A simple downhill descent technique for 3-D Inversion of MT data

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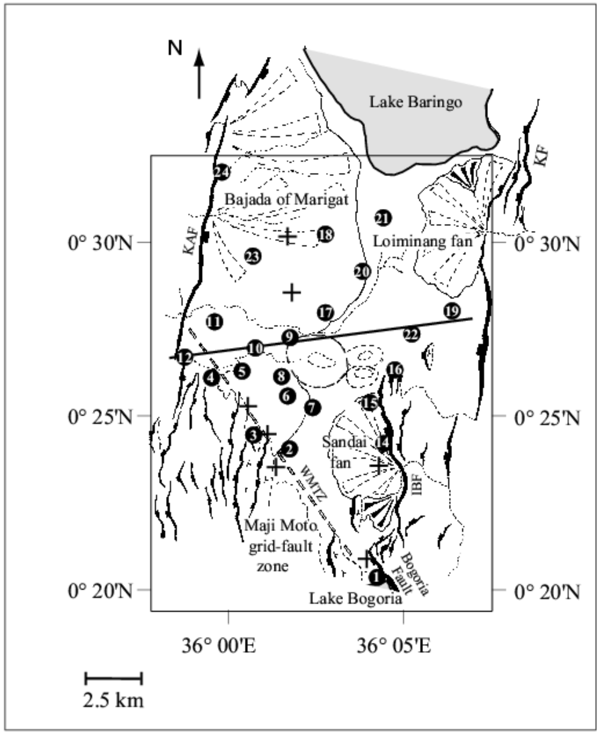
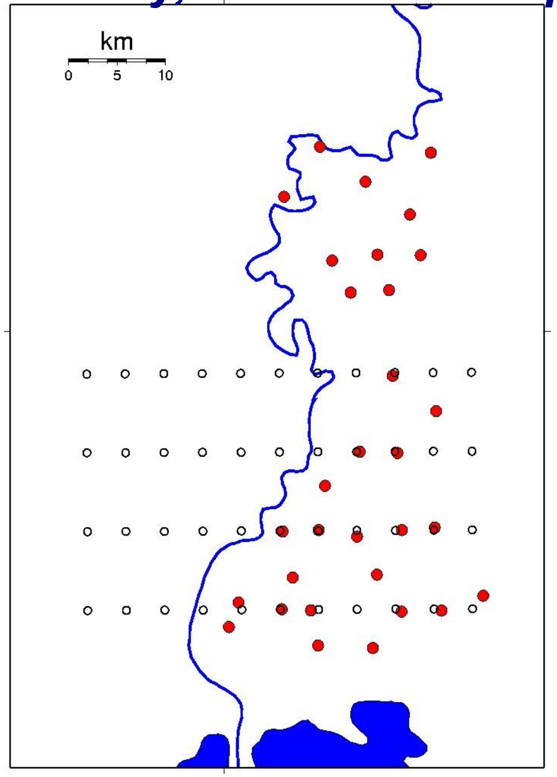
3-D Inversion of MT data

We developed a 3-D inversion scheme of the full MT tensor for the interpretation of real data with a non regular distribution (crustal studies).

Kenya rift



Omo Valley, Southern Ethiopia



3-D Inversion of MT data

Our 3-D inversion technique is based on an iterative procedure :

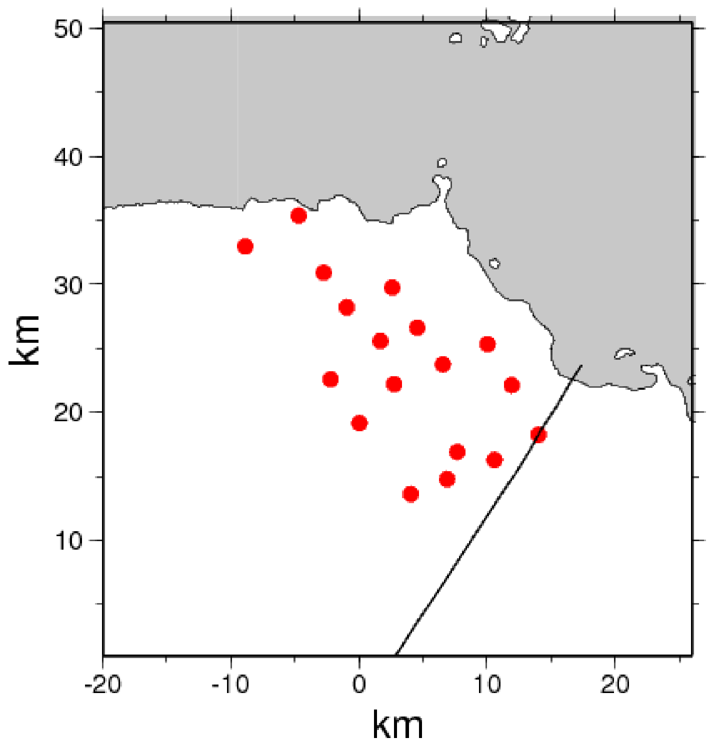
- Minimisation of an error function (χ^2) between the observed data and the model response using a non-linear steepest gradient method

