Non-invasive investigation of the saturated/unsaturated zone with magnetic resonance sounding – a field example at the testsite Fuhrberger Feld near Hannover, Germany

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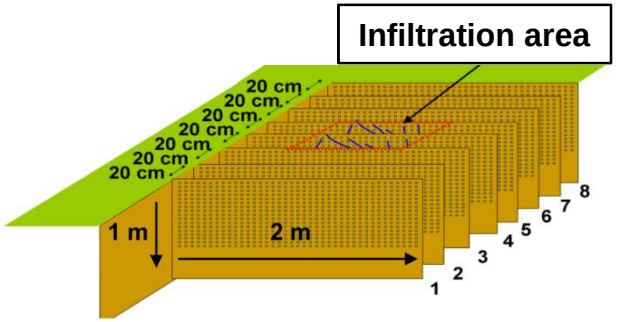
Institute of Soil Science

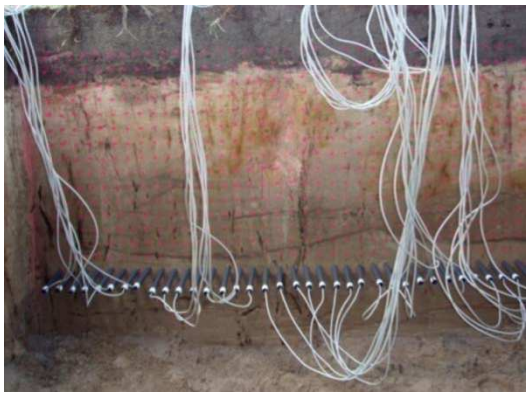
Soil physical investigations at the site Fuhrberger Feld

➢Material: Gley-podsol soil above eolian sand

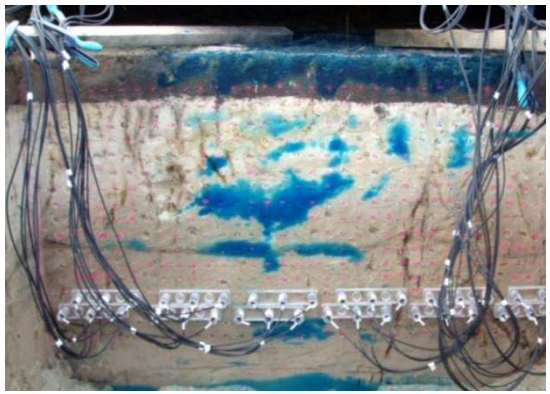
➢4D – electrical resistivit tomography (ERT) during infiltration experiment with a brillant blue tracer



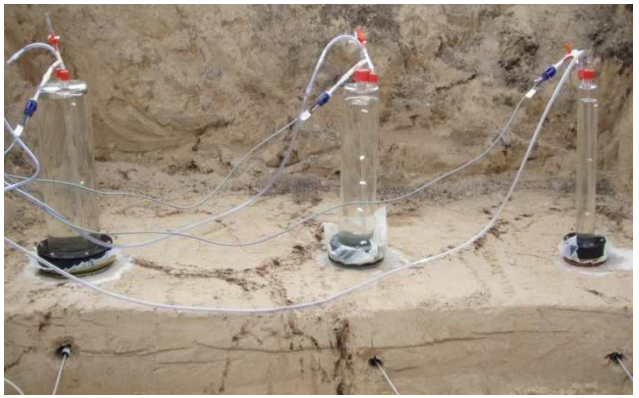
➢Slidewise trenching



➢TDR measurements after trenching

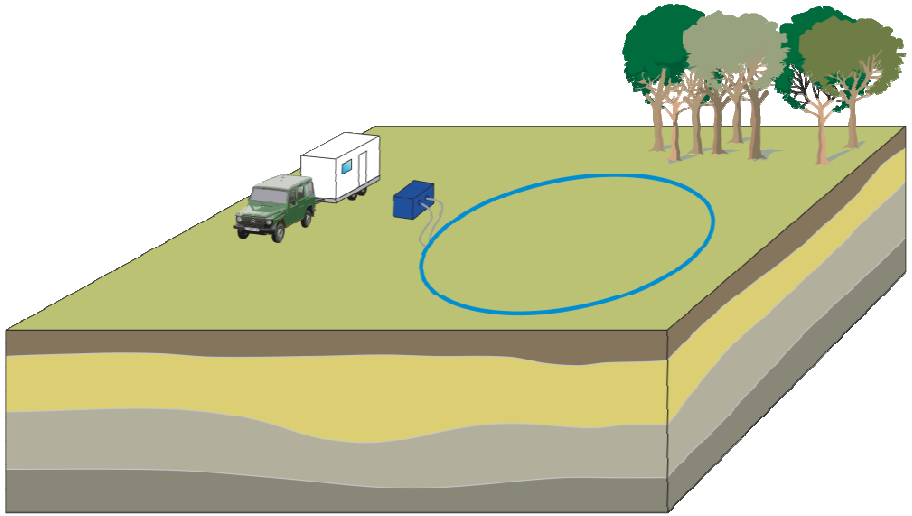


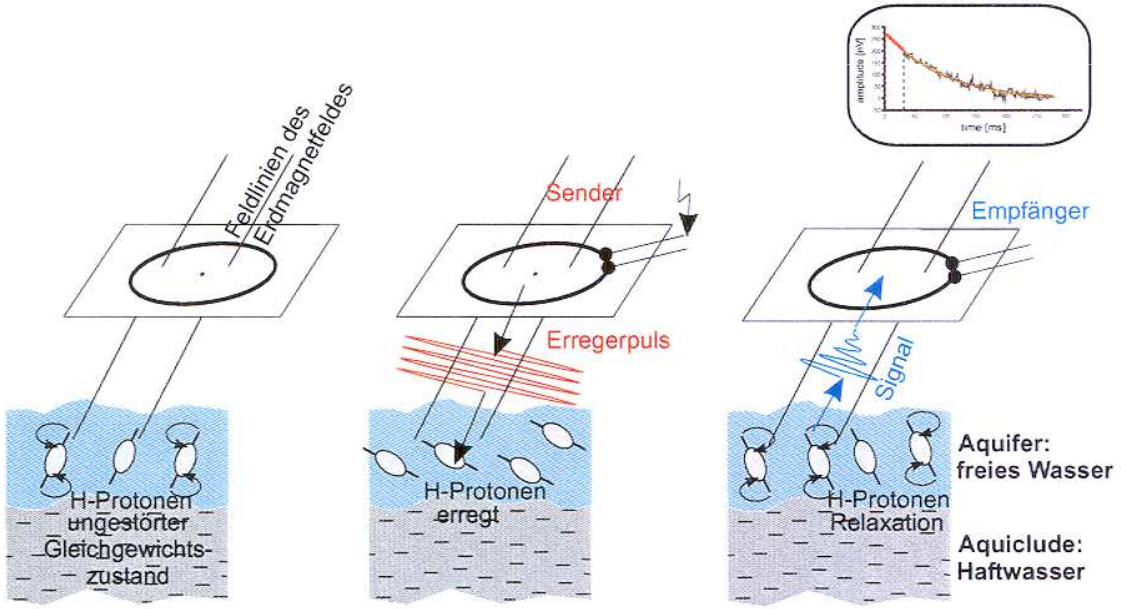
➢Tensiometer measurements after trenching



➢Tension infiltration measurements

Magnetic resonance sounding (MRS)





Large scale investigations with MRS

➢**Investigation of groundwater levels with large loops**

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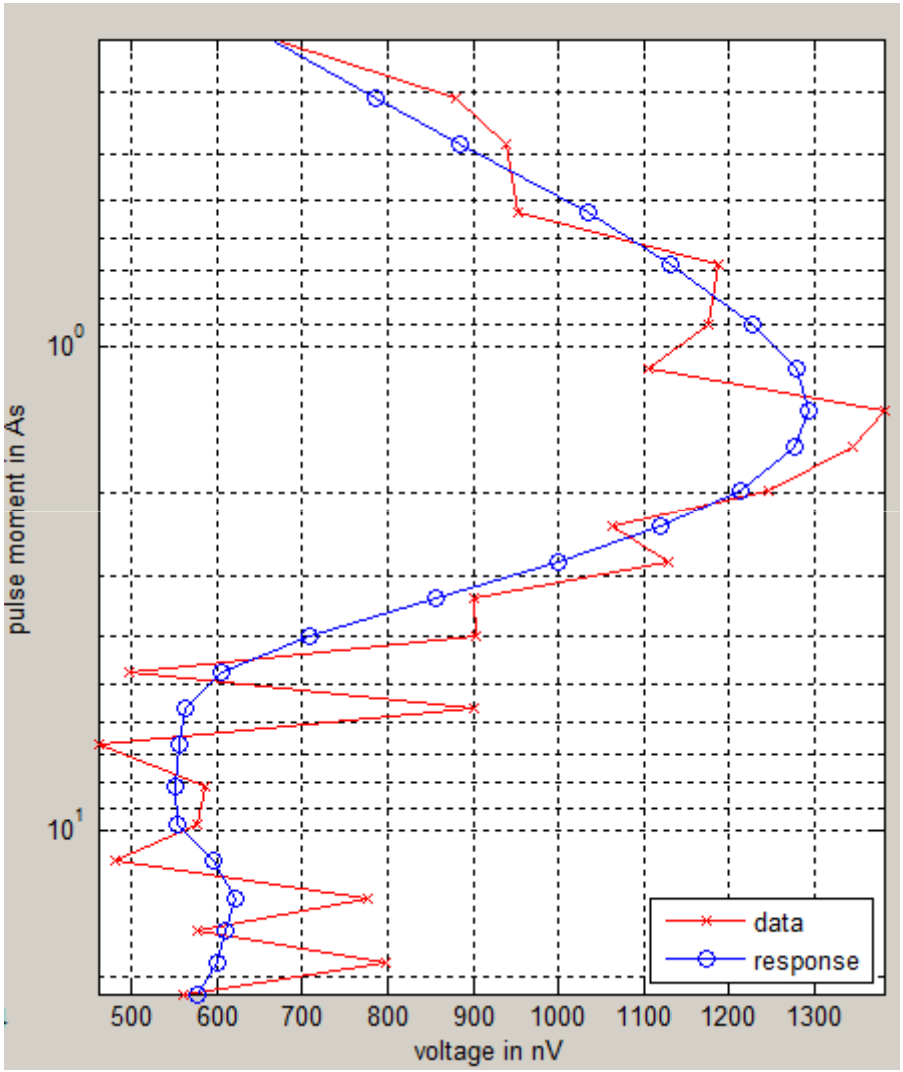
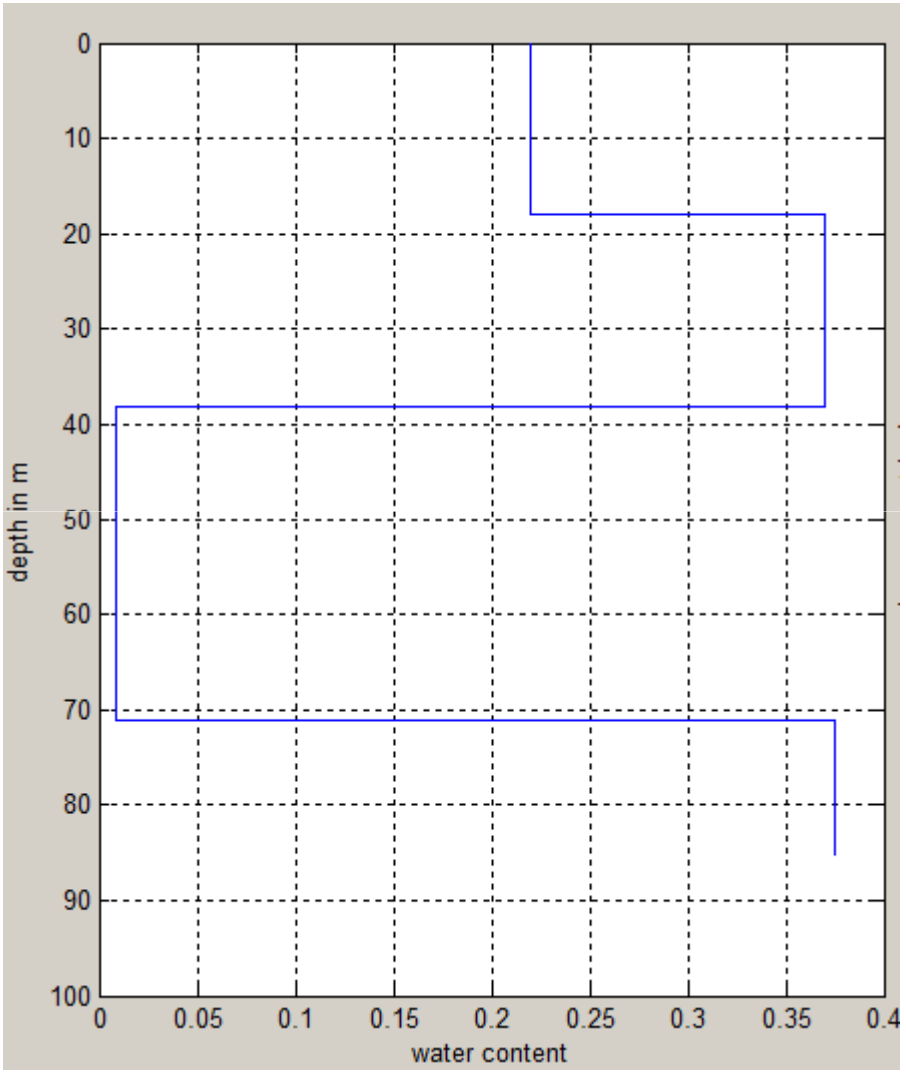


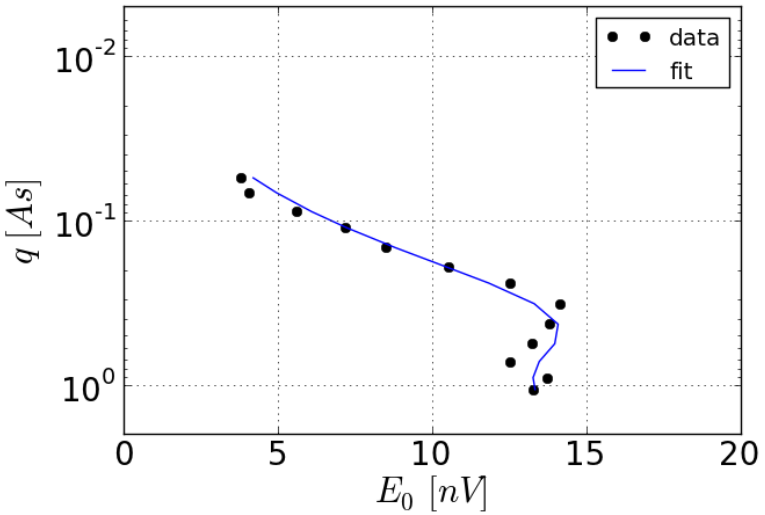


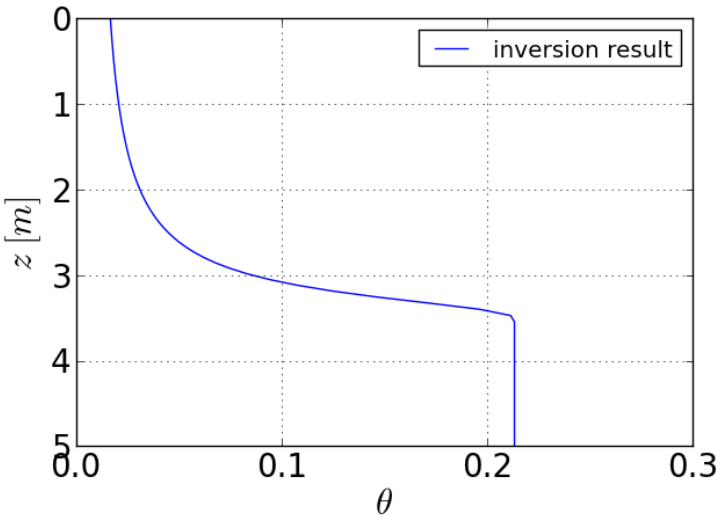
Small scale investigation with MRS

➢**Investigation of the unsaturated zone with small loops (and reference loops for EM noise cancellation)**

