VOXI Earth Modelling - Exploring Inversion Solution Space

Introduction

Voxel inversion of geophysical data is ill-posed: there are many models which satisfactorily fit the observed data. Producing one model which fits the data is certainly helpful, however, it would be far more informative to produce a suite of models; all of which also fit the data, and in this sense, to explore the space of viable inversion solutions. In this guide, we demonstrate how this can be achieved in VOXI, with respect to both the depth of sources (i.e. maximum physical property contrast) within the model, and their geometry (shape).

Exploring Inversion Solution Space

We begin by considering a simple prism in a half space model as shown in *Fig. 1*. For simplicity, in all that follows, we will view only the E-W section through the centre of the model. Simulating the TMI response at the magnetic pole over the prism yields the data shown in *Fig. 2*. Inverting the TMI data yields the result shown in *Fig. 3*. We will call this the "default" VOXI result and we can see that it is a reasonable approximation to the true model.

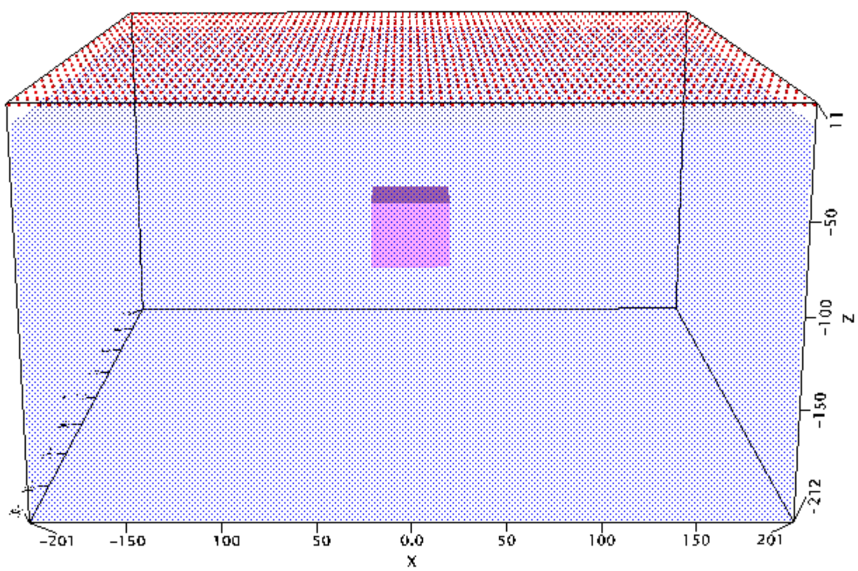

Fig. 1: The Prism Model

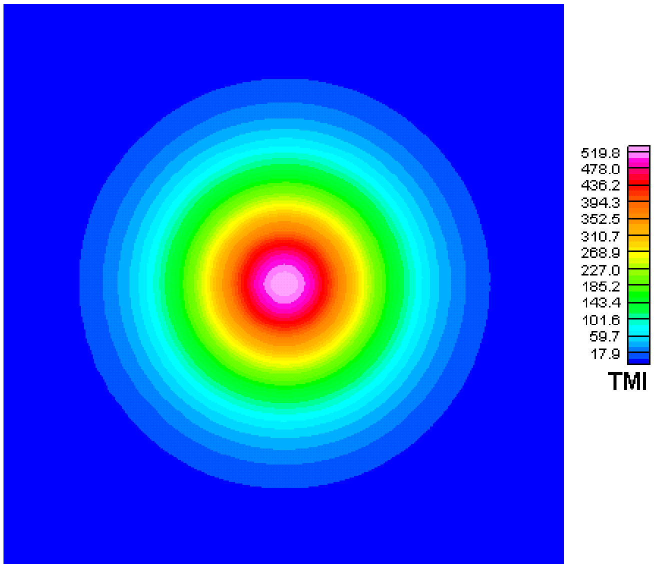

Fig. 2: The TMI response of the prism model

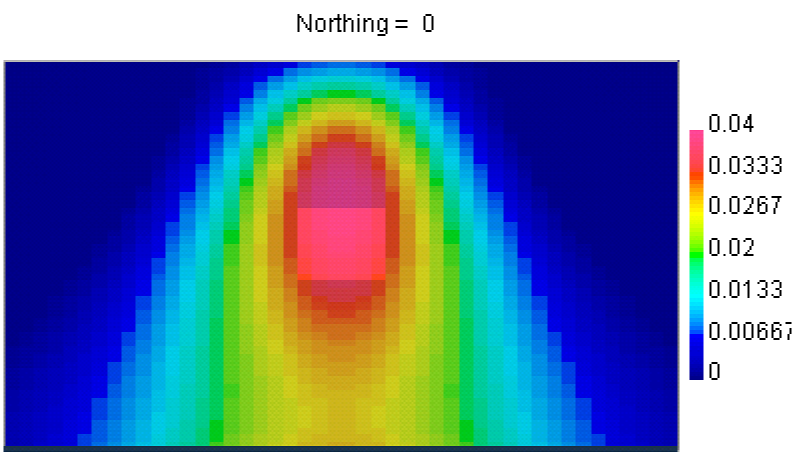

Fig. 3: East-west vertical slice (Northing = 0) through the default VOXI inversion result

Producing a Suite of Models

We can investigate a suite of models, all of which fit the same data, by varying the depth weighting. In VOXI, we do this by generating a vertically varying voxel model and using it as a reweighting constraint. In *Fig. 4*, we show E-W trending vertical slices from a suite of models, together with the corresponding depth reweighting function.