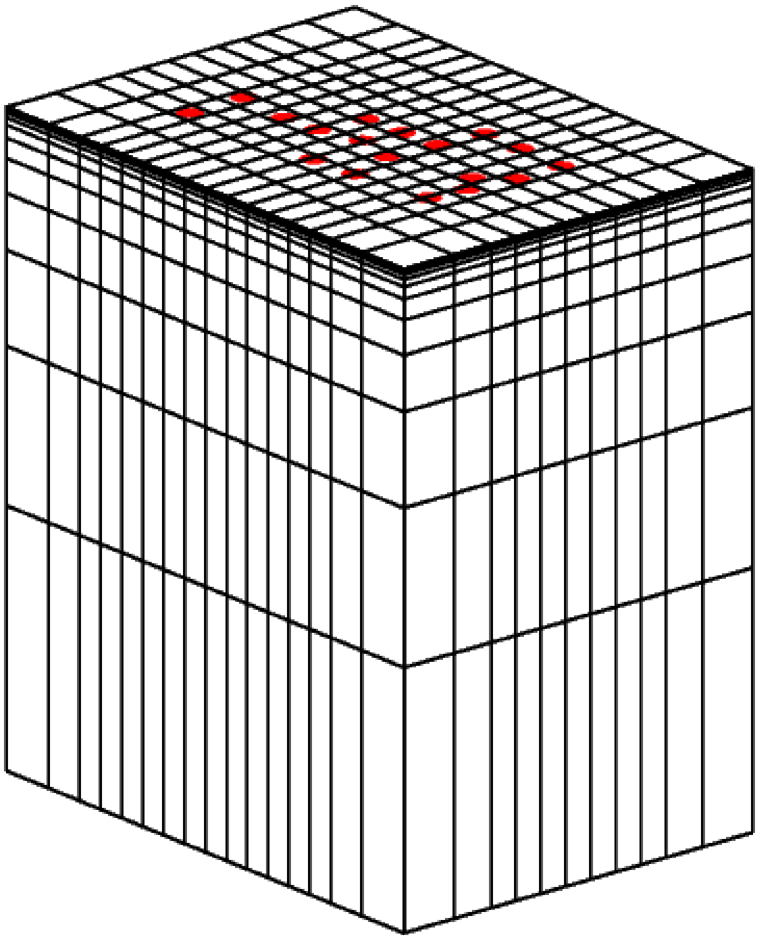
- Each iteration is a call to a forward solver (here 3-D FD code (Mackie et al., 1993)).

- Data : The 4 complex elements of the MT tensor at all available frequencies (as well as tipper if available).

The initial model

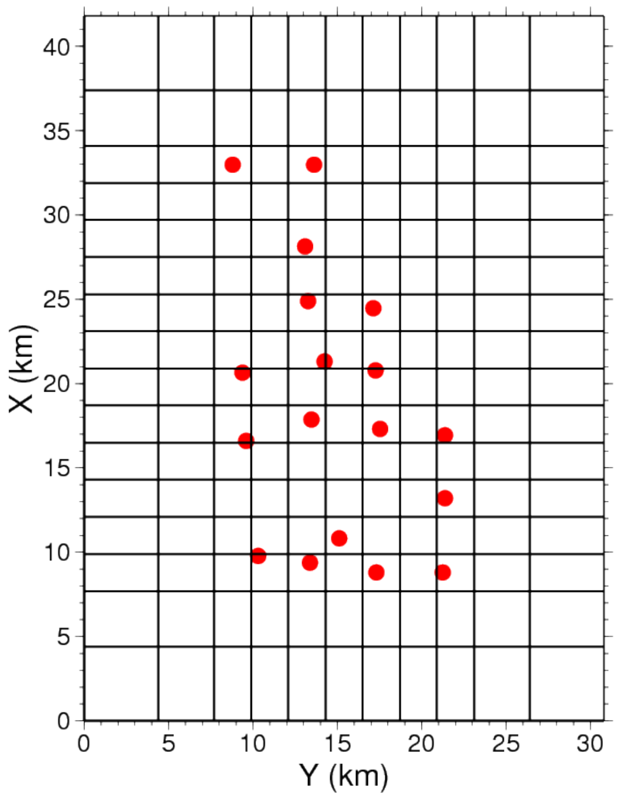
A 3-D grid for the forward computation is generated according to the data distribution and the period range (and estimated skin depth).



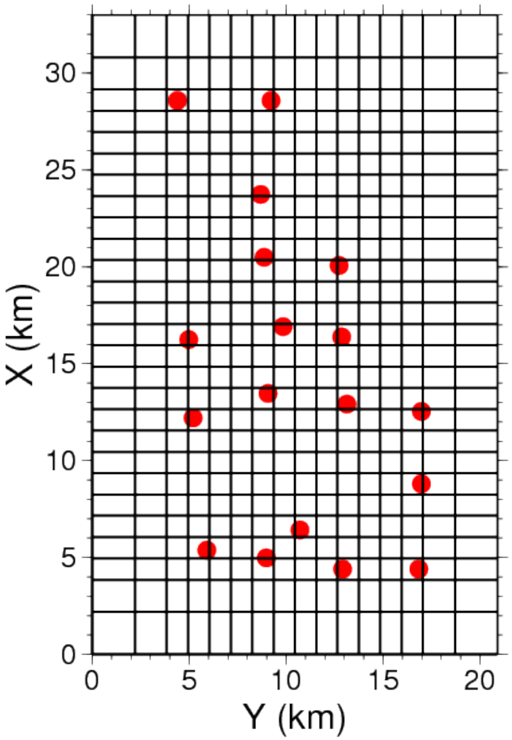


The initial model

We decide the size of the cells depending on the data quality, the heterogeneity of the structures, the ratio parameters/data,..