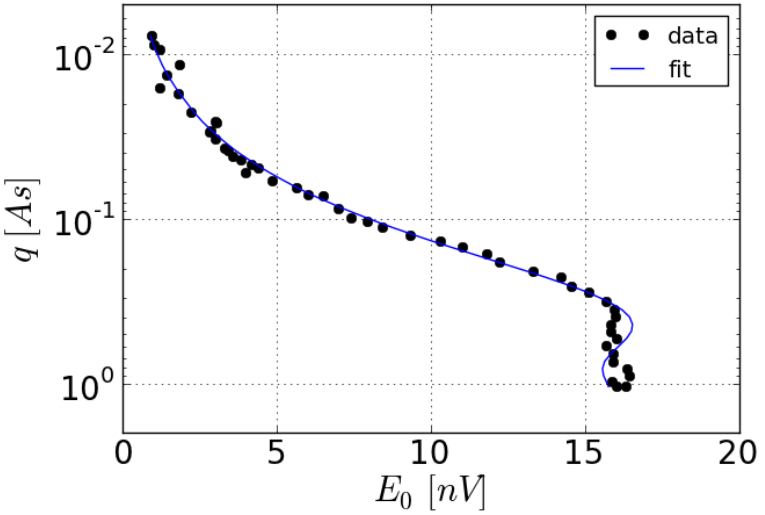
Small scale investigation with MRS

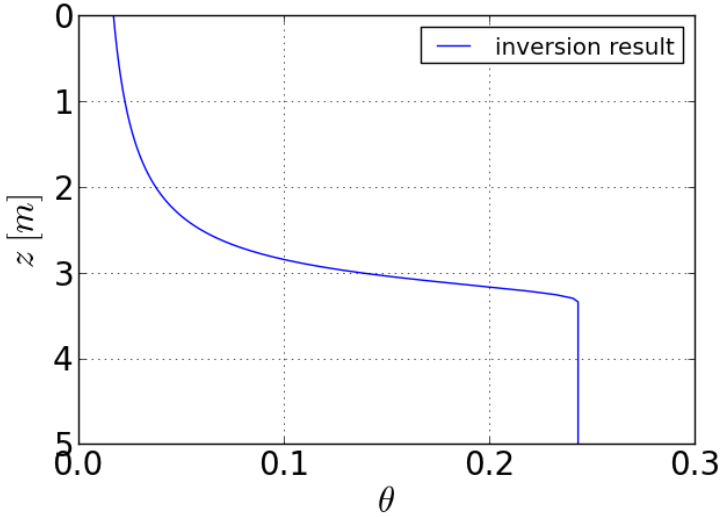
June 2011





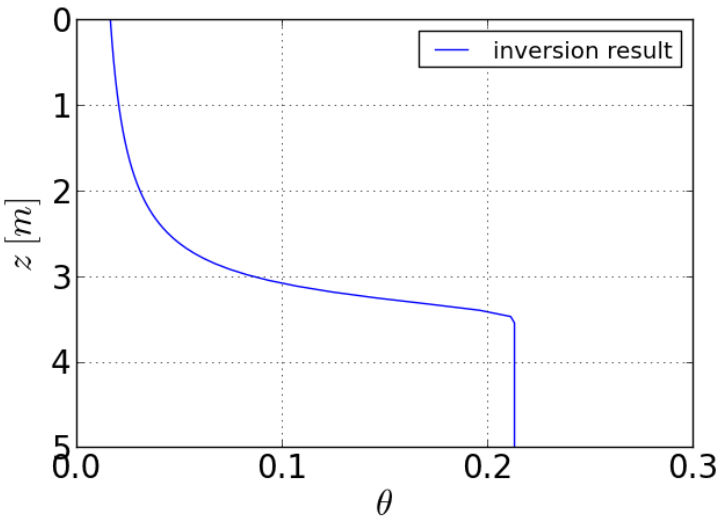
March 2012

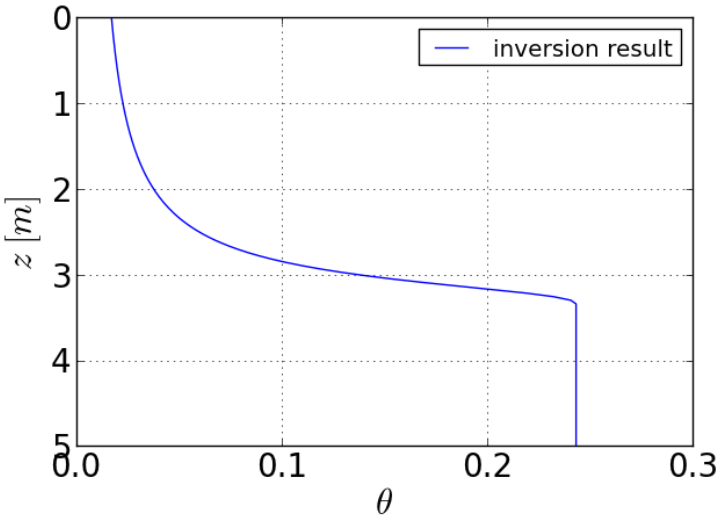




Small scale investigation with MRS - Results

Van Genuchten	June 2011	March 2012	Samples
Θ_S [%]	21.3 ± 0.5	24.3 ± 0.2	38
Θ_R [%]	0.8 ± 6.6	0.7 ± 1.3	0.7
n	2.2 ± 2.0	2.2 ± 0.4	2.8
z_{table} [m]	3.5 ± 0.4	3.3 ± 0.1	?
α [1/cm]	0.04	0.04	0.04



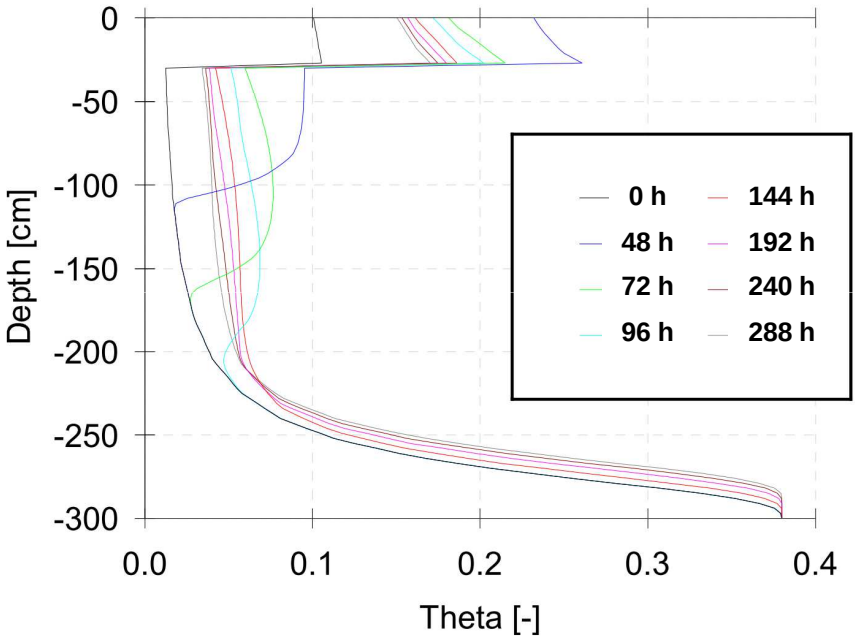


MRS forward modeling: Simulation of monitoring scenarios

➢**Rainfall event:**

•duration: 48 h
•Precipitation: 2 mm/h
•total infiltrated water amount: 96 mm
•Bottom boundary condition: zero water flux

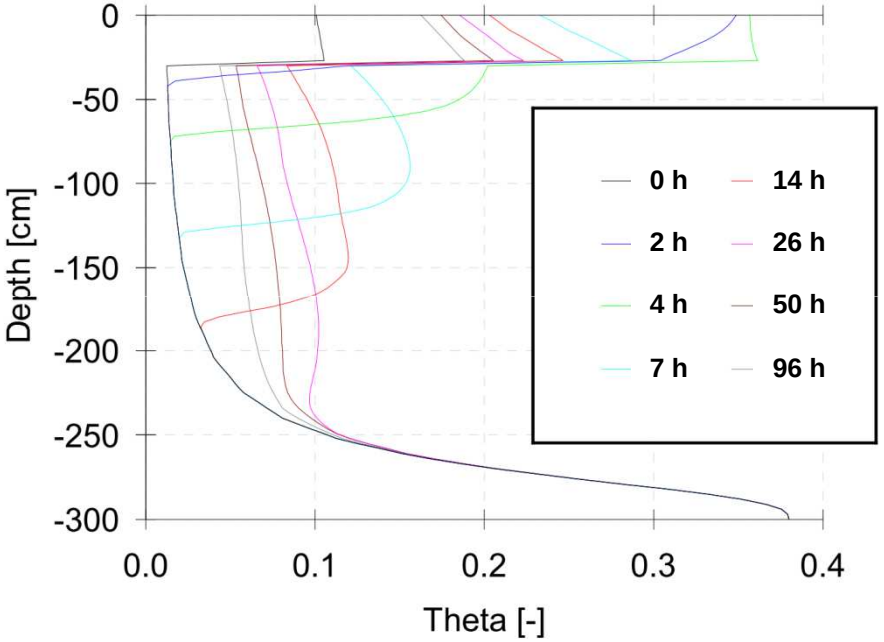
⇒**Scenario: observation of actual groundwater recharge**



➢**Irrigation experiment:**

•duration: 4 h
•Irrigation: 37 mm/h
•Bottom boundary condition: zero pressure head

⇒**Scenario: estimation of hydraulic conductivity**



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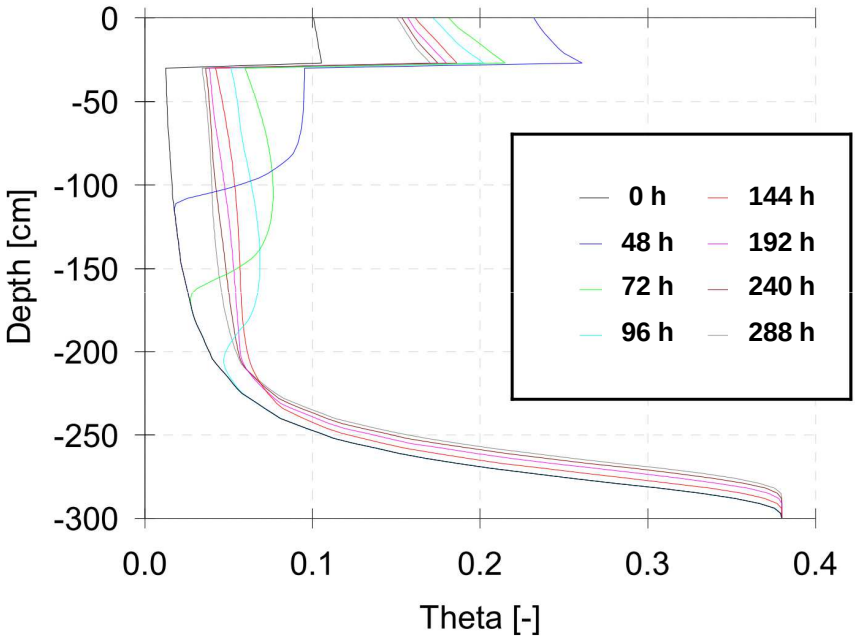

➢**MRS measurements:**
•Standard measurement layout
(1 to 3 h per sounding)
• high data quality > high spatial resolution
•Inversion on water content changes

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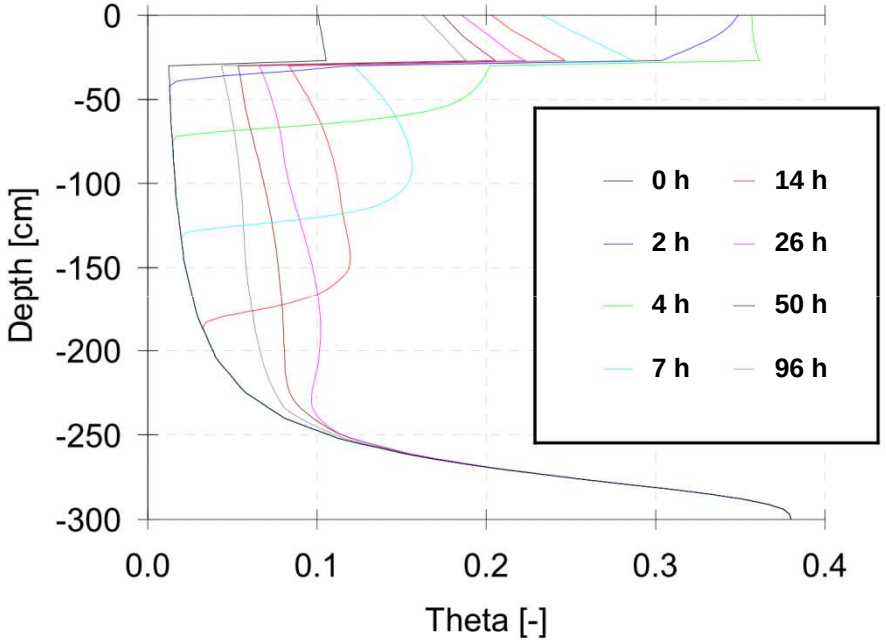

➢**MR measurements:**
•Alternative measurement layout
(5 to 10 min per measurement)
• fast repetition: high temporal resolution
•Observation of apparent water content

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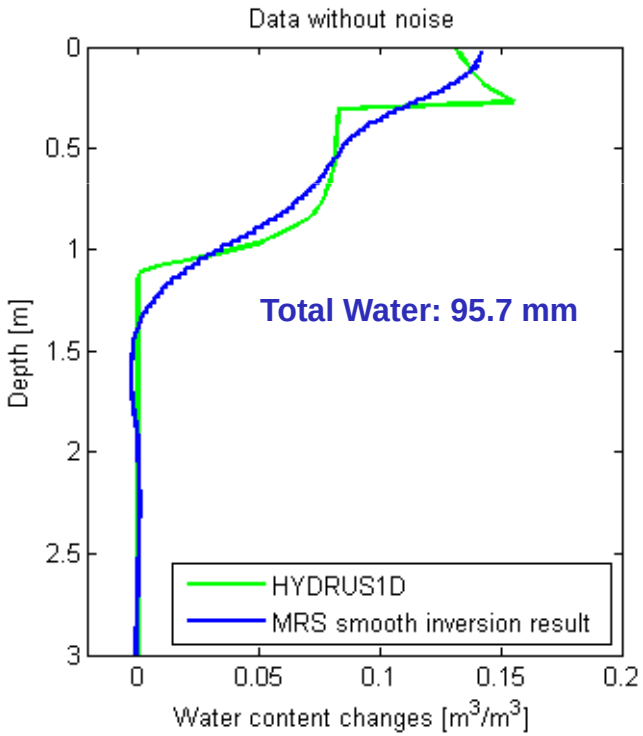

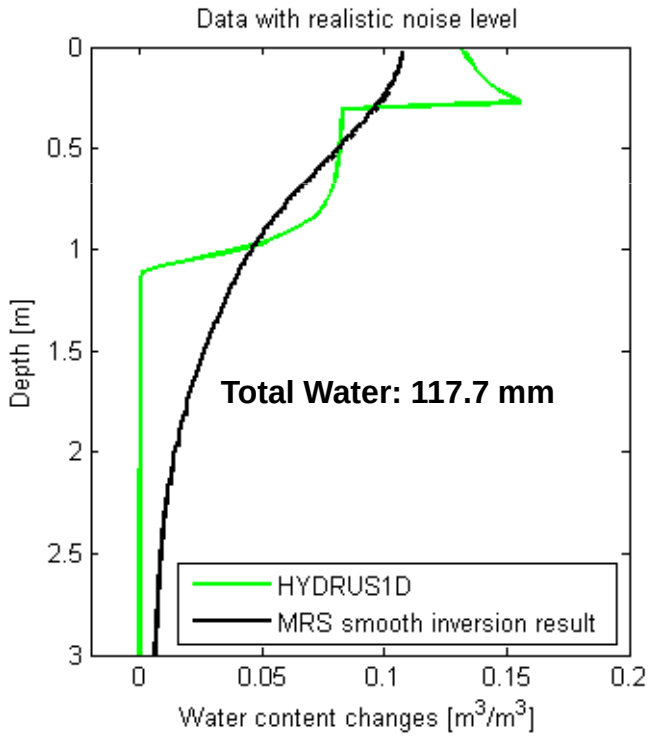

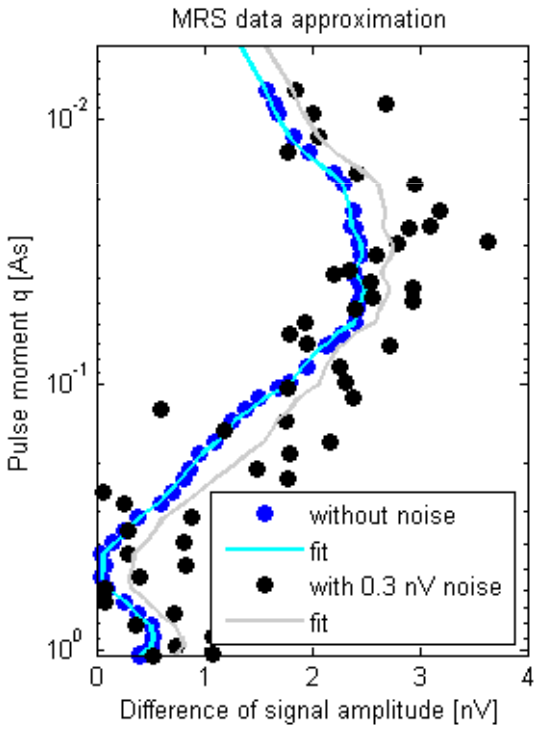

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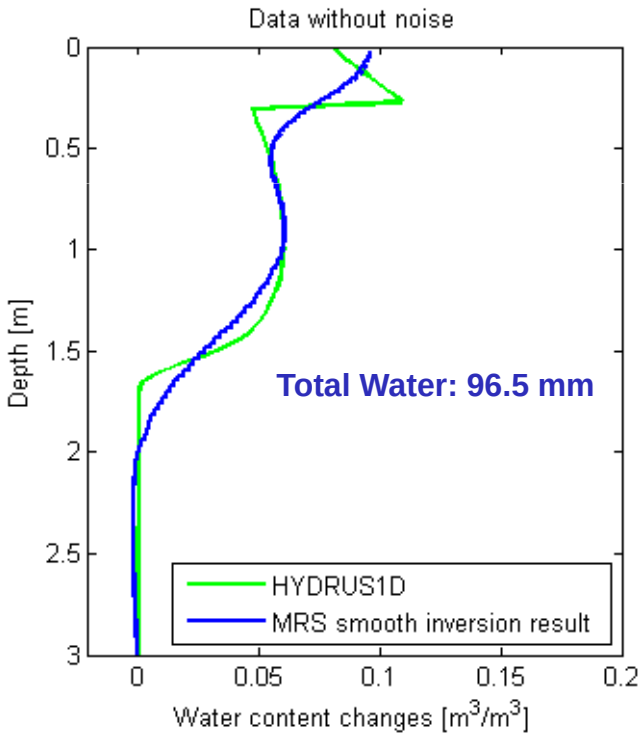

