Depth of Investigation

The depth of investigation (DOI) is a tool for the evaluation of inversion results. For diffusive methods, such as ground based or airborne EM, there is no specific depth below which there is no information on the resistivity structure. The question is to which depth the model is most reliable.

The DOI-method used by Aarhus Workbench is based on the actual inverted model, and it includes the full system transfer function and system geometry, using all measured data and their uncertainties. The methodology is based on a recalculated sensitivity (Jacobian) matrix of the final model. A priori information, model constraints or other information added to the system are not considered. Thus, the DOI is purely data driven.

To demonstrate the methodology, consider an example with SkyTEM data. Assuming a simple three-layer model like the one described on Figure 1, the sensitivity function can be plotted versus depth (left image in Figure 1). The sensitivity function comes directly from the recalculated sensitivity matrix (Jacobian). As expected, the sensitivity to the second layer is low, whereas there are high sensitivities to the first and the third layers.

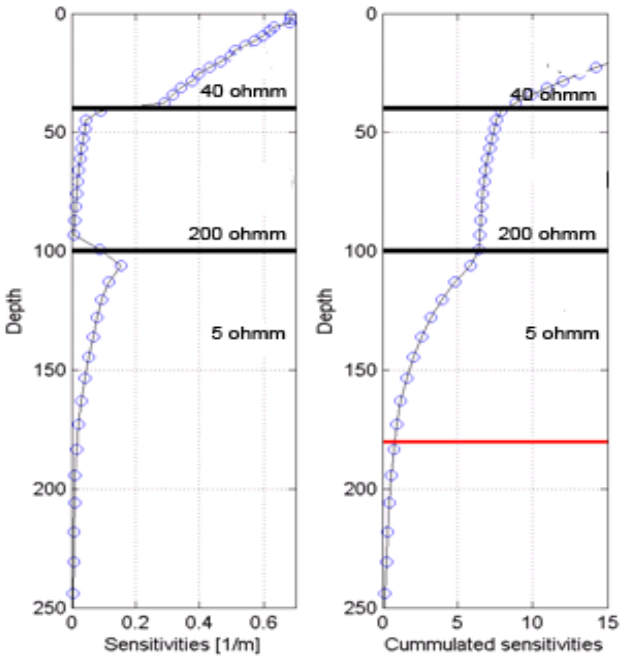

Figure 1. Sensitivities calculated for a rediscretized version of the model indicated by the black lines; resistivities of layers are written on the plot. The left plot is the sensitivity function itself. The right plot shows the cumulated sensitivities. The red line indicates the DOI given by the global threshold value.

If the sensitivities are summed up from deep to shallow, the right side image in Figure 1 emerges. This plot shows the total sensitivity in a given depth and downwards. Next, a threshold value that indicates the minimum amount of sensitivity needed for reliable information is set. In the example in Figure 1, a threshold value of 0.8 was settled upon, giving a DOI of approximately 180 m.

Setting the threshold value is very much a question of tuning based on experience and comparing different models with different methods. The threshold value used here has been tested on many different models and with different systems and produces trustworthy results. The same global value is used for airborne and ground based DC and EM methods with one exception. TEMPEST data inverted with reinstated primary field need a different threshold value to give comparable values to traditionally inverted TEMPEST data.

Understanding the setup

There are a few more implementation details that it is worth knowing about when using the DOI. The precision of the DOI calculation is limited by the number of layers used in the calculation. This was a potential problem for few-layered models like the one shown in Figure 1. Rather than using the layers in the actual model, the final model is sub-discretized and it is those layers (the center of the blue circles on Figure 1) that end up being used. Additionally, the DOI is interpolated between the layers to allow for greater precision. The example in Figure 1 would have produced reasonable precise DOI values of 3-5 meters already with 12-15 layers, but more are often used.

In practice the setup of these layers are done through the advanced configuration settings for inversions.