shortest distance between 2 sites



Half the shortest distance between 2 sites

The data and error function

Data : The 4 complex components of the MT tensor

$$\chi^2 = \sum \frac{(Zm - Zd)^2}{\sigma^2 w^2} + R$$

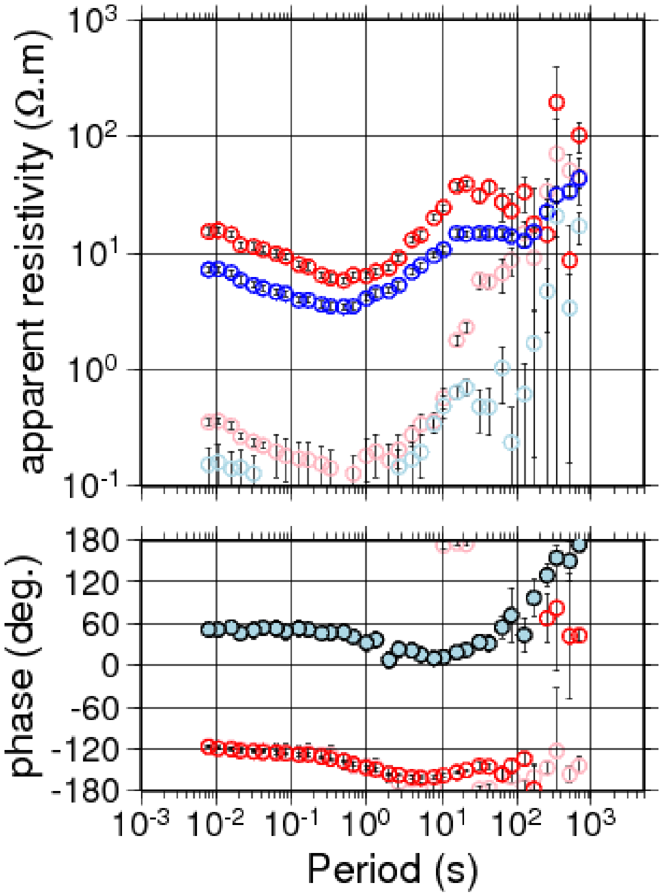
Zm : Response of the model (real and imaginary part of the 4 components)

Zd : Data (real and imaginary part of the 4 components)

σ: Data error = standard deviation of amplitude of Z with an error floor of 3% (20% for very small values).

w: weight (by default 1, only applied for outliers with small standard deviation)

R: regularisation term to prevent large resistivity contrast between adjacent cells

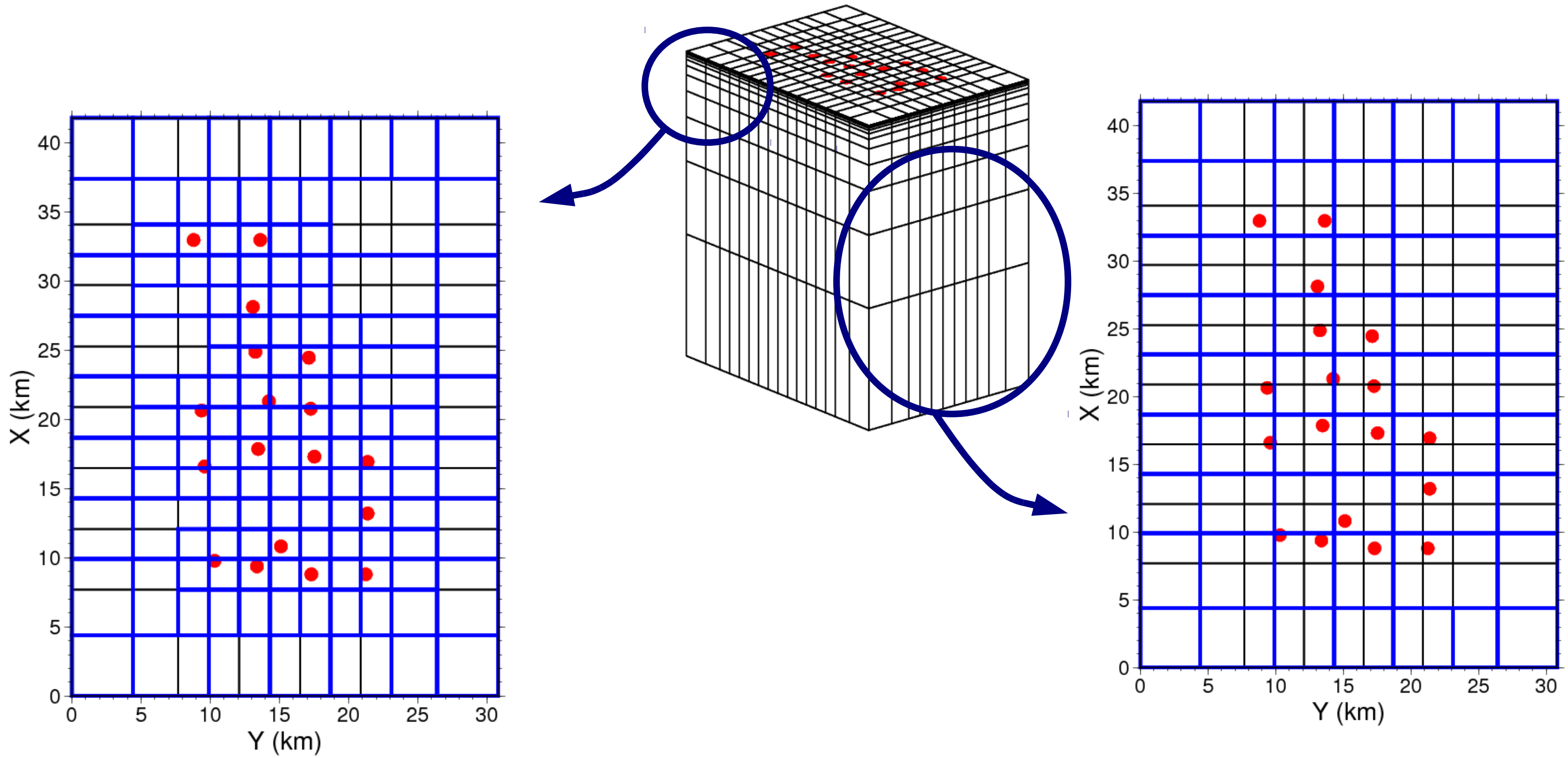


The parameters used for the inversion

The grid used for the inversion is different from the grid used for the forward calculation

In the uppermost layers, the size of blocks increase with the distance to MT sites