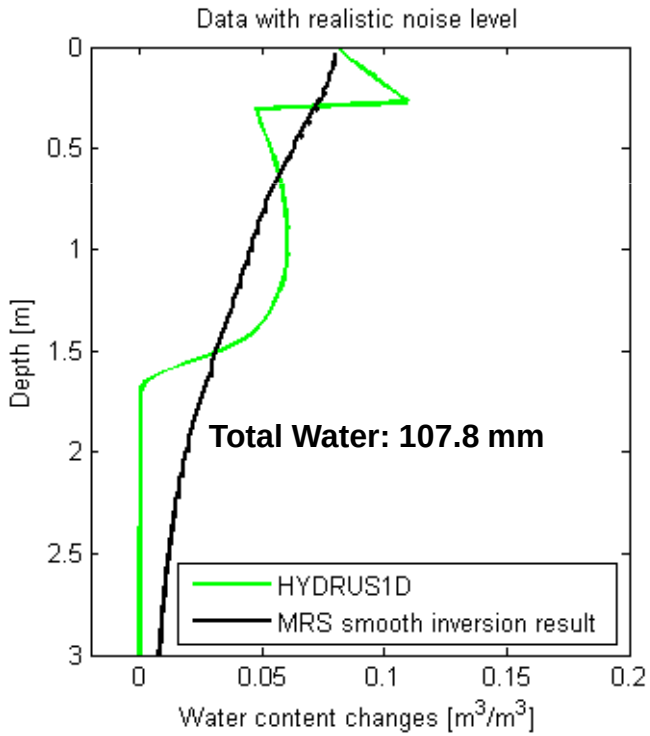

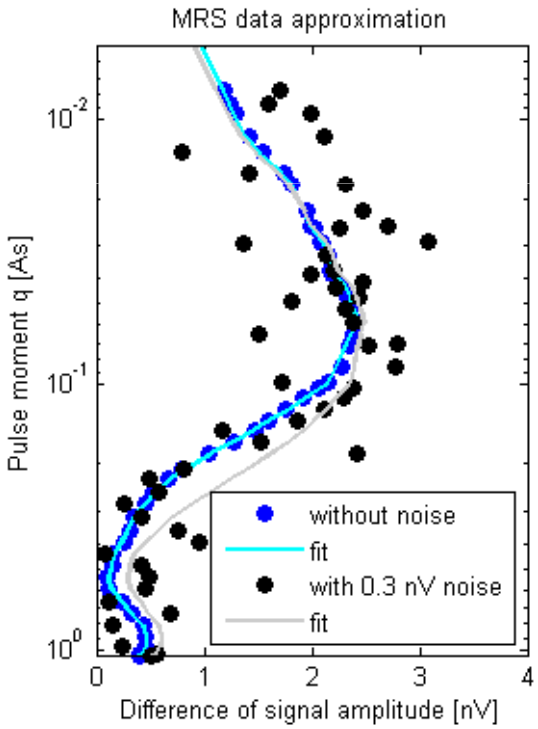

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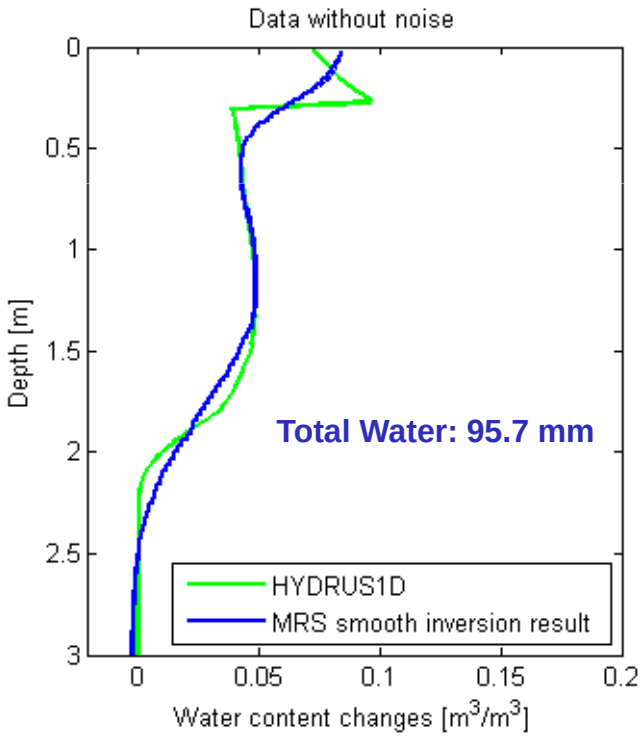

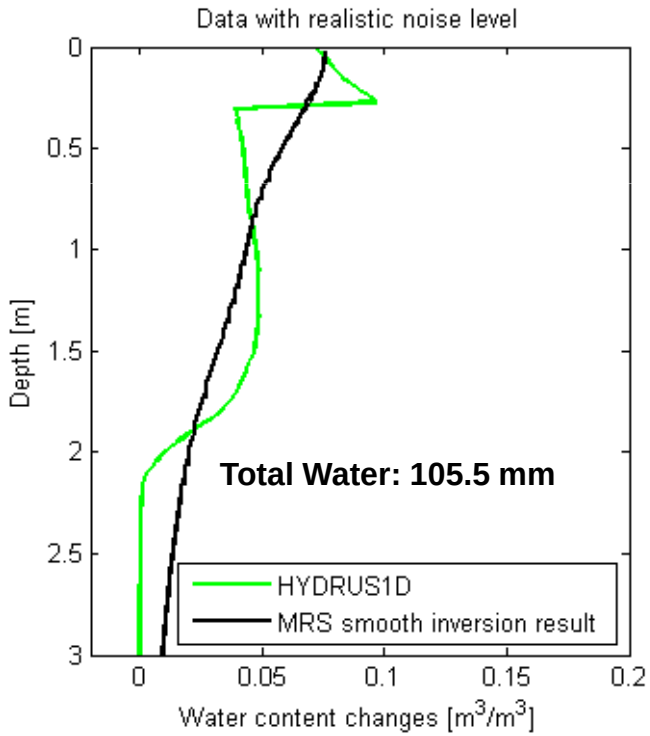

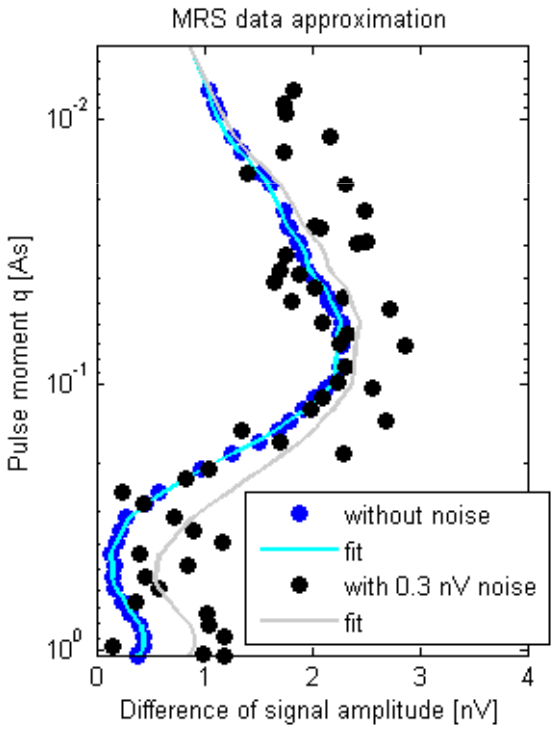

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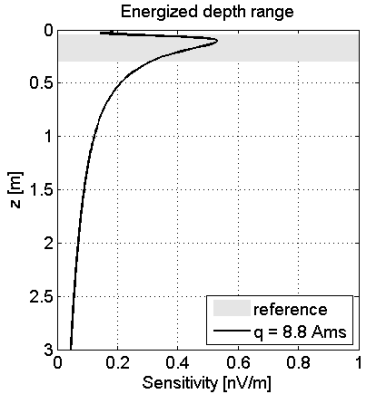
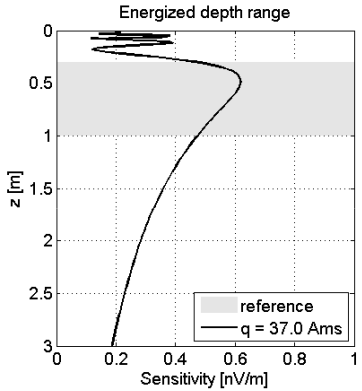
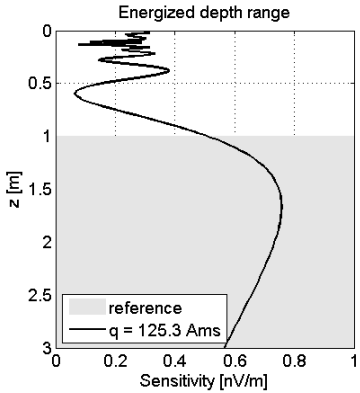
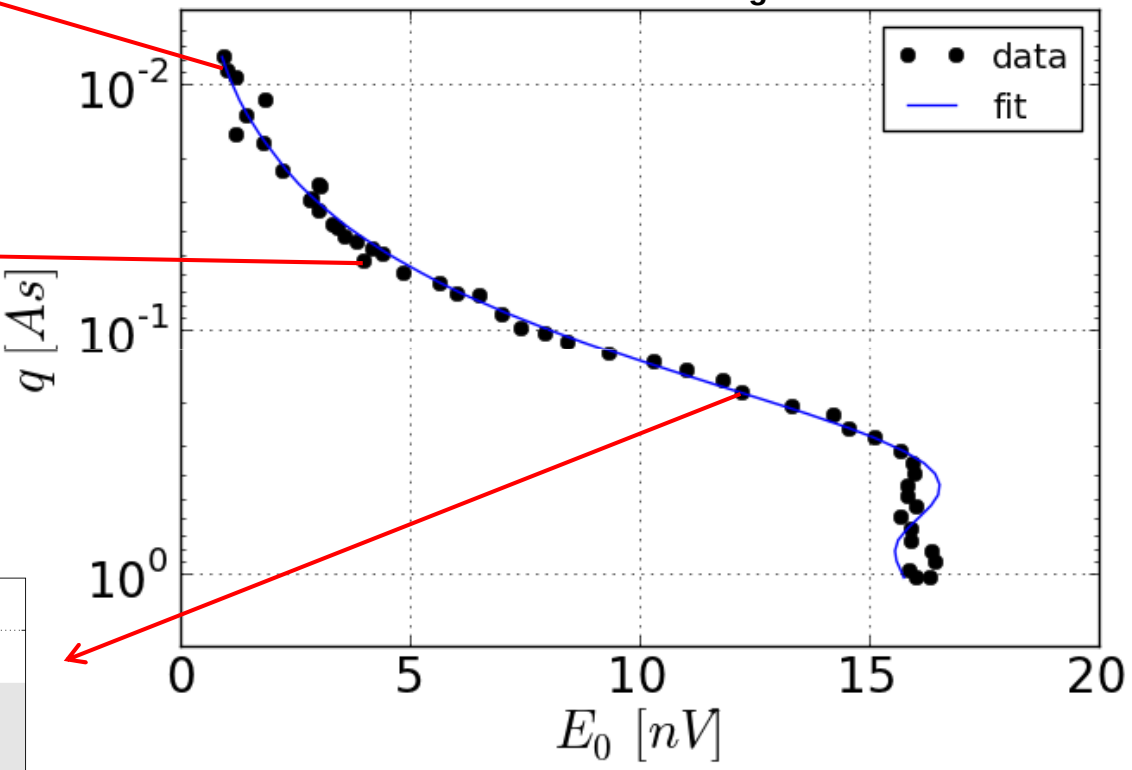






Standard sounding curve



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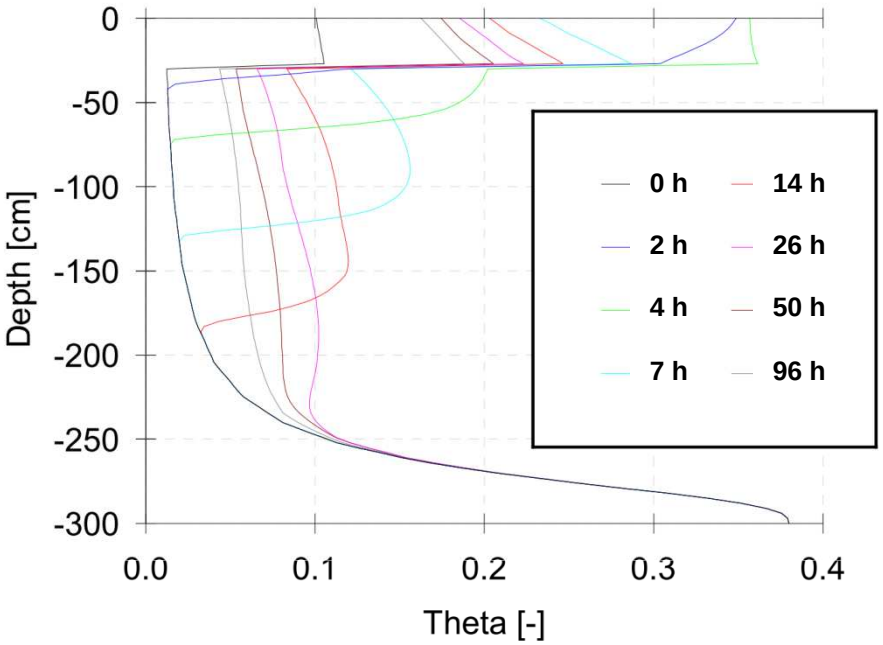

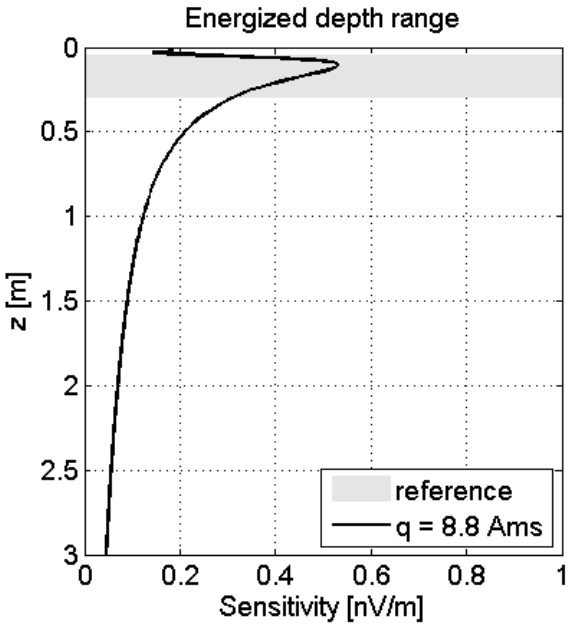

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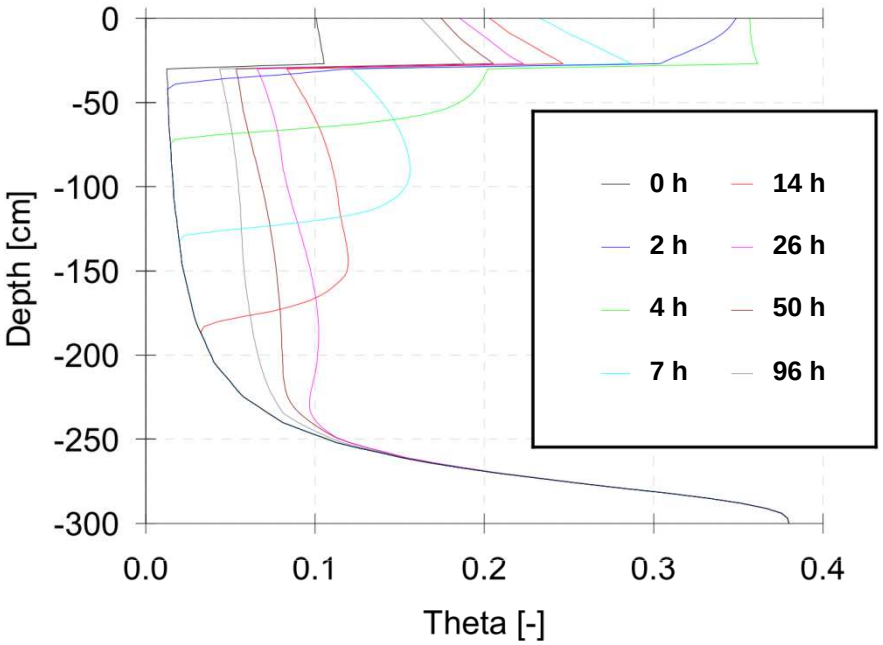

