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Exploration of Deep Aquifers in North Jordan using TEM and MT

German -Jordanian Cooperation Project

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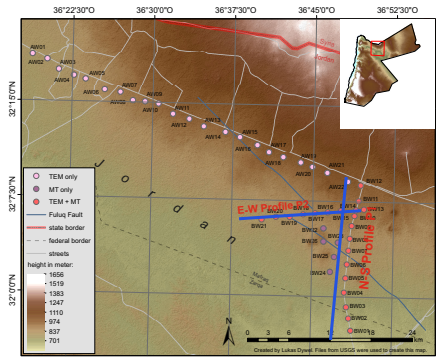
Improved Groundwater Resources Management in Responses to the Syrian Refuges Crisis-Project

The groundwater resources in Jordan are extremely overused and decline since decades. The Syrian crisis and the influx of hundreds of thousands of Syrian refugees brought the issue even more into focus.
For a sustainable groundwater management and an assessment of the remaining resources a better knowledge about the Geology is required. Particularly in North Jordan the hydrogeological conditions are not sufficiently understood. No geophysical investigations have been carried out so far.
Time domain electromagnetic (TEM) and magnetotelluric (MT) studies conducted in 2018 and 2019 are the first geophysical investigations in North Jordan that aim to image the conductivity distribution between tens of meters and several kilometers and to map the aquifer structures and the thickness of the water saturated layers.



Electromagnetic investigations

TEM survey
- active method, low penetration
- April/May 2018
- 42 sites

TEM Acquisition settings
- Zonge GDP-3224 (Zonge, 2002)
- GGT10 transmitter
- loop size: 200 x 200m
- currents: 10-25Amps
- repetition rates: 32Hz and 8Hz at all sites and 4Hz, 2Hz and 1Hz at few sites until the transients reached at late-times the level of background noise.
- number of cycles : 256-1024
- number od stacks: 3-10

Processing
- TEMAVGW (Zonge)
- ramp time: 220µs
- transients: up to 90ms (for low rep. rate)

MT survey
- passive method, deep penetration
- March/April 2019
- 25 sites

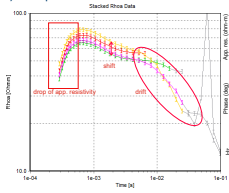
MT Acquisition settings
- Metronix (ADU)
- Metronix magnetic coils (MFS06 and MFS07
- Electric field (Ex, Ey)
- Magnetic Field (Bx, By, Bz)
- recording time ≥ 2 days

Processing
- Procmt (Metronix), EMAP (M. Becken pers. comm.)
- remote reference
- period range of transfer functions 10^{-4}-10^{3}s

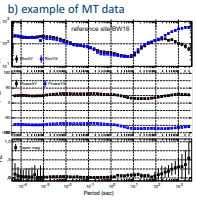
Data

Both, TEM and MT data show a good quality.
However, the TEM curves (a)) of different repetition rates are slightly shifted and drift apart with the time. Similarly, the transients of the single stacks don't overlap at late-times. At times < 600µs a drop of the apparent resistivity is observed at some sites.
The MT apparent resistivities and phases look very similar at all sites and ρxy and ρyx overlap (with a shift along the whole periode range) between 10^{4} and 10^{5}s (c)). The magnitude of the vert. magnetic transfer functions is about 0.1. This indicate to one-dimensional (1-D) subsurface in shallow depths and a static shift effect.