In the deeper layers, the size of block is larger

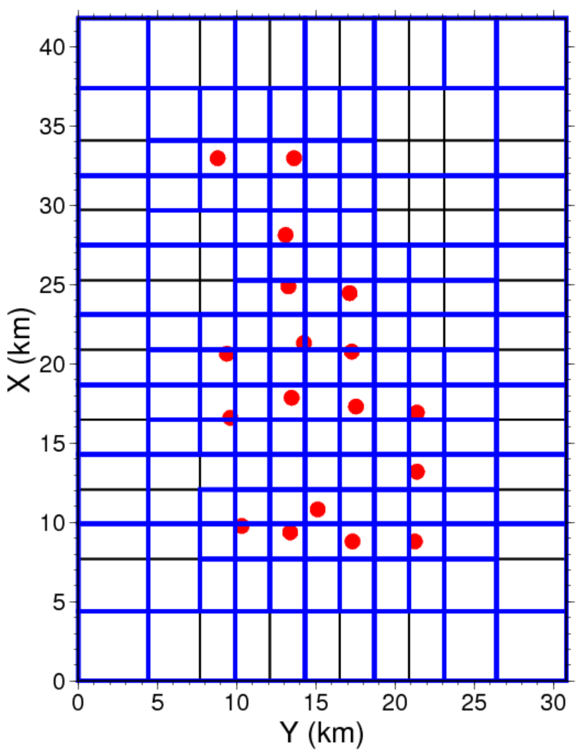


Strategy used for the inversion

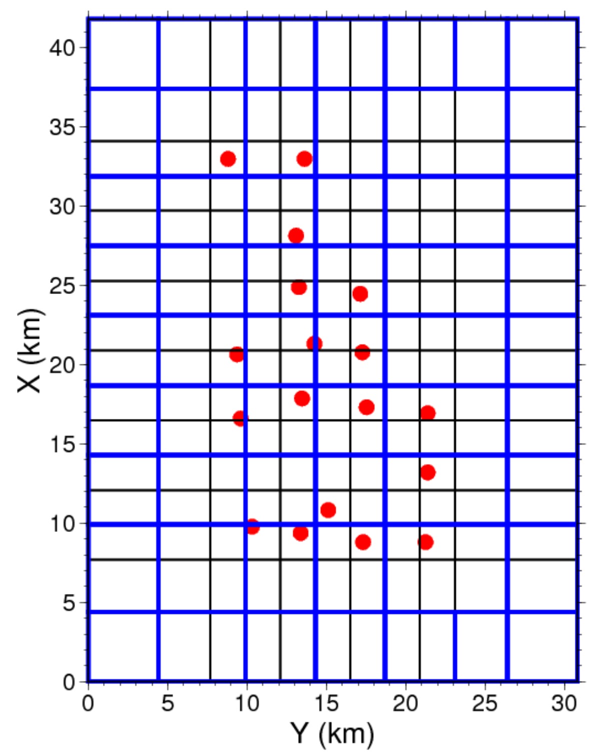
Three different steps are considered for the inversion

Step 1 : Fast progression of the descent technique. Allows to find a solution for the regional structure with a limited number of parameters

Larger resolution down to a depth ~ size of the cells



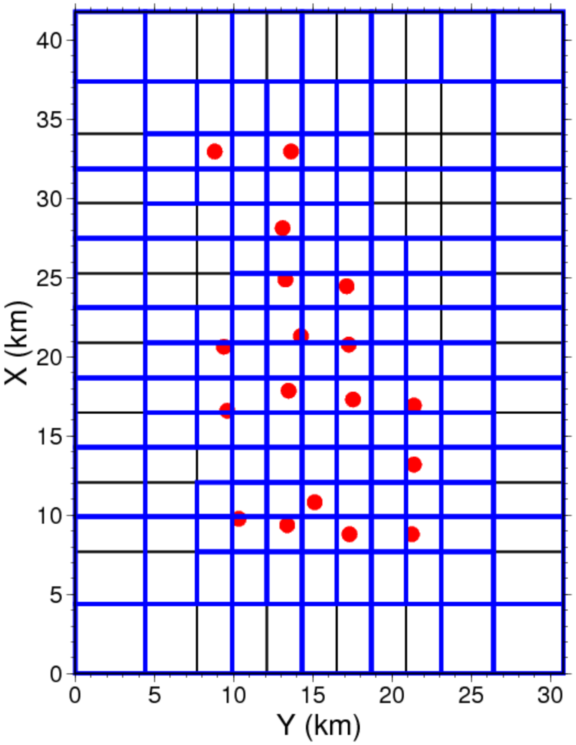
«Coarse» grid in the deeper layers



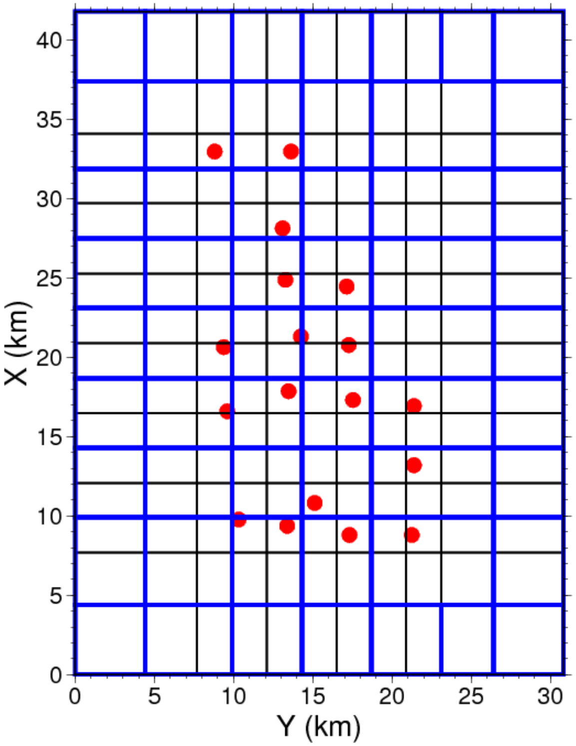
Strategy used for the inversion

Step 2 : Slower progression of the descent technique (in order to refine the resistivity structure) and increased number of parameters.