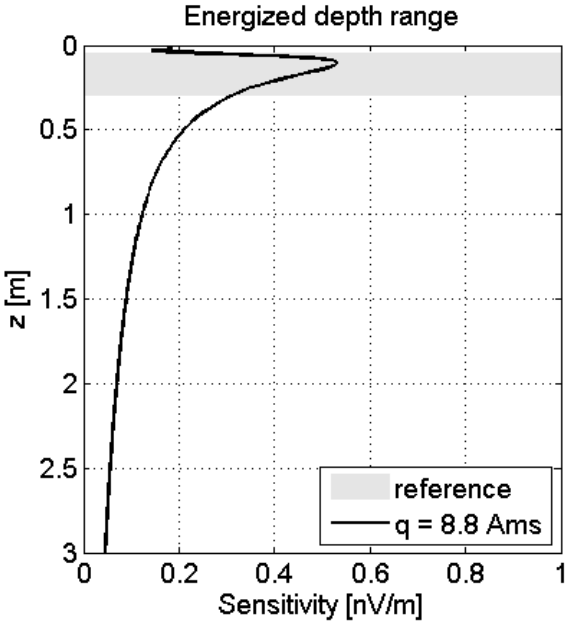

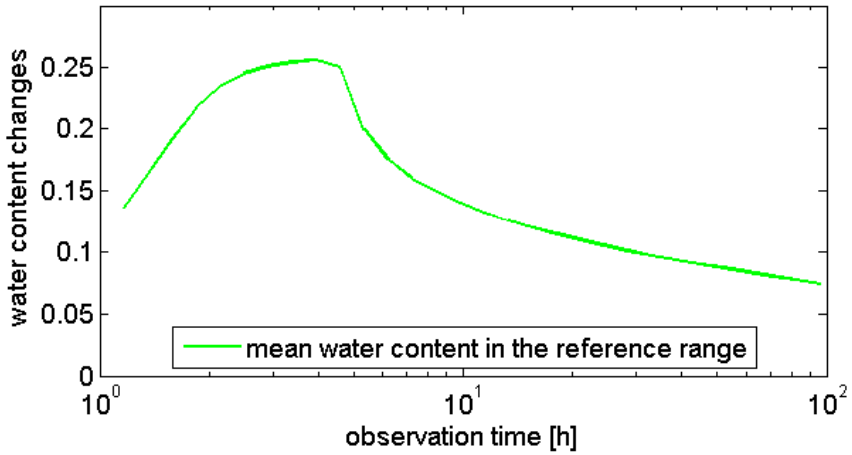

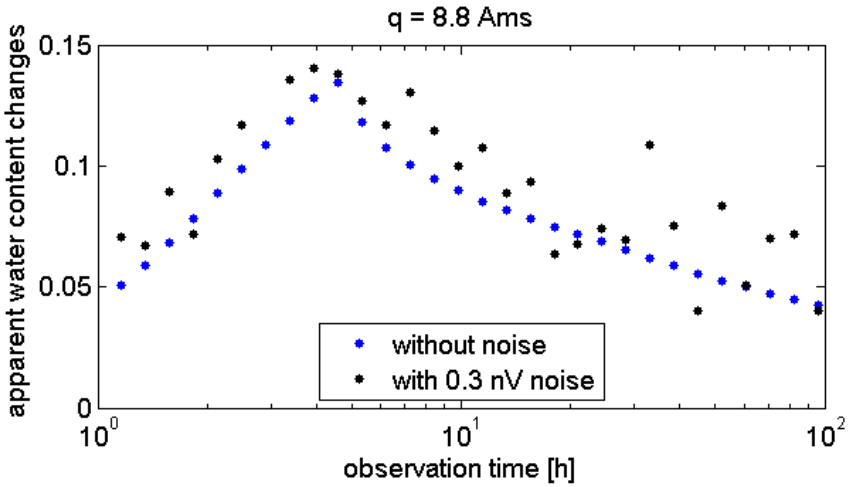

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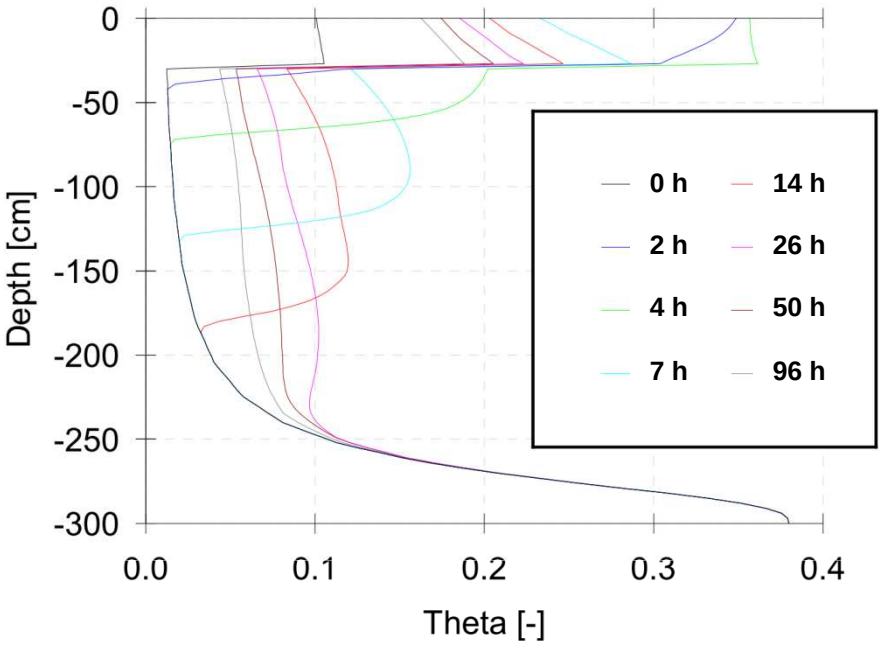

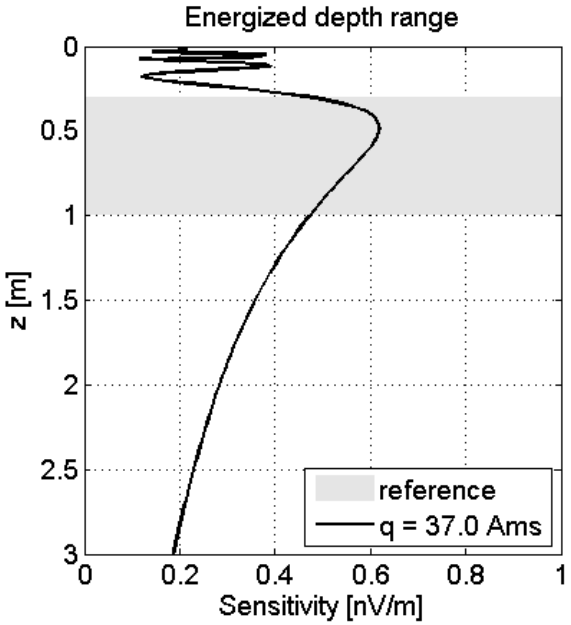

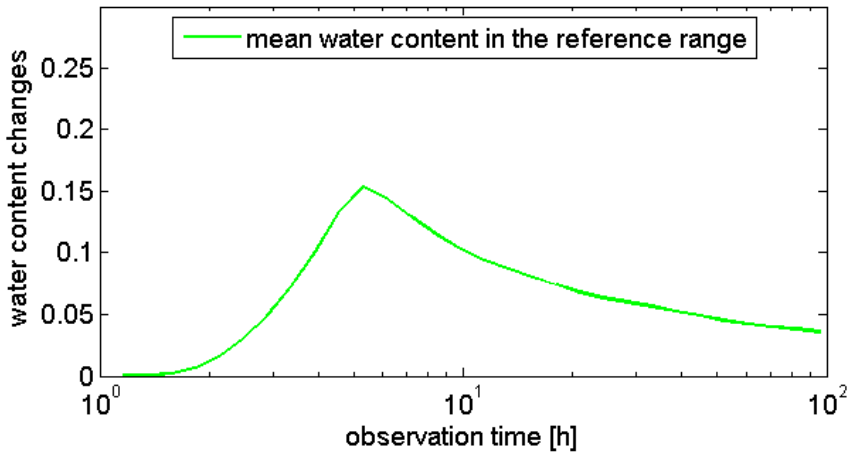

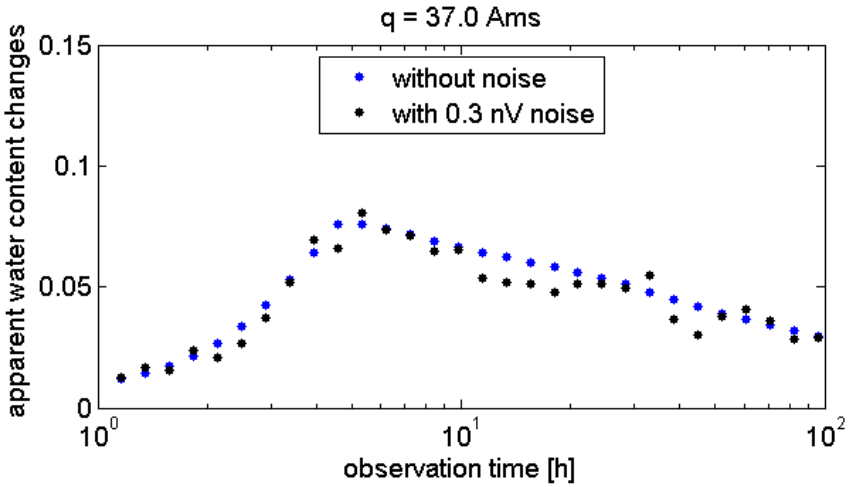

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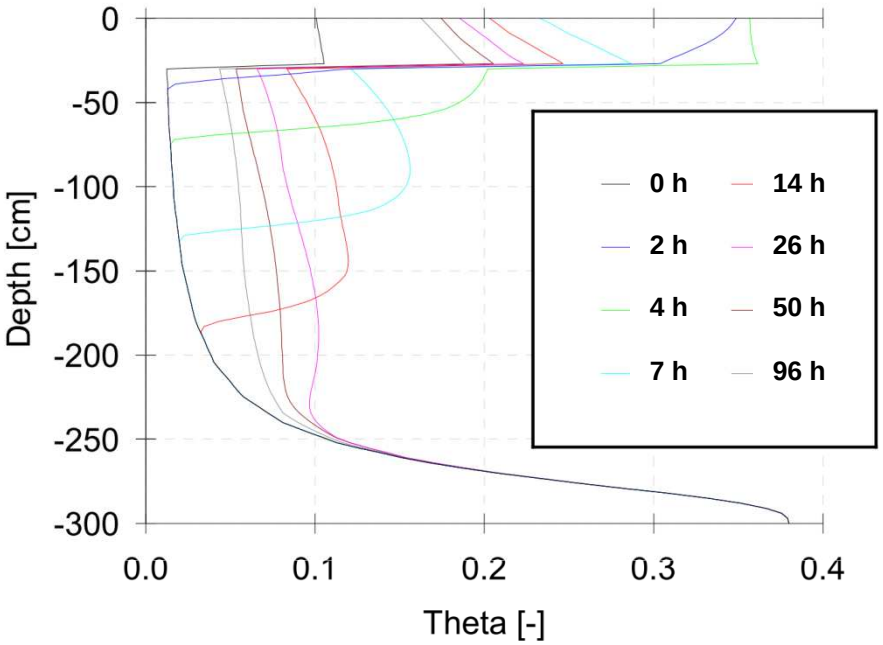
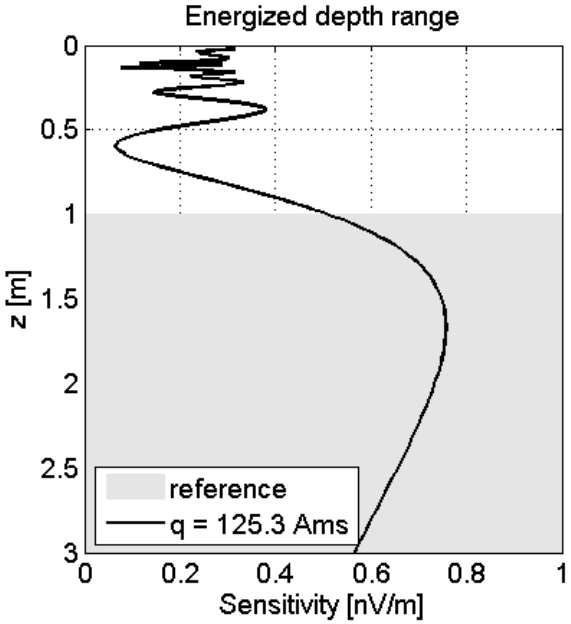
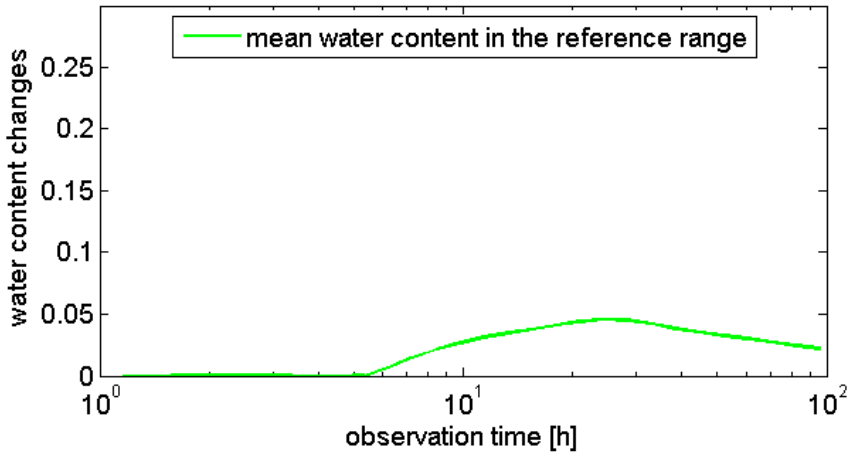
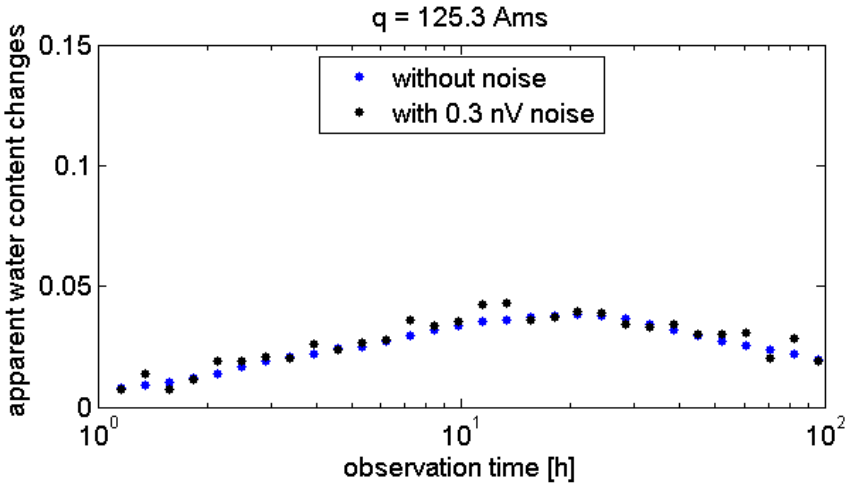








Conclusions

➢**By parameterizing the capillary fringe, for instance using the van-Genuchten model, MRS is able to:**

- … non-invasively observe water table changes with time
- … estimate the relative hydraulic conductivity roughly from the slope of the capillary fringe