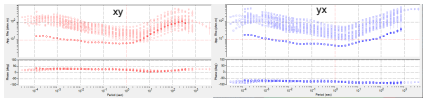
a) example of TEM data



b) example of MT data



c) apparent resitivities and phases of all MT data along the N-S profile P1

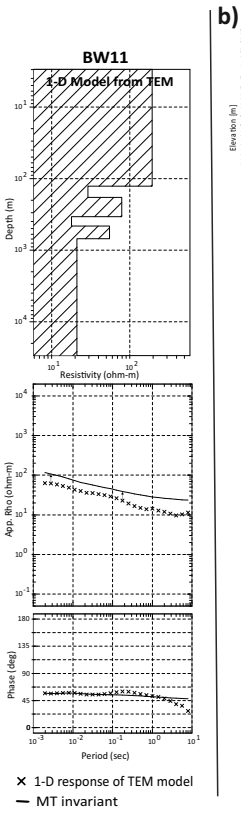


Modeling TEM and MT

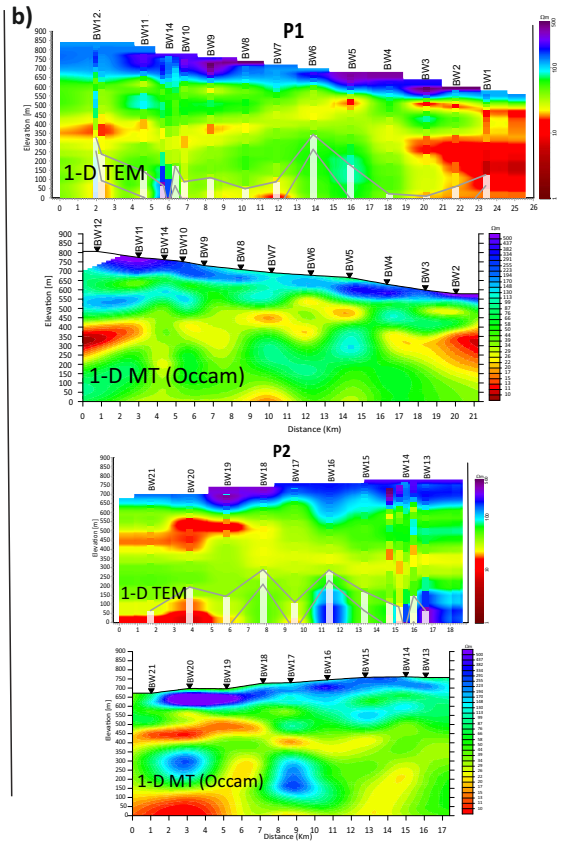
If the data indicate to one-dimensional underground, the TEM data can be used to correct the static shift effect in MT data (e.g., Ruthsatz et al.,2017) as shown in a) (left) for a representative site BW11 from the profile P1. This was done as follows:
- Calculation of 1-D TEM models with SPIA software from TEM data (Auken et al., 2014).
- Calculation of forward MT responses from 1-D TEM models in frequency domain with Winglink . These model responses are free from static shift.
- Comparison of 1-D MT model responses with MT invariants calculated from the MT impedances.
- Shift of MT invariants along the vertical axis until they coincide with the static shift-free MT 1-D model responses (static shift correction of invariants).
- Calculation of one-dimensional models (Occam) from the static shift-corrected MT invariants.

1-D TEM and MT (Occam) models (after the static shift corrections) along the Profiles P1 and P2 are presented in b) (right) as cross sections.

a)



b)



The knowledge about the geological structures is based on the structure contour maps according to which the thickness of the basalt layer varies between 85m in the south and 300m in the north (Margane et al., 2015). The 1-D TEM and MT conductivity models indicate a depth-varying conductivity of this layer. Inhomogeneities in the basalt are also observed by first seismic test measurements in 2015 (Noell et al., 2015). The inhomogeneities can be explained by the formation process of the basalt. It assumed that the basalt formed over previously weathered Cenozoic surface by successive basaltic lava flows and periods of weathering. Borehole data reveals basalt interlayered by several red soft clay layers up to more than 300m depth. The generally poor resistivities of the basalt are also observed in previous studies in the neighbouring area and coincide with a high hydraulic conductivity, which is probably caused by a water-saturated fractured and porous rock matrix (Yogeschwar, 2014).
The modeling (also 3-D) is still ongoing and the interpretation, of in particular deeper aquifers and aquitards is skipped here. For a hydrogeological interpretation of the TEM and MT models, data from a planned borehole is of great importance.

Conclusions/Outlook

- First geophysical investigation with 42 TEM and 25 MT soundings was conducted in the Aqeb and Basalt Wellfields in North Jordan and high quality data acquired. The data indicate a one-dimensional underground in shallow depths.
- Preliminary 1-D TEM and MT models are compatible. The modeling is still ongoing.
- Available (few) borehole data are used to constrain the resistivities and thicknesses of the underlying structures.
- The basalt cover is less resistive than usual and hetreogeneous (basalt aquifer).
- For a hydrogeological interpretation data from a planned borehole is important.

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