Version: May 15, 2024

Logistics

This exercises requires the usage of Matlab. We understand that some of you have not yet any contact with programming and that's ok. Here we use Matlab (or Python) just as any other software without the requirement of programming skills. Consider this as using a software while also seeing the insides of it. The only inconvenient thing to do is that you need to install the Matlab (or Python) environment. **This will not be in vain, for all of you an introduction to Matlab is mandatory at some stage so consider this as a headstart.** The learning goal is not on technicalities, instead you should internalize the principal of forward modelling how this can be used to interpret your field observations. You will use this approach again during the applied field exercises.

Date until which this should be done: Thursday 10th lecture.

Useful resources: ZDV Matlab Installation - `https://uni-tuebingen.de/de/3078`

Background: Resistivity and Induced Polarization (Binley and Slater via library) `https://www.cambridge.org/core/books/resistivity-and-induced-polarization/A767136D8C584D3820D1A810381891ED`

1 Exercises for Resistivity mapping

1.1 Matlab Installation

Install Matlab using the instructions provided by the ZDV using the link above. No special toolboxes are needed for this exercise and a basic installation should suffice. If you encounter troubles, do not spend too much time on it but rather contact us early (e.g., Paulina). Alternatively, you can use the computers of the GUZ Computer pool (Level 2) or we may even be able to organize a temporary Laptop for you. Use this opportunities and make it work, you will need it again for the applied exercises.
In order to check if everything works, download the Matlab files from Ilias and store them in a local directory. Both files must be in the same directory. Then open Matlab, open the VESModelling.m and press on the green "Run" button. A Figure should open and you are good to go!
If you are already experienced and you want to use Python instead, we also provide a Python version. In this case we assume that you broadly know what you are doing. A basic Python installation (with numpy, matplotlib etc) should suffice.

1.2 VES forward simulations for different scenarios

Use the Matlab script to simulate a possible sub-surface scenario which you may encounter in a fluvial setting such as the Neckar valley: dry top soil (thickness $d_1 = 0.5m$), dry gravel (thickness $d_2 = 0.5m$), semi-saturated vadose zone (thickness $d_2 = 1.5m$), fully-saturated aquifer (thickness $d_2 = 2m$), some type of bedrock. Try to find values for the resistivities of the materials online or in textbooks. Answer the following questions:

- What are expected apparent resistivities ρ_a for a sub-surface scenario described above?

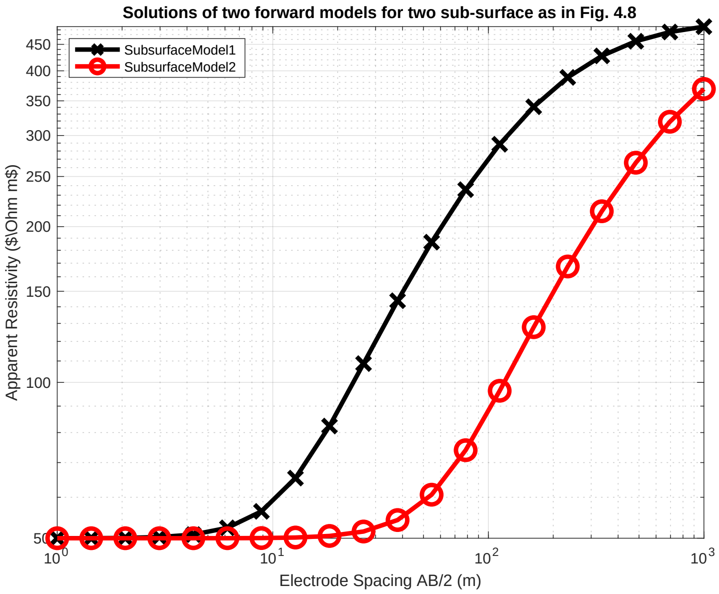

Figure 1: This is a reproduction of Fig 4.8 in Binley & Slater. If you see this Figure your Matlab installation works well.

- What type of electrode spacing would you suggest to recover the full signal with the minimum amount of work? Is a linear or a logarithmic spacing interval better?
- Do you get the expected end member apparent resistivities for very small and very large spacings, respectively?

1.3 The LaPlace Equation

(*Level 1*) In the lecture we derived that the potential field of a single electrode (second electrode is located at infinity) satisfies the Laplace equation:

$$\vec{\nabla}^2 V = \Delta V = 0.$$

Show that our *Ansatz* $V(r) = \frac{A}{r}$ satisfies this equation in spherical coordinates. Note that the Laplace operator in spherical coordinates is $\nabla^2 = \frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2\frac{\partial}{\partial r}\right)$.

1.4 Geoelectric Array Types

(a, level 1) Show explicitly that for a Wenner (α) array the geometry factor is $K = 2\pi a$ where a is the distance between between all electrodes.
(b, level 1) In preparation of the applied exercises, make a table with the different array types (Wenner α, Schlumberger, and half-Schlumberger (or pole-dipole), and dipole-dipole). Without going into too much detail, mention two importantpoints that require consideration when choosing a specific type.

1.5 Appendix

```
%Make sure that VESForward_RD.m is in the same directory as this script.

%Clear all variables and figs from previous runs
clc; clear; close all;


%% In this block you will need to change the numbers!
%% Here we exemplify how to get Figure 4.8 in Binley and Slater
%% ------------------------------------------------------------------------

%The Subsurface model is defined by the resistivities (first) and
%layer thicknesses (last). A three layer model with two
%boundaries would be:
% SubSurfaceModel = [Resist1, Resist2, Resist3, Thick1,Thick2]
%Here we assume two, two-layer models:
SubSurfaceModel1=[50,500,10];
SubSurfaceModel2=[50,500,50];

%This defines the number of Meausrements
NumberOfMeasurements=20;

%This defines min-max Distance between A and B in meters
MinABDistance = 2
MaxABDistance = 2000

%This defines the spacing of measurements
%Do you want to do it linearly or logarithmically? Try it!

%Linear spacing
% L = linspace(MinABDistance/2,MaxABDistance/2,NumberOfMeasurements);
%Logarithmic spacing
L = exp(linspace(log(MinABDistance/2),log(MaxABDistance/2),NumberOfMeasurements));
%% ------------------------------------------------------------------------

% Running the forward model. Here we do it twice for the two
% models defined above. If you change this, change it here as well.
%% ------------------------------------------------------------------------
ApparentResistivity1 = VESForward_RD(SubSurfaceModel1, L)
ApparentResistivity2 = VESForward_RD(SubSurfaceModel2, L)


% Visualizing the results
%% ------------------------------------------------------------------------
figure(1)

loglog(L,ApparentResistivity1,'k-x','LineWidth',3,'MarkerSize',13); hold on
loglog(L,ApparentResistivity2,'r-o','LineWidth',3,'MarkerSize',13);grid on
legend('SubsurfaceModel1','SubsurfaceModel2','Location','northwest')
xlabel('Electrode Spacing AB/2 (m)')
ylabel('Apparent Resistivity ($\Ohm m$)')
title('Solutions of two forward models for two sub-surface as in Fig. 4.8')
%Export Figure as PDF
%saveas(gcf,'Outputfig.pdf')
```

Src/VESModelling.m