➢**Observing the infltration front after a rainfall event seems not possible, spatial resolution under realistic noise conditions is not high enough!**

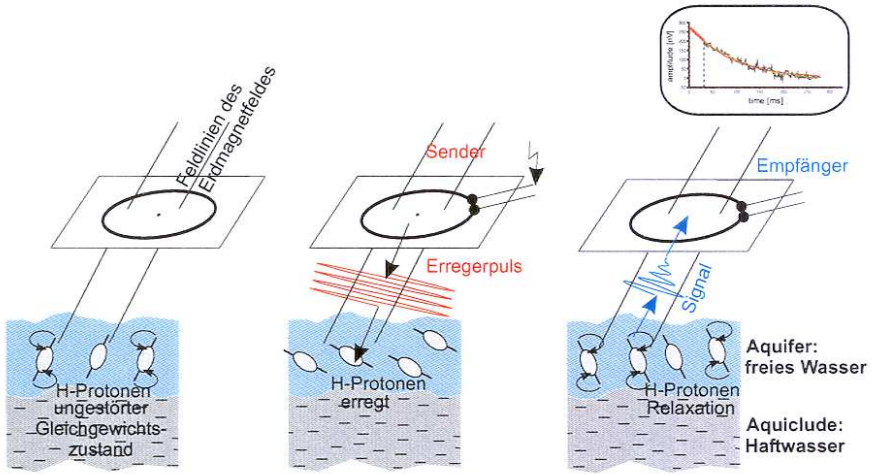
➢**Outlook, Monitoring of irrigation experiments:**

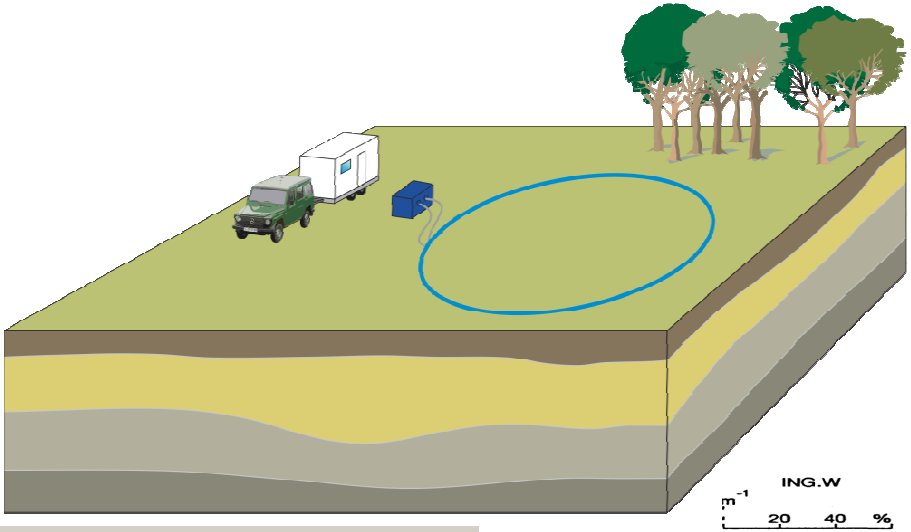
-fast repetitions of single MR measurements are possible
=> Observation of water content changes in specific depth ranges

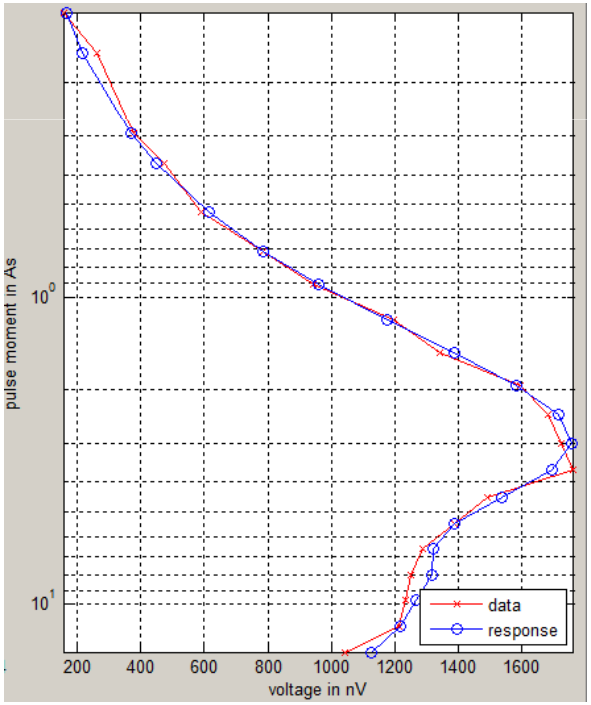
➢**Outlook: Combination with ERT measurements:**

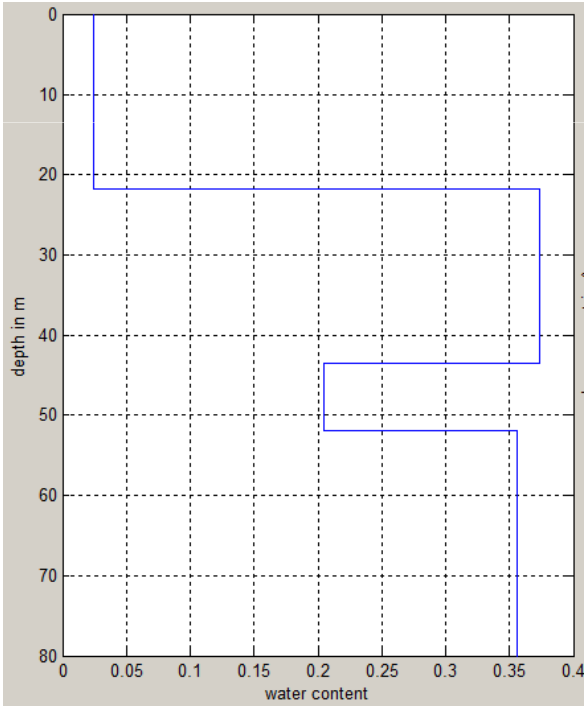
-Benefit of ERT: high spatial and temporal resolution
-Benefit of MR measurements: determination of water content changes with time in specific depth ranges (very low spatial resolution !)

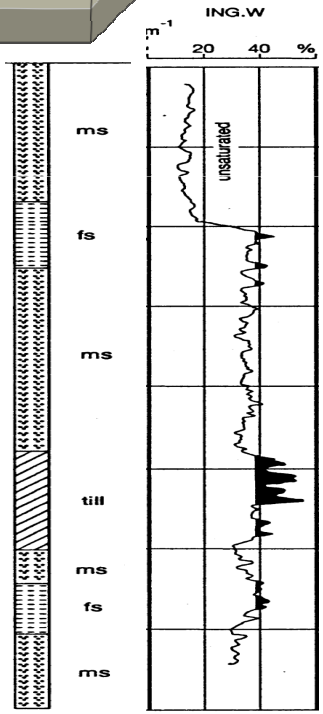
Magnetic resonance sounding (MRS)



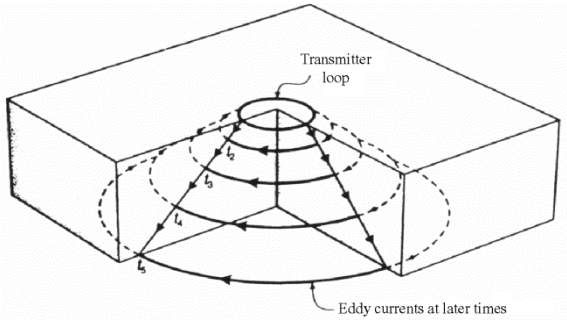


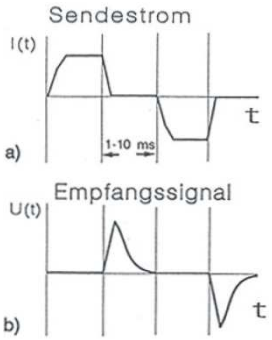


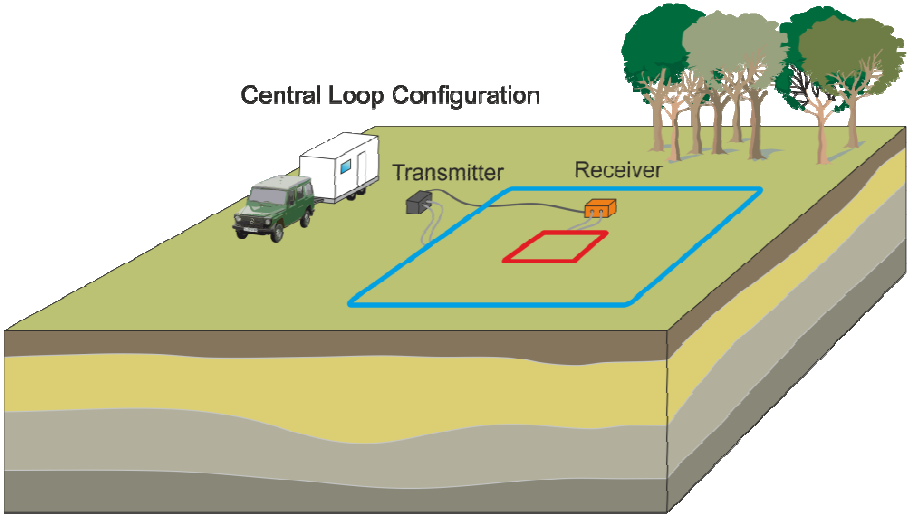


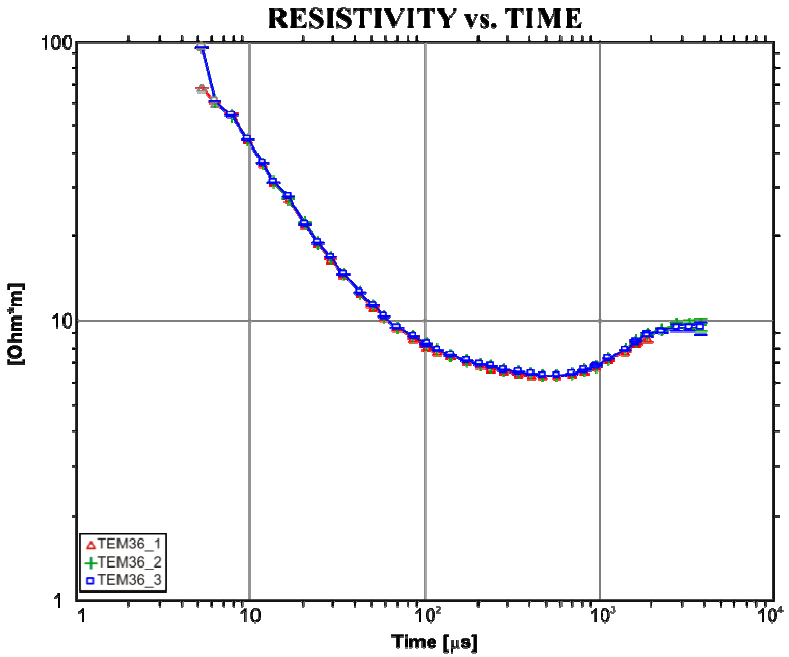


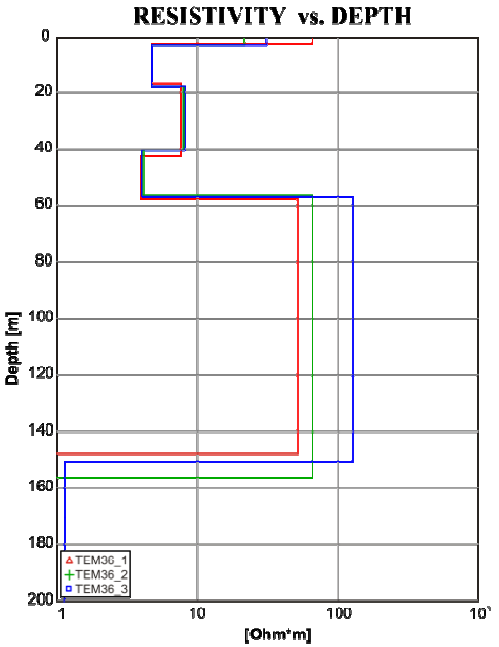
Hydrogeophysics – electric and electromagnetic methods