Larger resolution down to a depth ~ twice the size of the cells



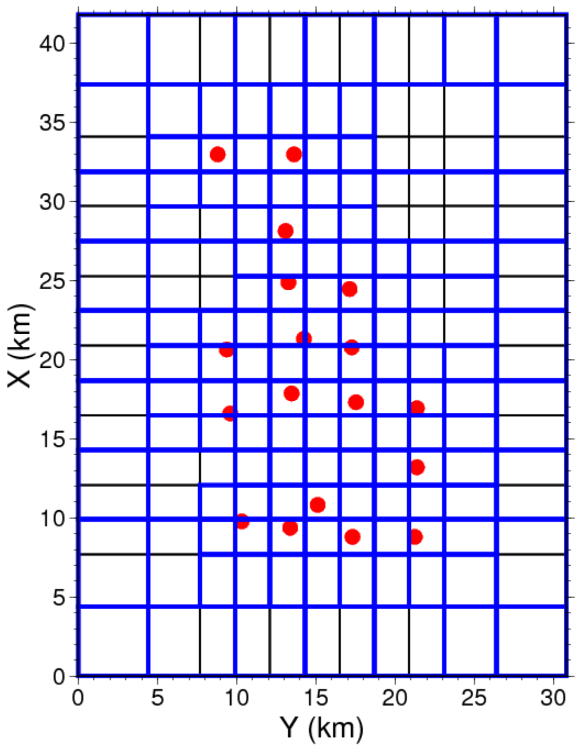
«Coarse» grid in the deeper layers



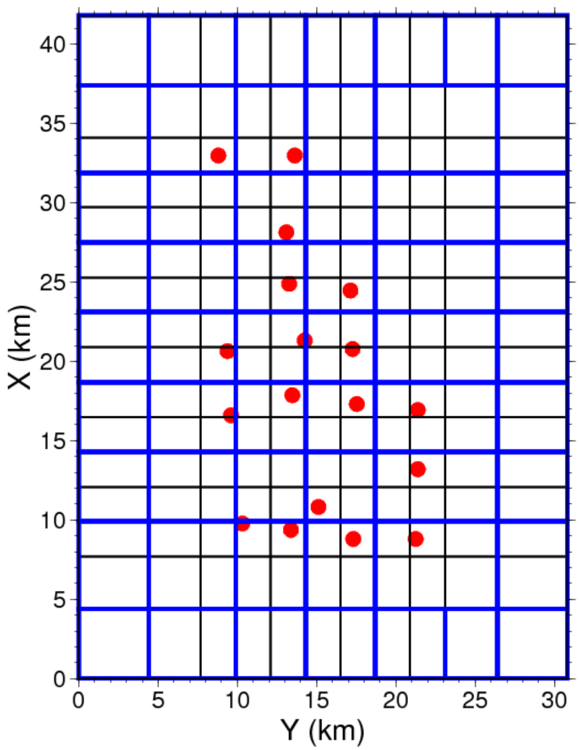
Strategy used for the inversion

Step 3 : Same as step 2 but a regularisation term is added to the error function