- **DOI**: This controls whether the DOI is calculated or not.
- **DOINLayers**: This sets the number of layers in the DOI calculation which controls the discretization intervals of the DOI calculation. More intervals will increase the computation time, while fewer intervals will decrease the accuracy of the DOI calculation. The final DOI values are found by interpolation between the layers.
- **DOIDepth1**: This sets the minimum depth of the discretization intervals which should reflect the ideal resolution capabilities of the used system/method.
- **DOIDepthN**: This sets the maximum depth of the discretization intervals which should reflect at least the maximum depth of investigation by the used system/method.

The first and last layer setup here are not based on the used model, but rather on the capabilities of the used system/method. The idea here is, that even for a smooth model, the DOI should be setup to look deeper than the actual model, because it should be able to map the DOI in areas where it might be deep enough to go into the last infinite depth layer of the model.

Understanding the results

The DOI is purely data driven, which means that information above the DOI is data controlled whereas the information below the DOI is mainly controlled by the inversion settings, such as starting model, lateral and vertical constraints. Thus, sometimes the DOI is well above the deepest layers of the model.

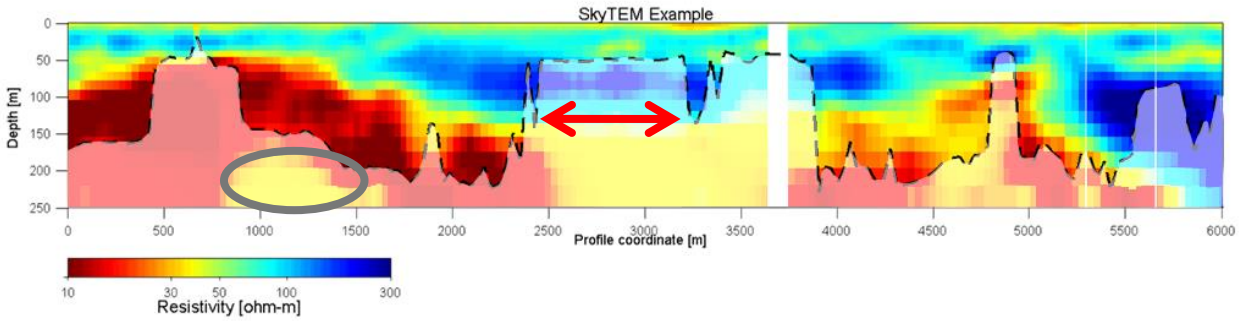

Figure 2. SkyTEM resistivity section example with DOI shown as a black dashed line. In the area marked with a grey circle, the DOI indicates that there is no information on the less conductive structure. The red arrow marks an area where the high-moment data are missing, which results in a shallower DOI.

Figure 2 shows a smooth inversion of SkyTEM data from Denmark. The black dashed line indicates the DOI. In the area marked with the grey circle, the DOI indicates that data have no information on that less conductive structure. The arrow indicates an area where the high-moment data are missing, which means a shallower DOI. The effect of the constraints is clearly seen as the high-resistive layer is nicely pulled through to create a geologically reasonable interpretation. This is exactly one of the main functions of the constraints - they are user defined numbers for the geological homogeneity and thus ensure model smoothness even in areas with limited information from the data themselves.

The implementation allows for two DOI values to be displayed with slightly different threshold values. A standard DOI value (a threshold of 0.75) and a conservative DOI value (a threshold of 1.5). As a guideline the layers above the conservative DOI value are well founded in the data. The layers between the conservative and the standard DOI values are less well founded in the data. And finally the layers below the standard DOI are very weak in the data, and interpreting these parts of the model should be done with caution and a look to nearby models with a deeper DOI if present.

In practice most only use the standard DOI value, but being able to show both DOI values can in some cases be beneficial as it makes it possible to say something about how steep the sensitivity curve is near the two threshold values.

The article that introduced the depth of investigation can be found here.