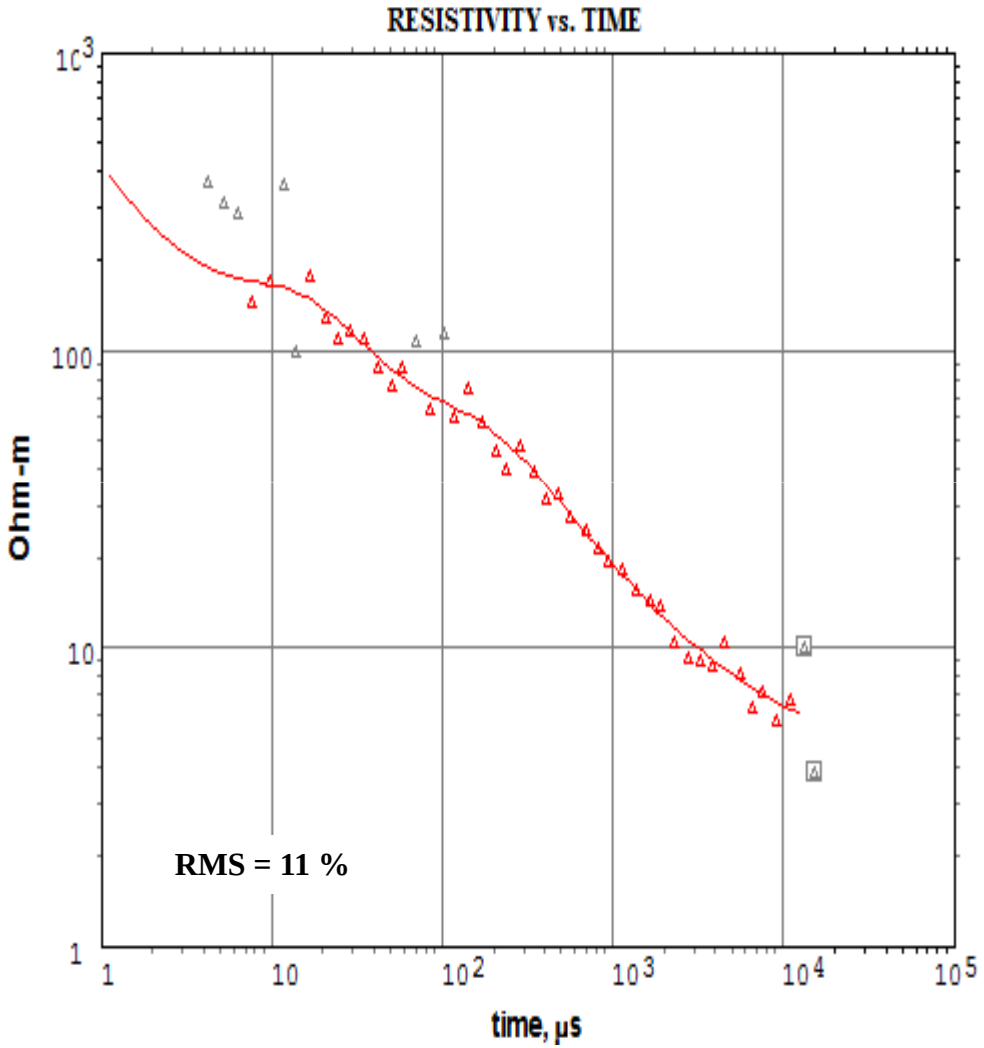


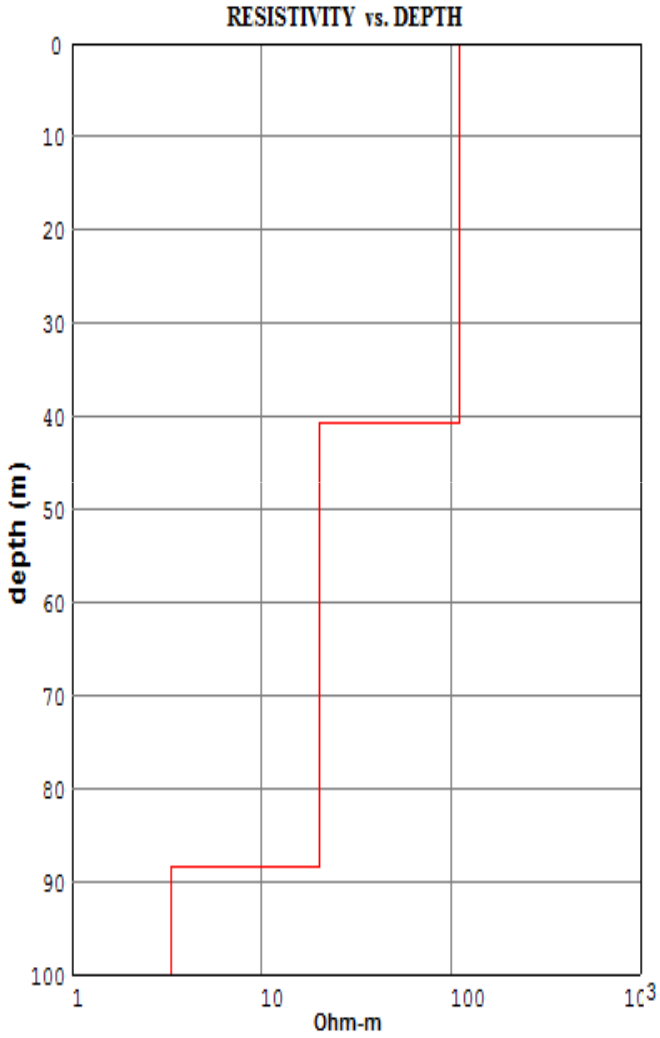




Large scale investigations with TEM

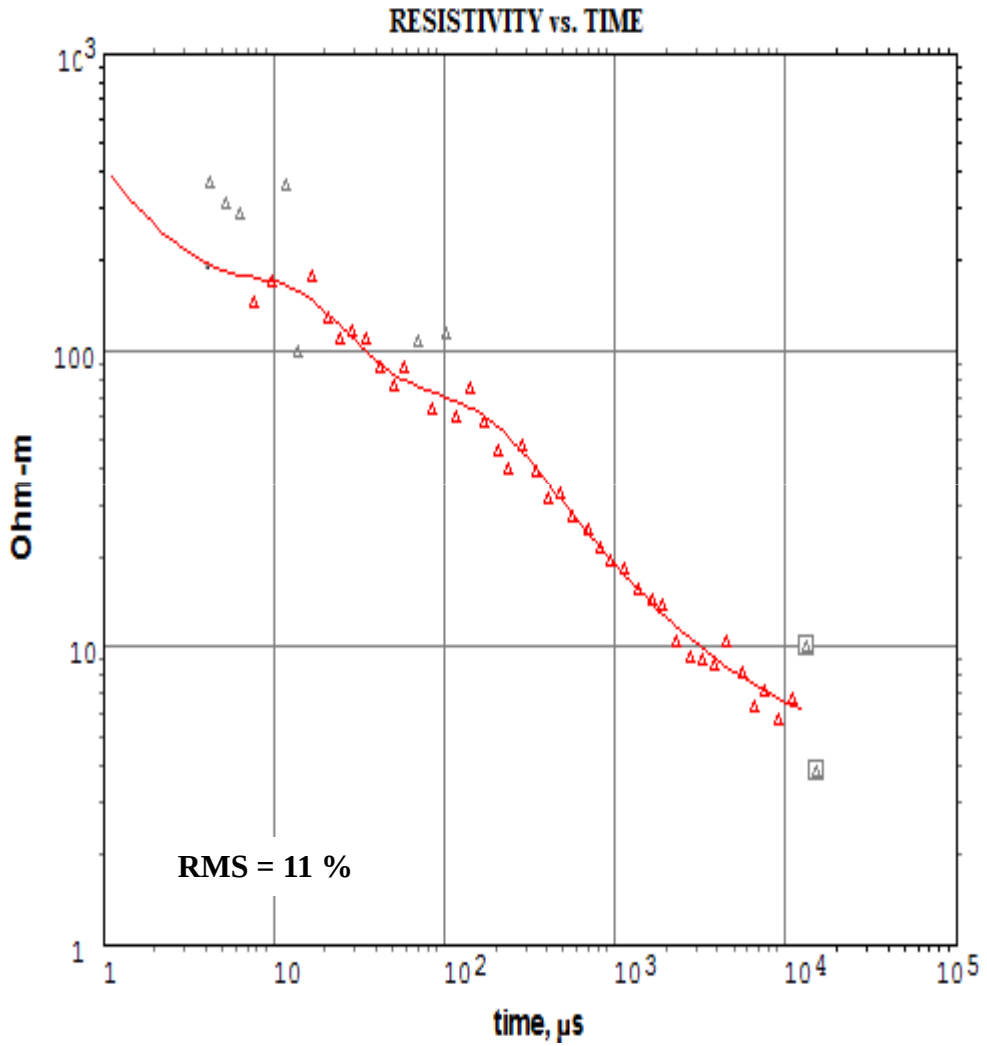
➢**Second aquifer not detecable with transient electromagnetic**

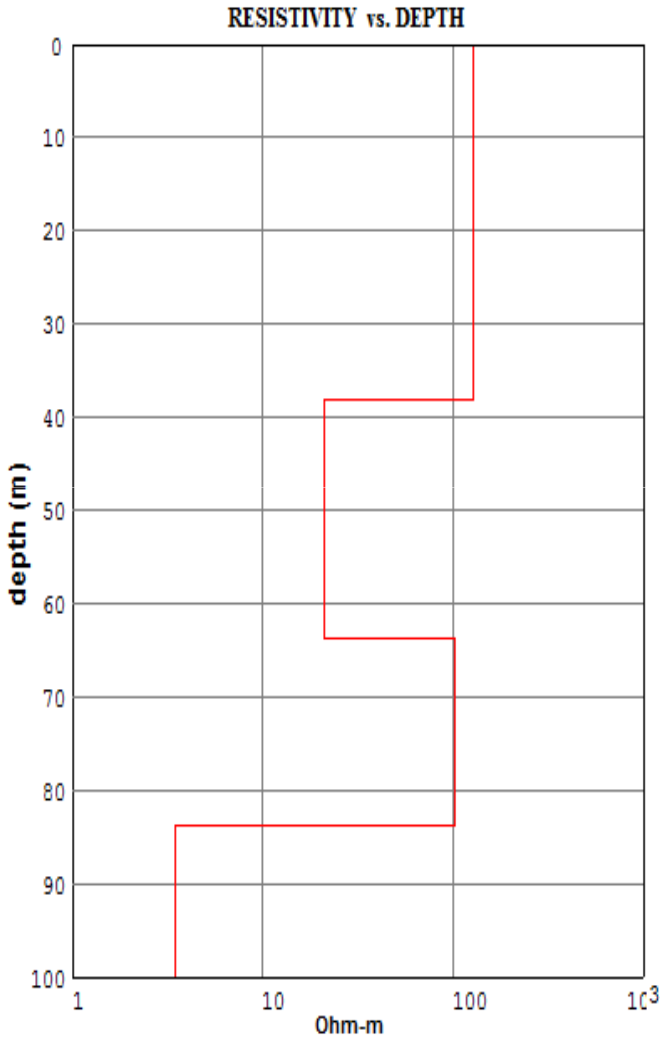




Large scale investigations with TEM

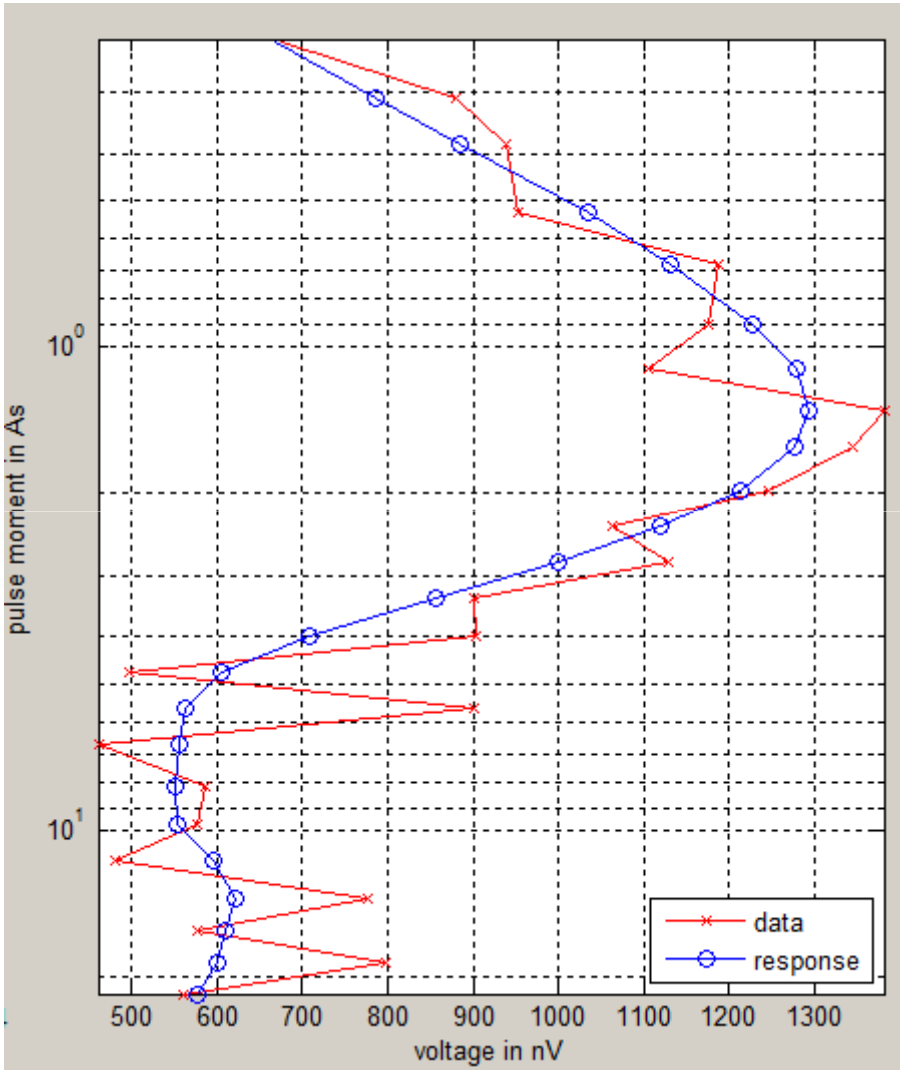
- **Model with second aquifer does also explain the measured TEM data**