Larger resolution down to a depth ~ twice the size of the cells



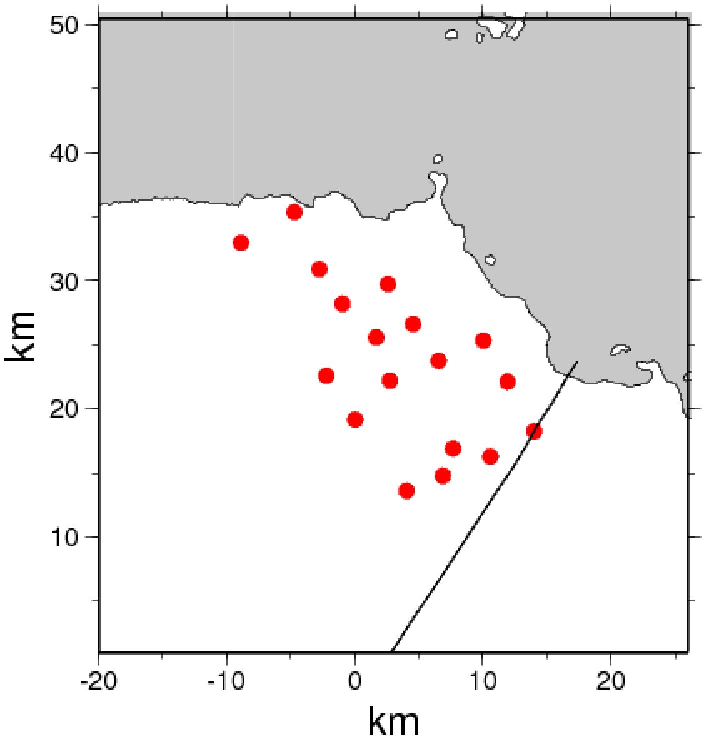
«Coarse» grid in the deeper layers



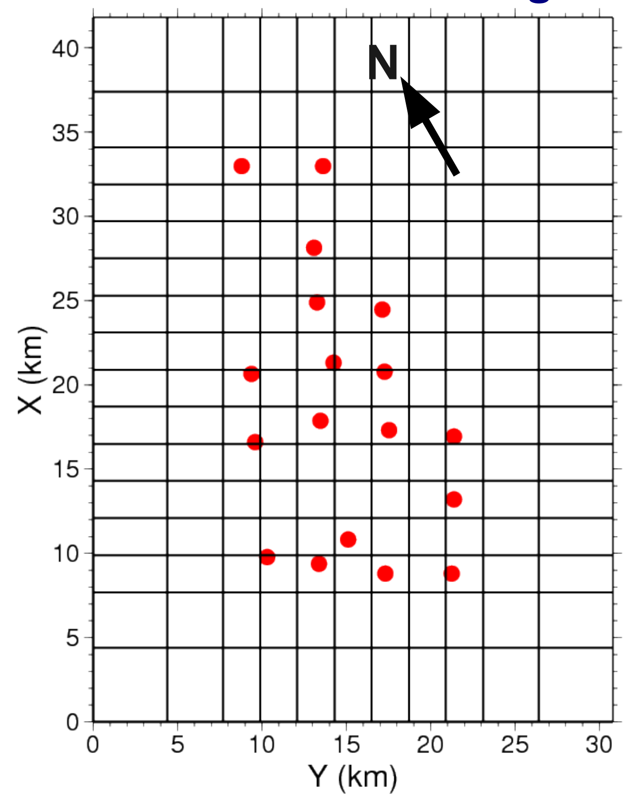
Example of real data set 3-D inversion

18 MT sites collected in the Republic of Djibouti

Location map



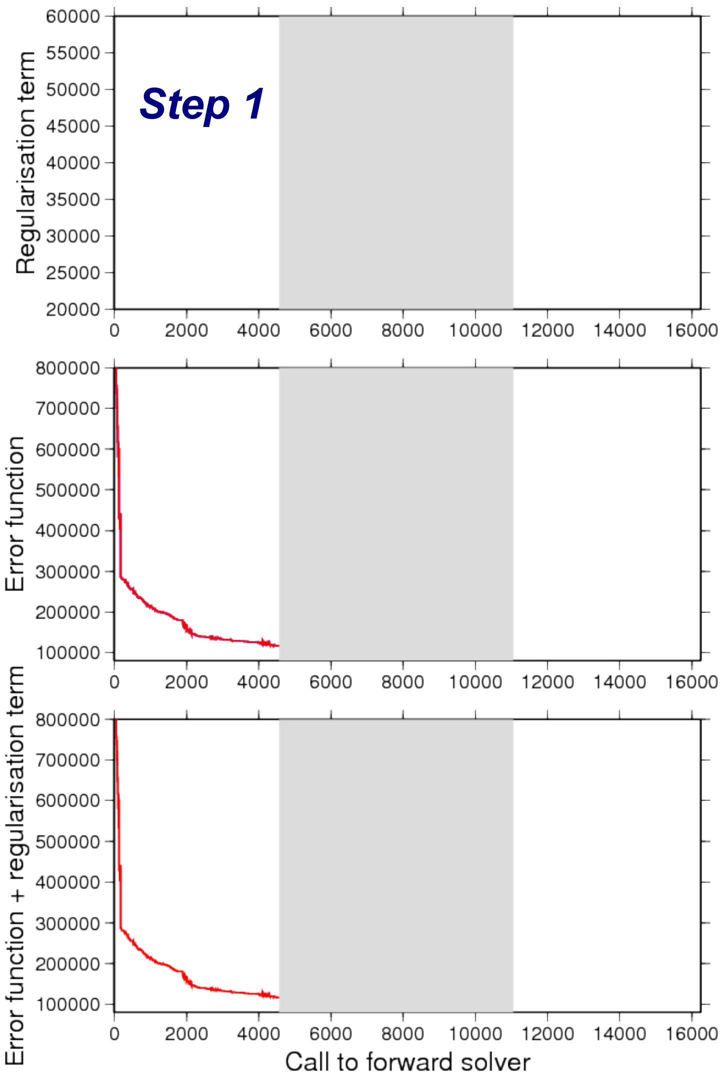
