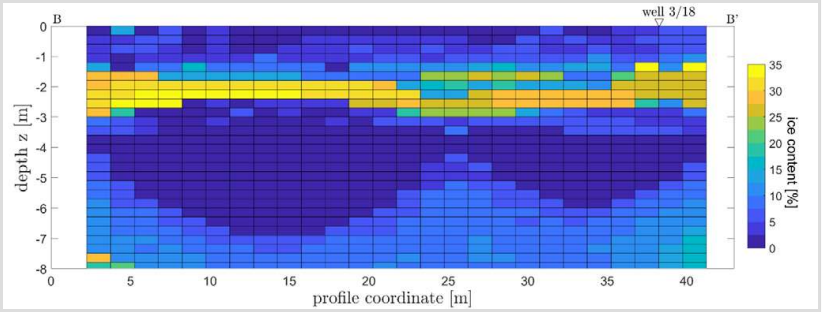
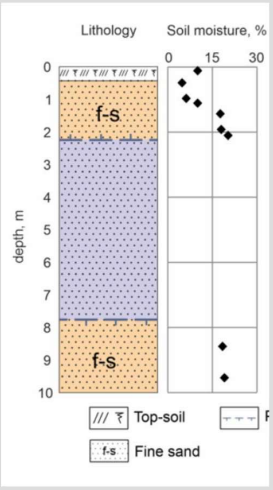
Results from Shestakovka site





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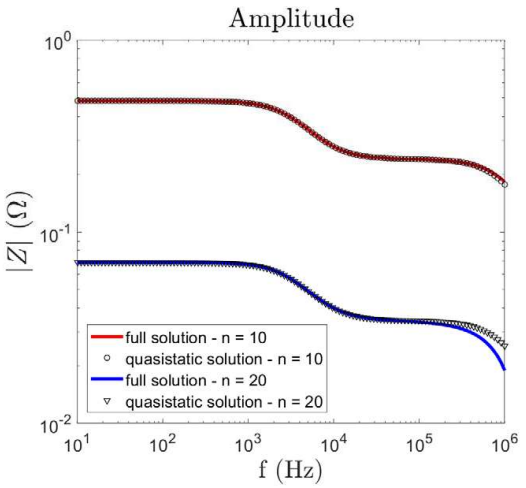
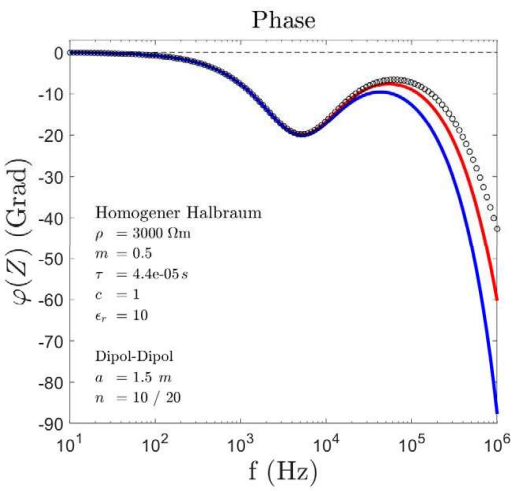
EM induction





(Simulation based on 1-D code by Ingemann-Nielsen et al., 2006)

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Conclusions

- Good data quality apparently even at 200 kHz
- Ice content estimation seems feasible with HFIP
- Induction not dominant

Outlook

- Investigate other petrophysical models
- Petrophysical model (Z+A) directly into inversion
- EM induction in 2-D inversion

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Acknowledgements

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