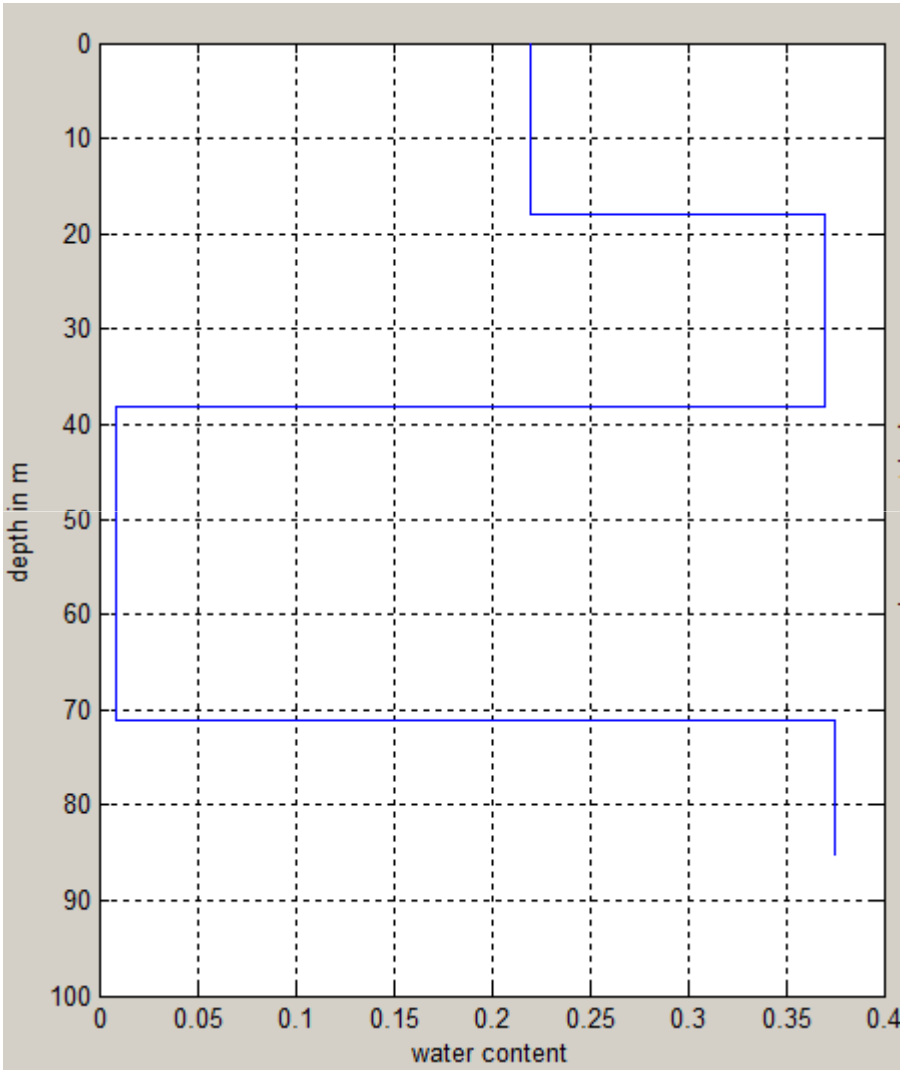




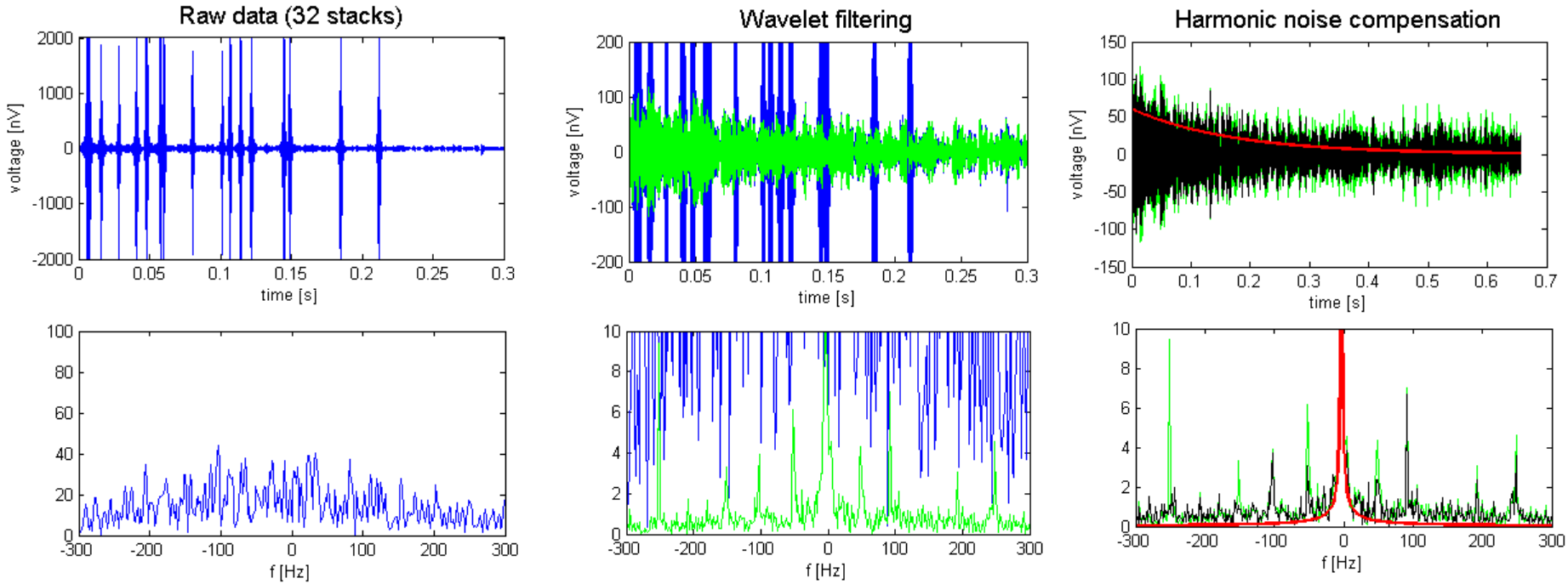
Large scale investigations with MRS

➢**Investigation of groundwater levels with large loops**

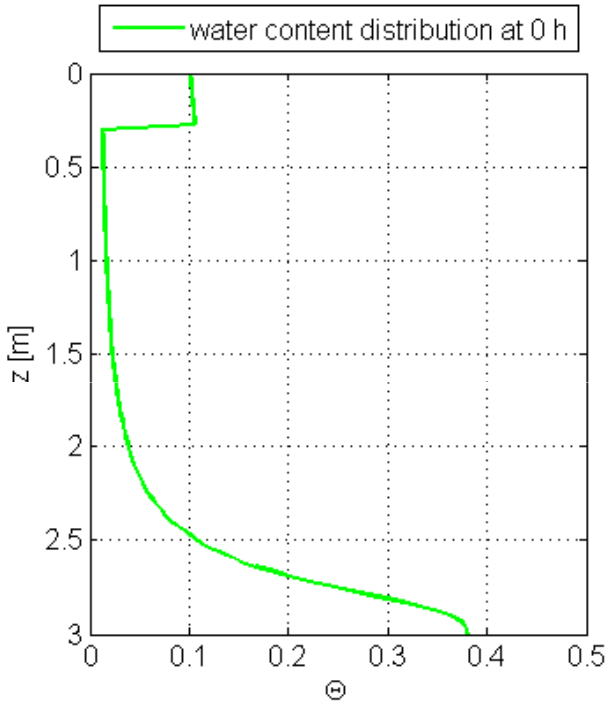


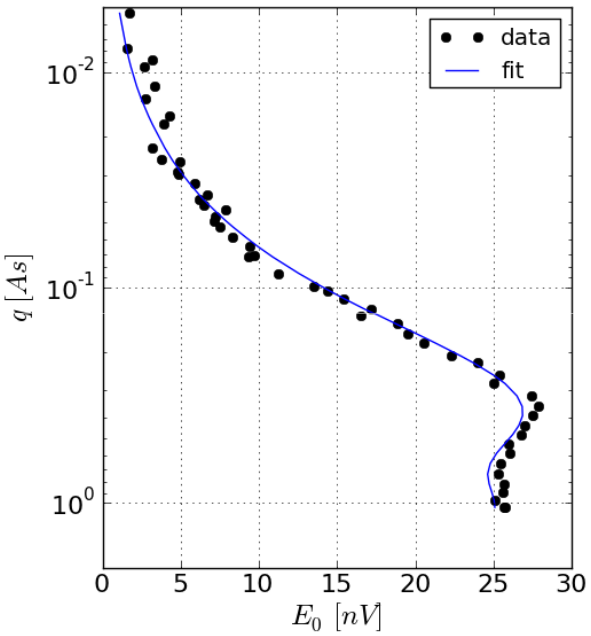


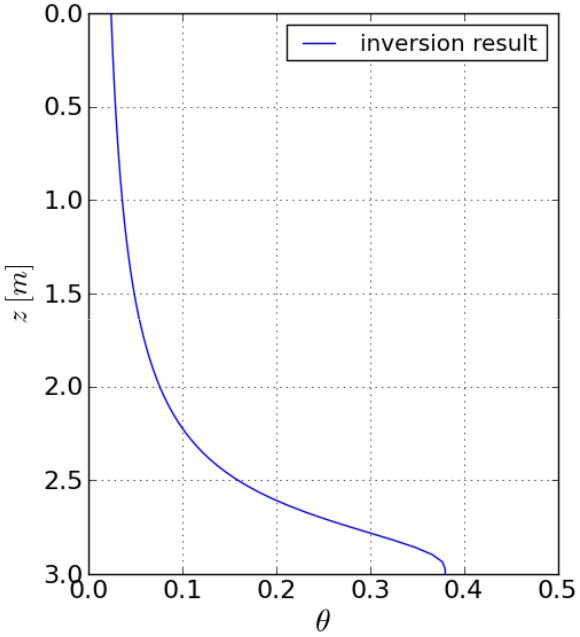
Small scale investigation with MRS – Data processing



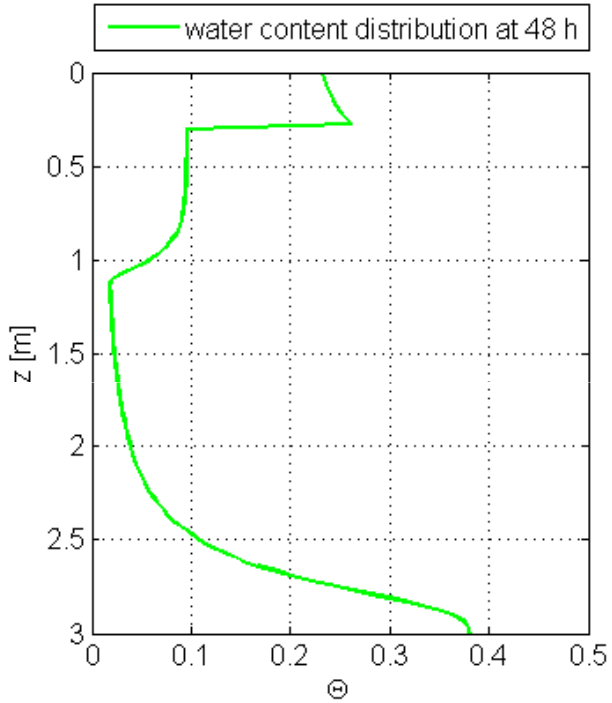
MRS forward modeling: Simulation of monitoring scenarios

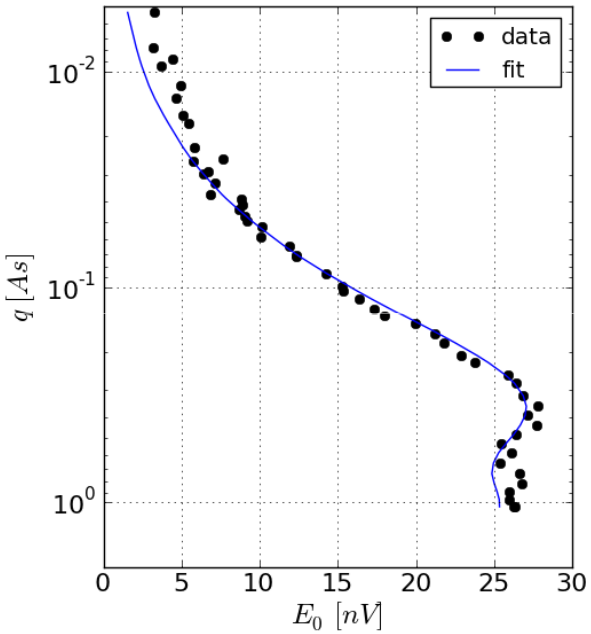


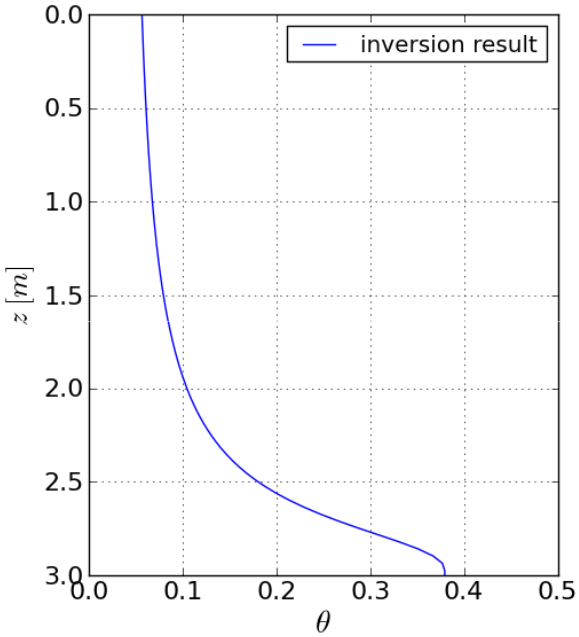




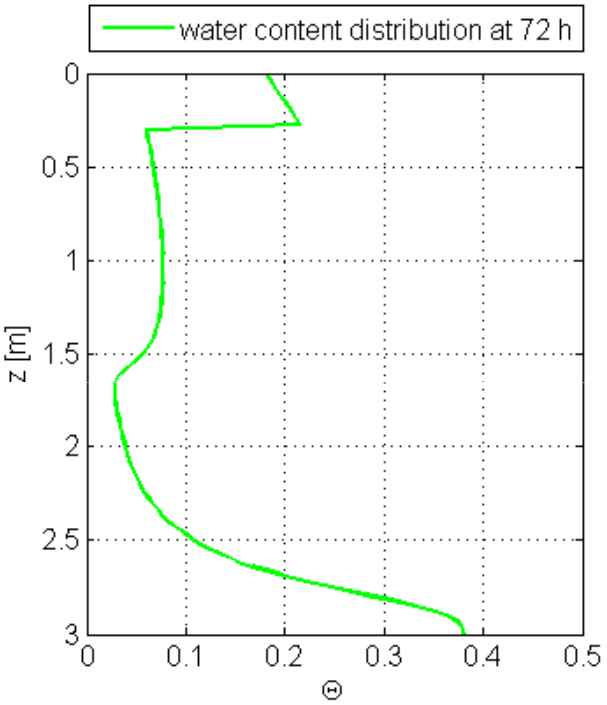
MRS forward modeling: Simulation of monitoring scenarios

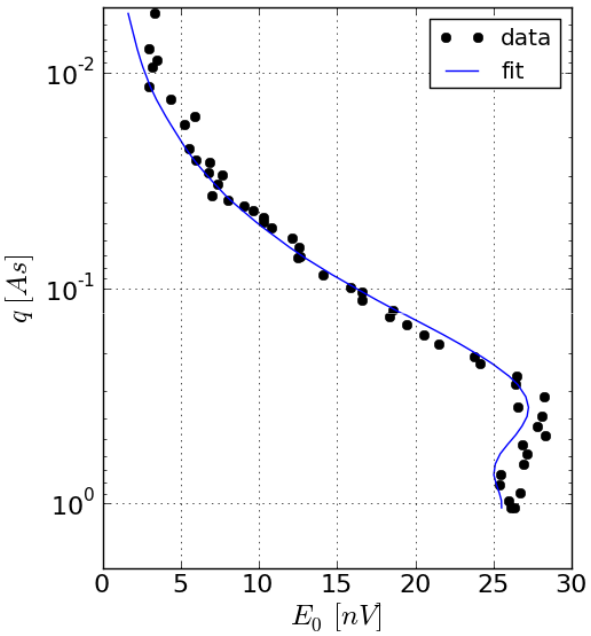


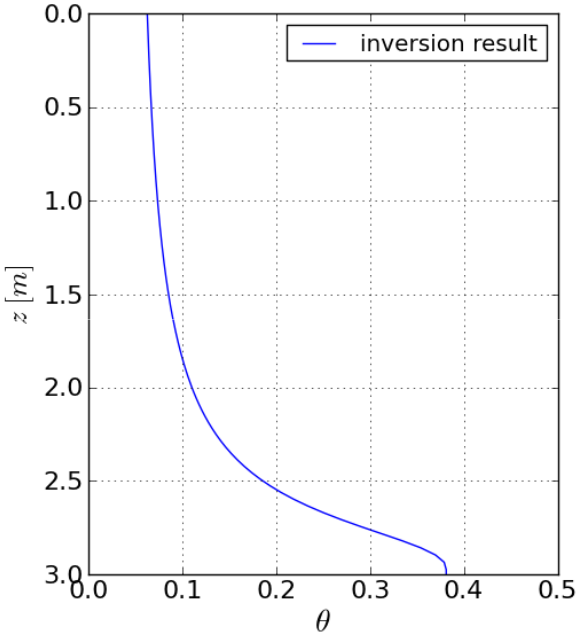




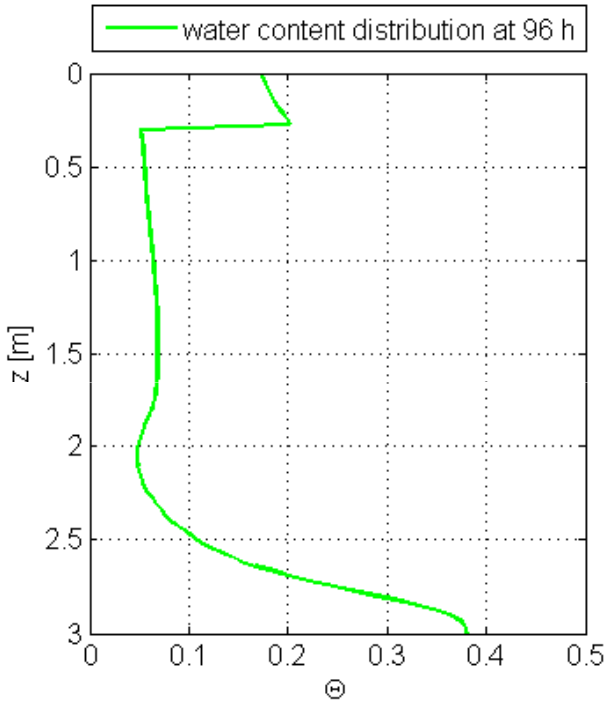
MRS forward modeling: Simulation of monitoring scenarios

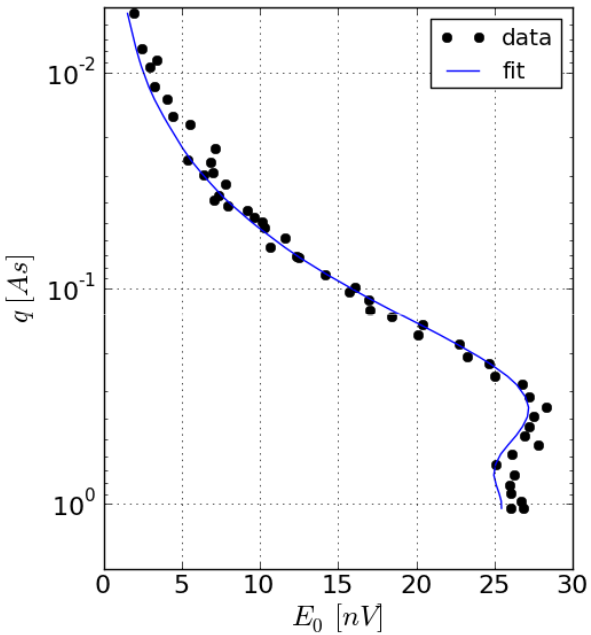


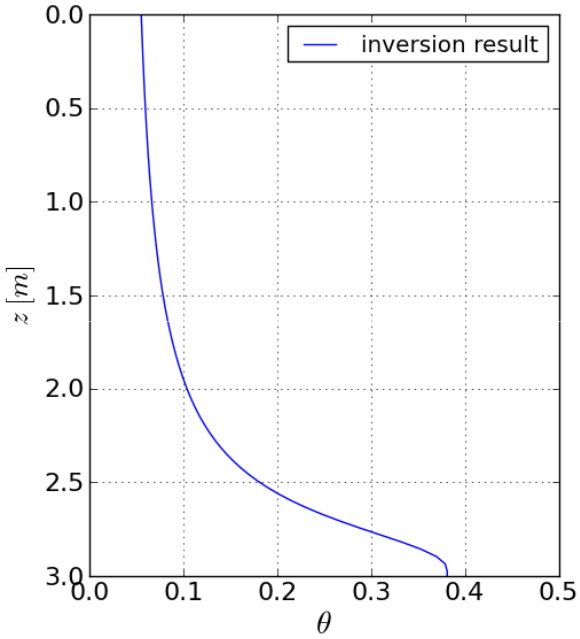




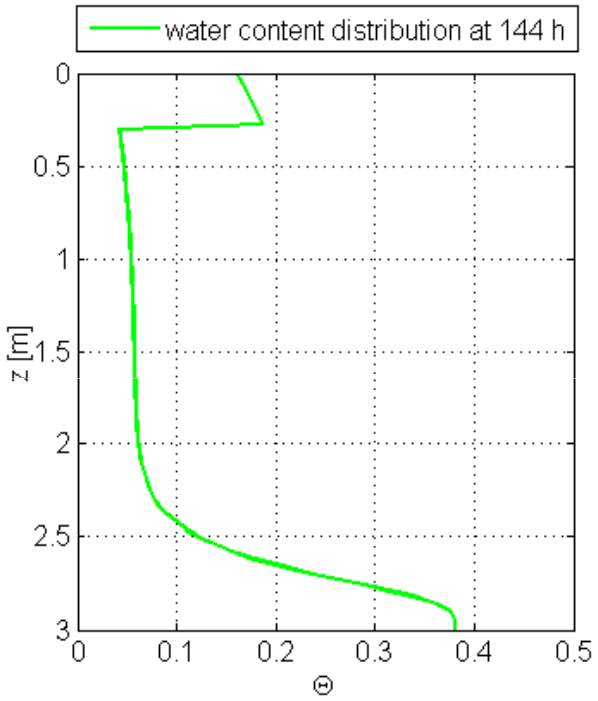
MRS forward modeling: Simulation of monitoring scenarios