Plan view of the 3-D grid

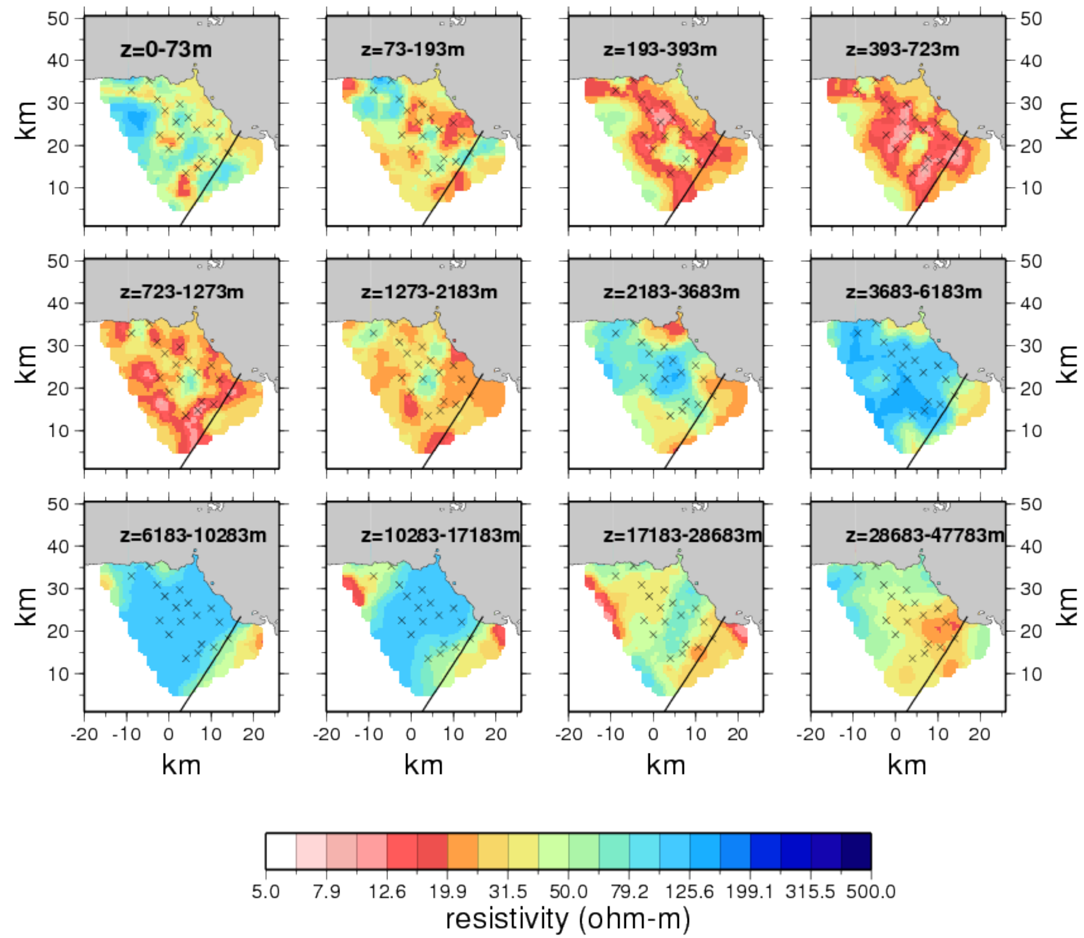


30 Ohm-m homogeneous half-space
Maximum number of unknown: 1300
Number of data: 4240

Example of real data set 3-D inversion

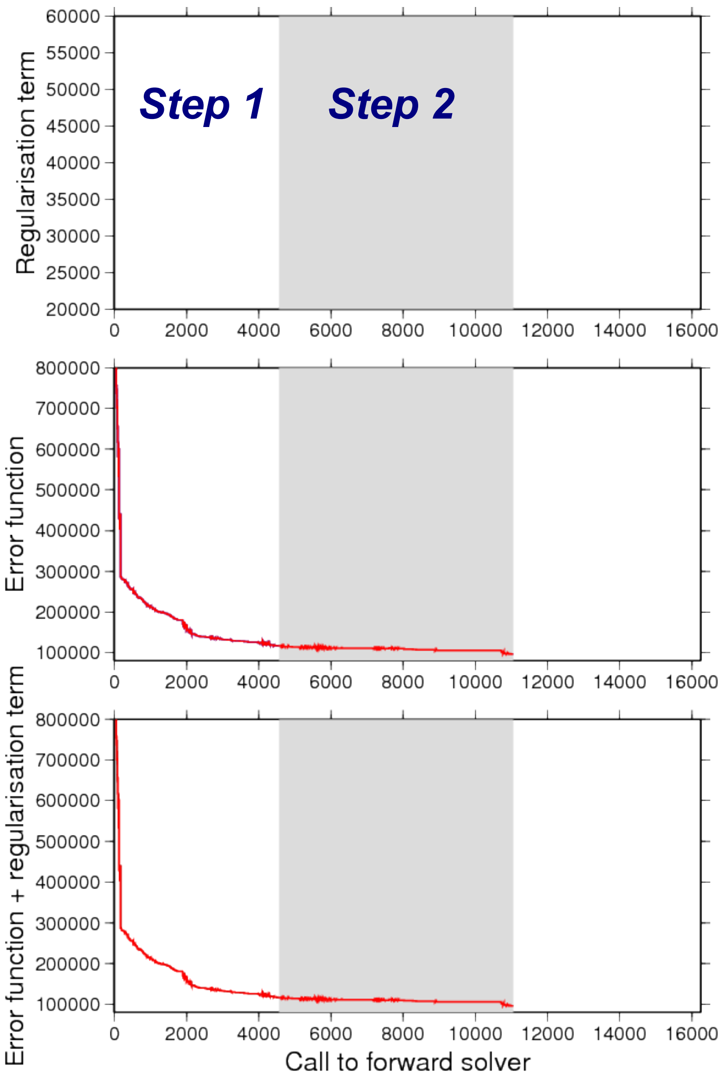
Result after step 1

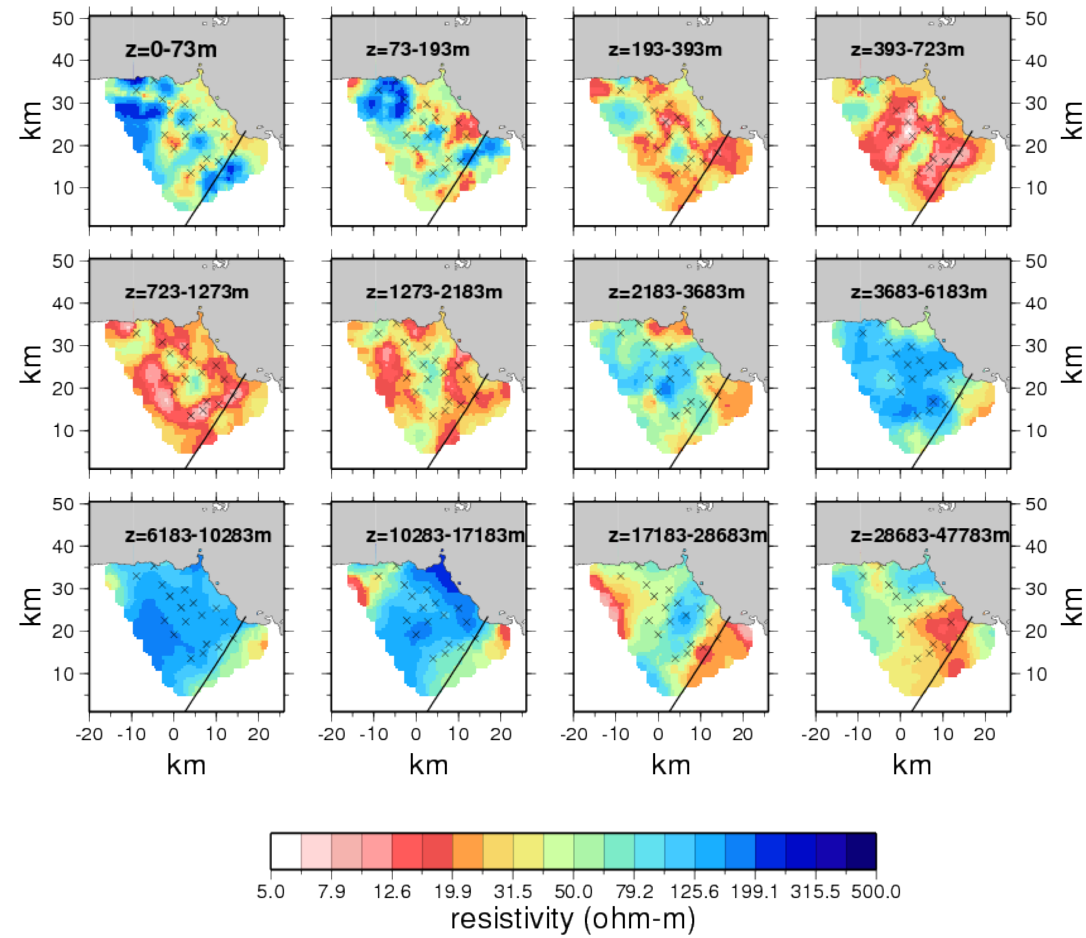