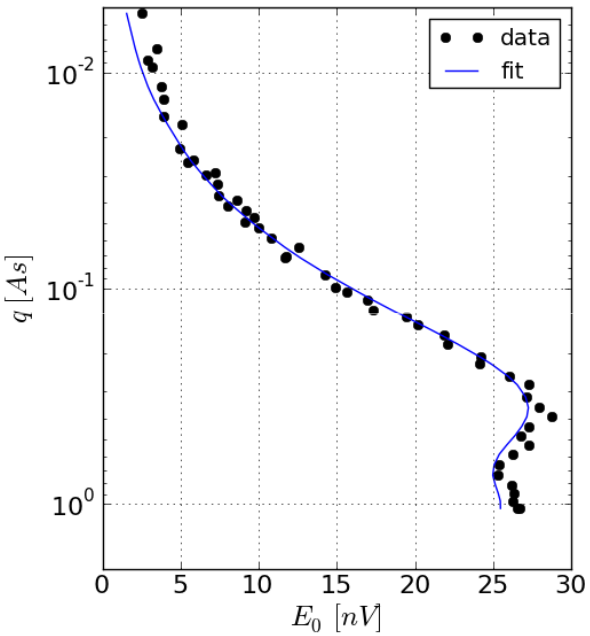


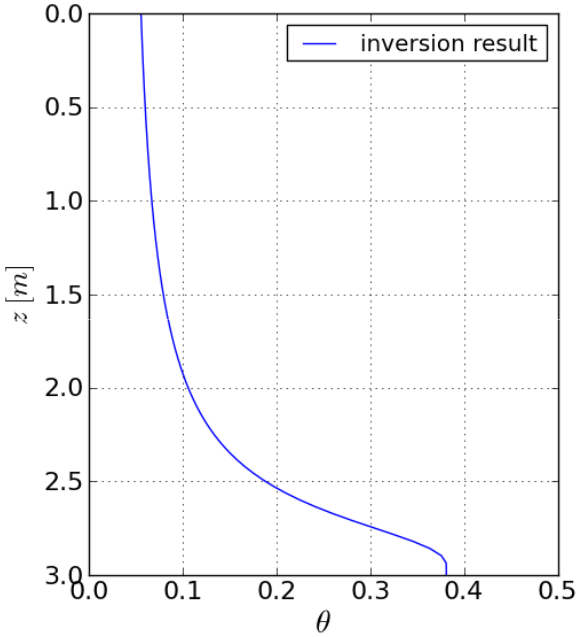




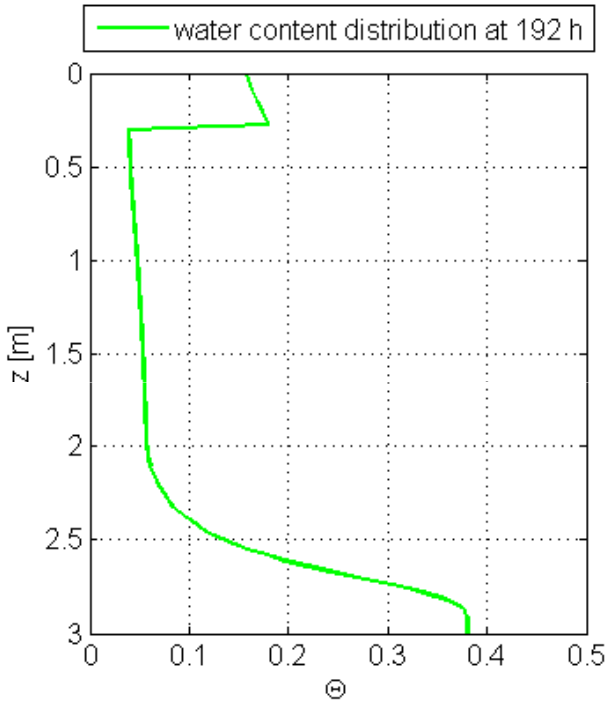
MRS forward modeling: Simulation of monitoring scenarios

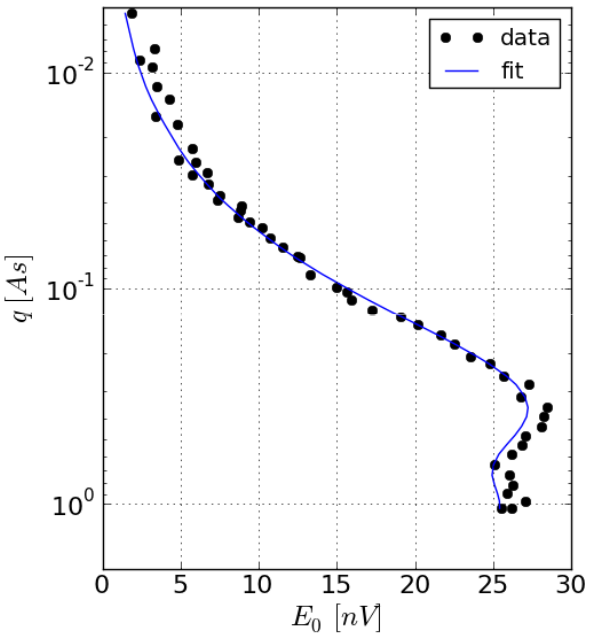


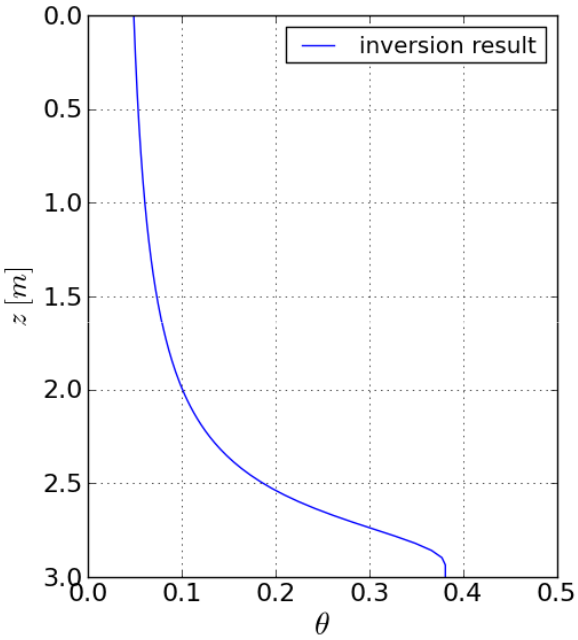




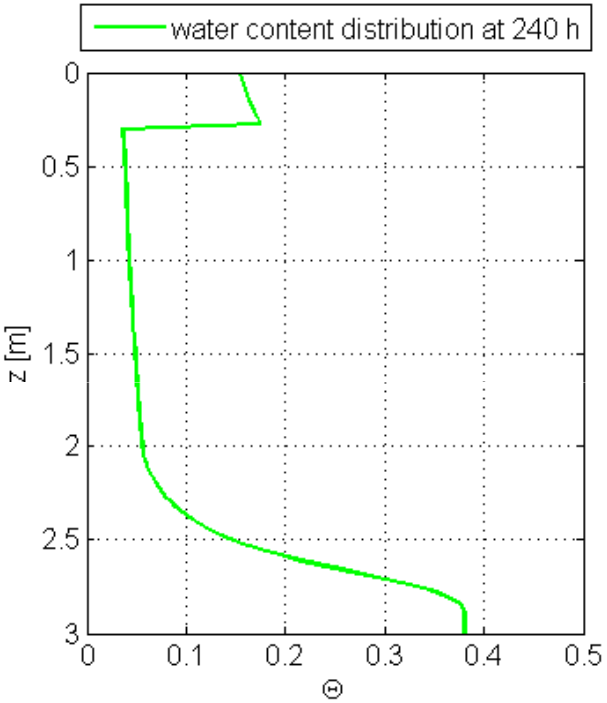
MRS forward modeling: Simulation of monitoring scenarios

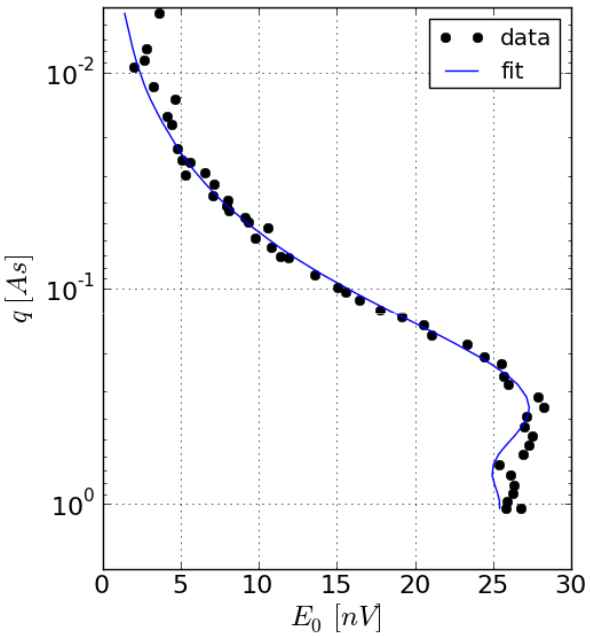


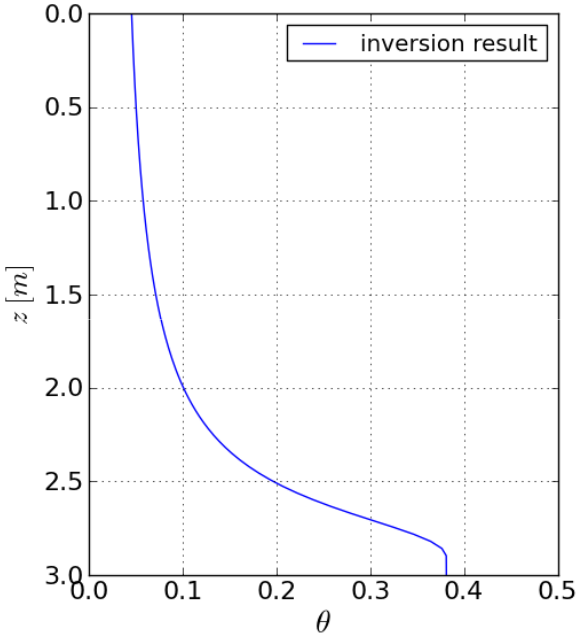




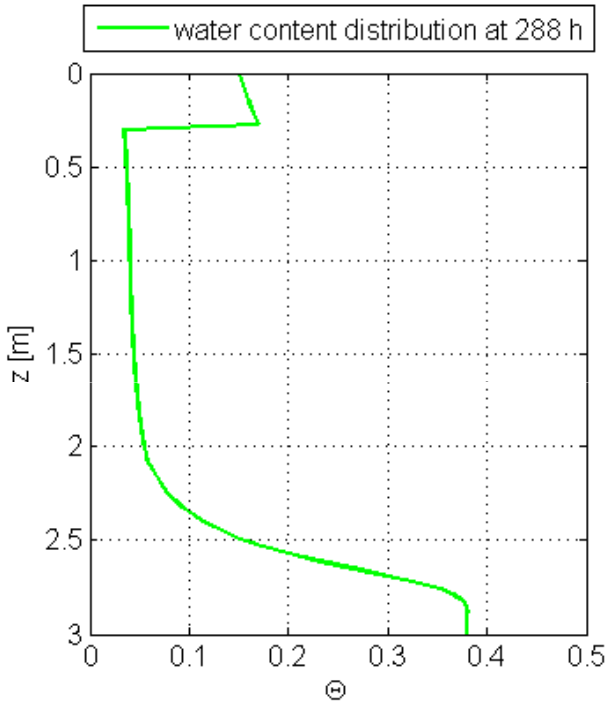
MRS forward modeling: Simulation of monitoring scenarios

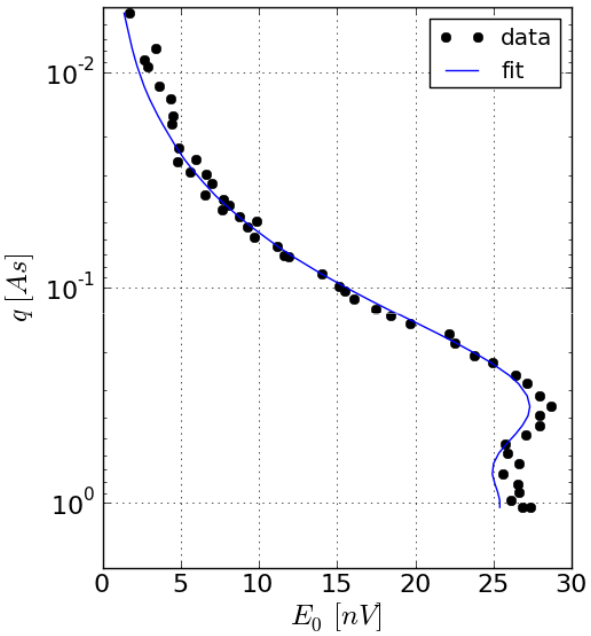


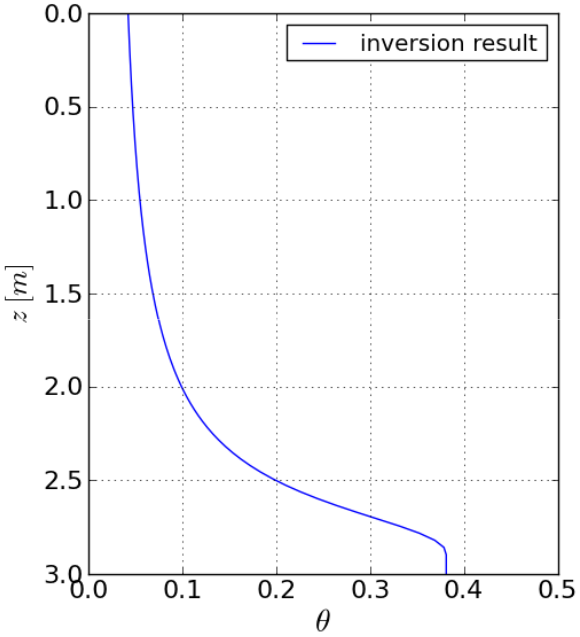




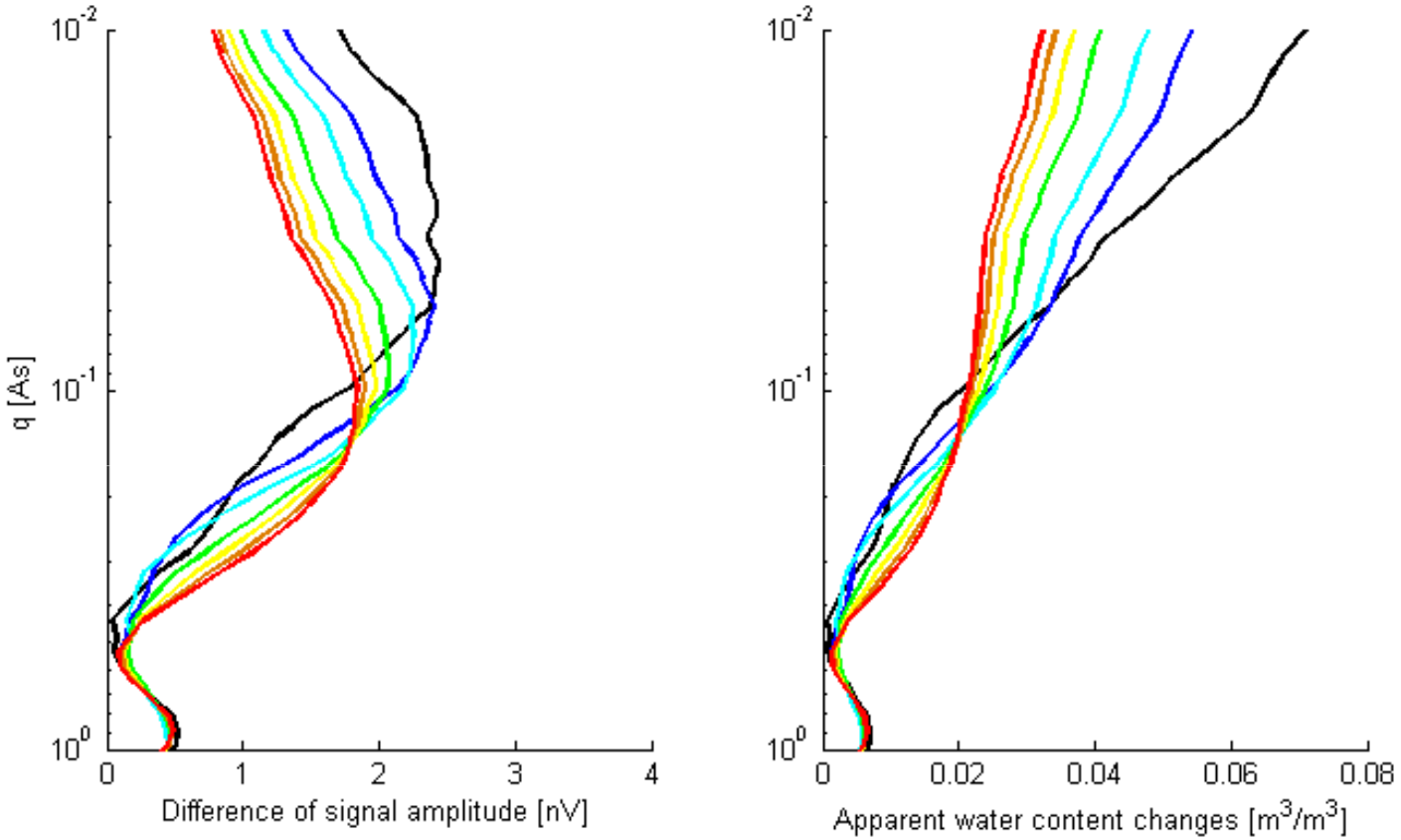
MRS forward modeling: Simulation of monitoring scenarios







1D-Forward modeling: Simulation of monitoring scenario



1D-Forward modeling: Simulation of monitoring scenario