Example of real data set 3-D inversion

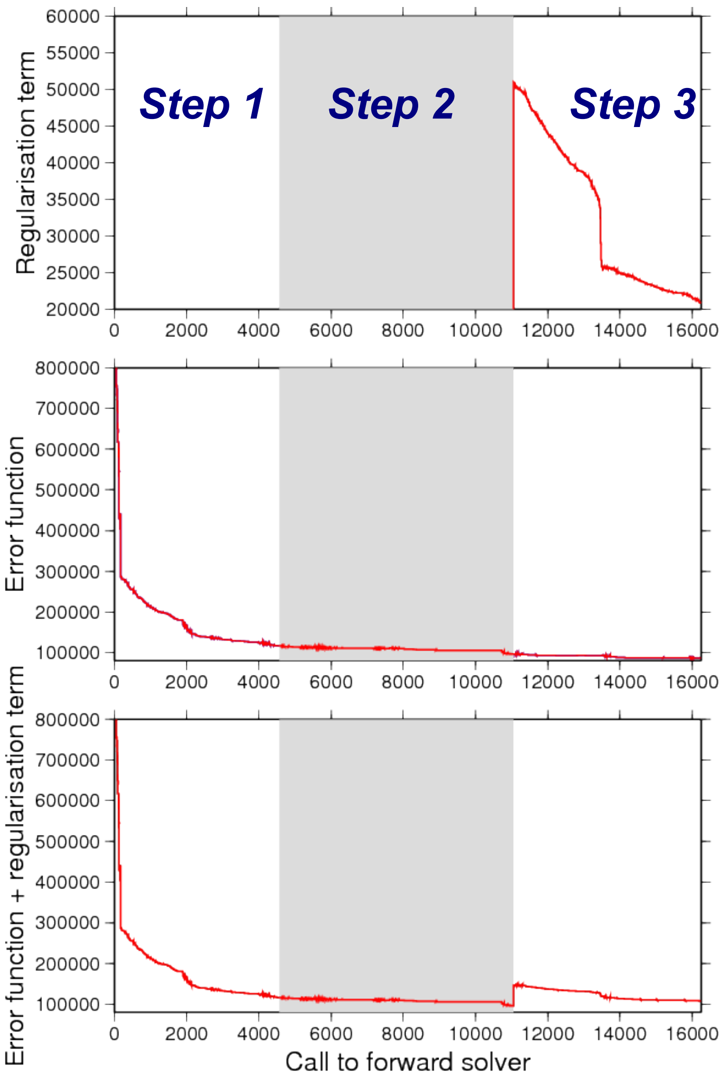
Result after step 2

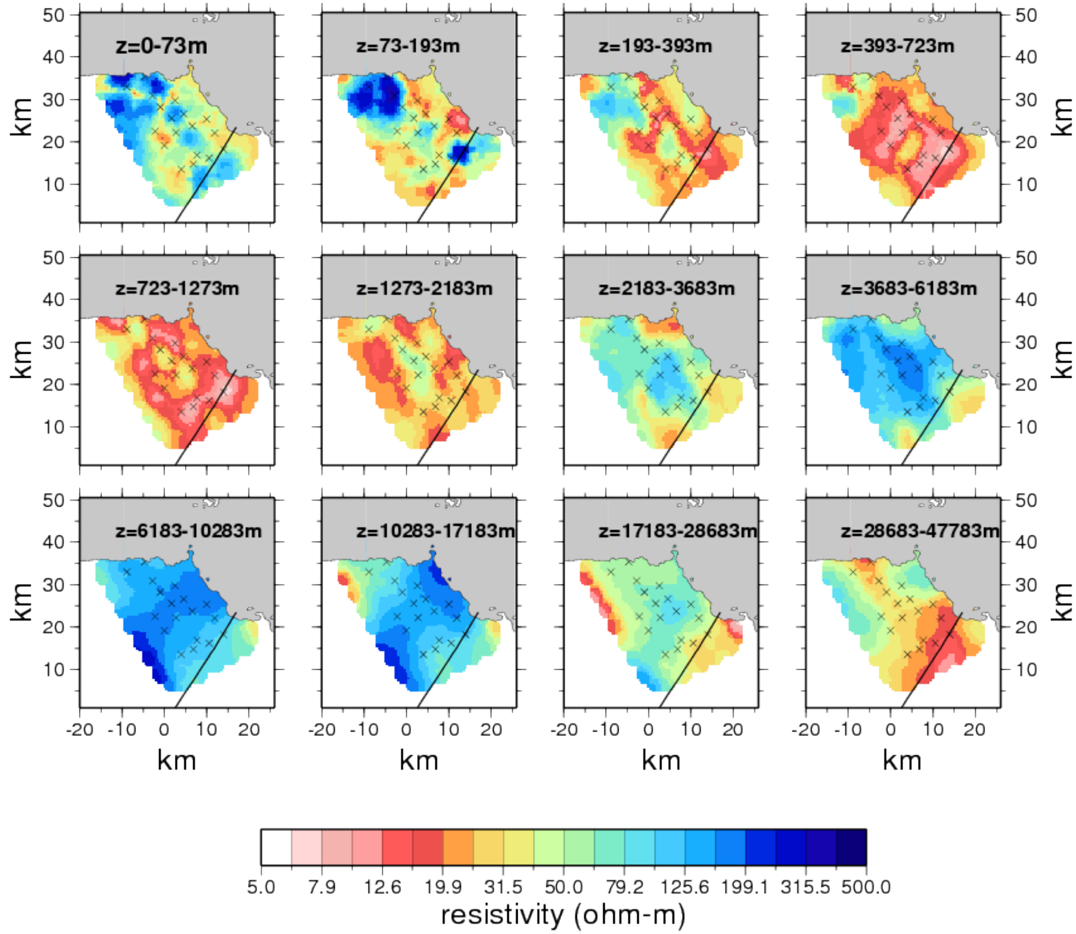




Example of real data set 3-D inversion

Result after step 3





Example of real data set 3-D inversion

Some examples of misfit between the model response and the observed data