Proceeding from top to bottom in *Fig. 4*:

1. Depth weighting z^{-1} produces a very shallow model,
2. Depth weighting $z_{\max} - z$ produces a somewhat shallow model,
3. Depth weighting 1 produces the default model,
4. Depth weighting z produces a deep model.

With an appropriate choice of depth weighting, the inversion output model transformed continuously between (and beyond) the cases shown in *Fig. 4*. In this manner, we are able to explore the space of viable solutions.

Exploring Inversion Space: Source Depth

We have produced a suite of models, all physically reasonable, and all of which fit the data shown in *Fig. 2*. In a mineral exploration context, in the absence of any other information, the geoscientist performing the inversion must keep in mind the ambiguity inherent in the geophysical data, and would be advised to convey that ambiguity to rest of the exploration team. Doing so will allow the team to decide on an appropriate strategy to reduce the ambiguity in the interpretation, leading to a more effective and efficient interpretation.

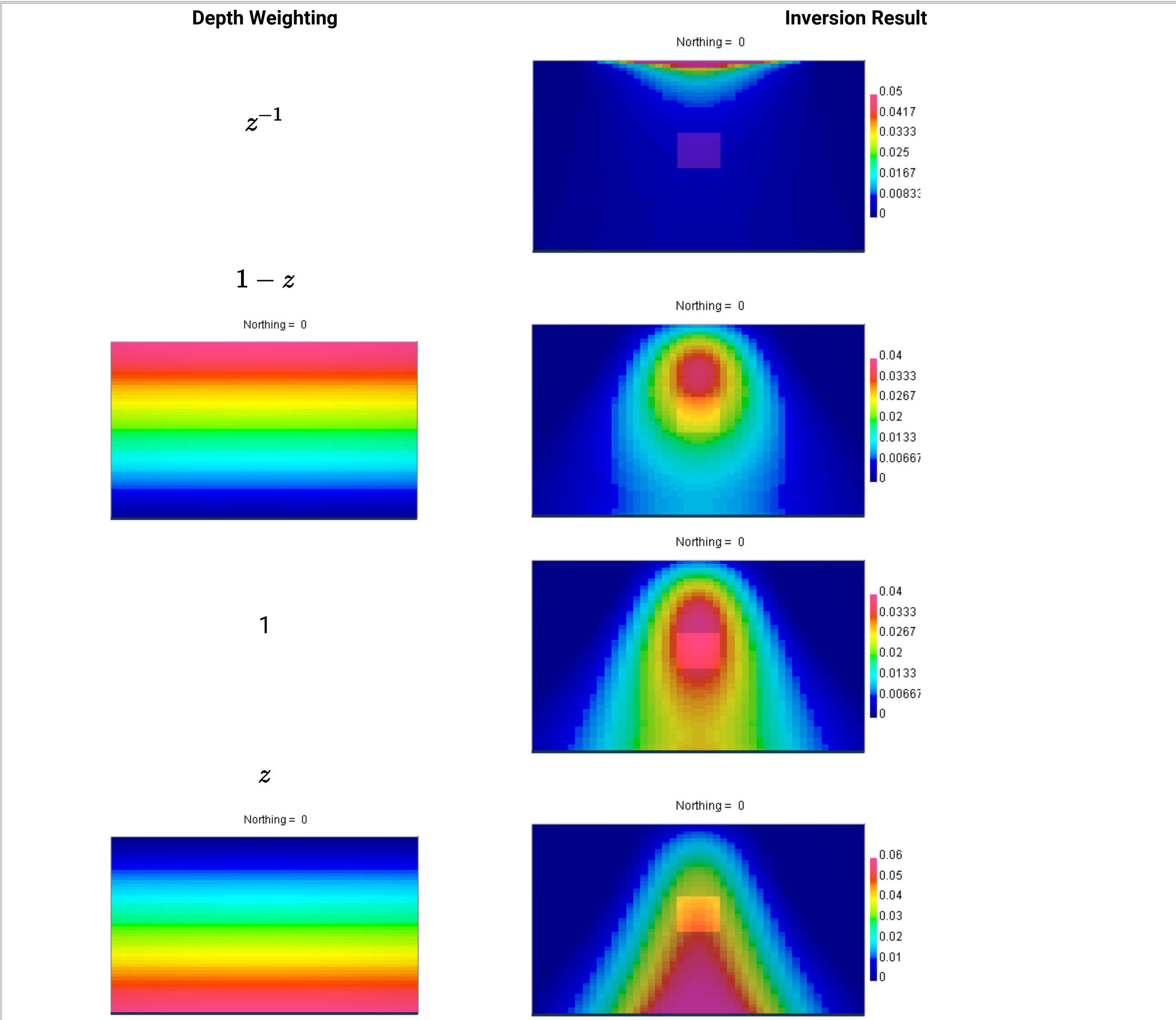

Fig. 4: On the left, the depth weighting function imported via the iterative reweighting constraint into VOXI. On the right, the corresponding inversion result.

Exploring Inversion Space: Source Geometry

In the previous section above, note how applying a depth weighting influences not only the depth, but also the shape of the source in the inversion model. One geometry that can be very difficult to return from unconstrained inversion in VOXI is that of a flat-lying lens or sheet type source.

In the example shown in *Fig 5* below, we demonstrate that this type of geometry can be returned by creating a depth weighting voxel, using the expression ($V_z = V_0 * (z_{max} – z)^3$). Applying this and the (on by default) IRI focusing constraints returns an inversion model that much more closely approximates the original model, shown at top right, than the unconstrained model (note the true prism location is superimposed on the vertical slices from each model).

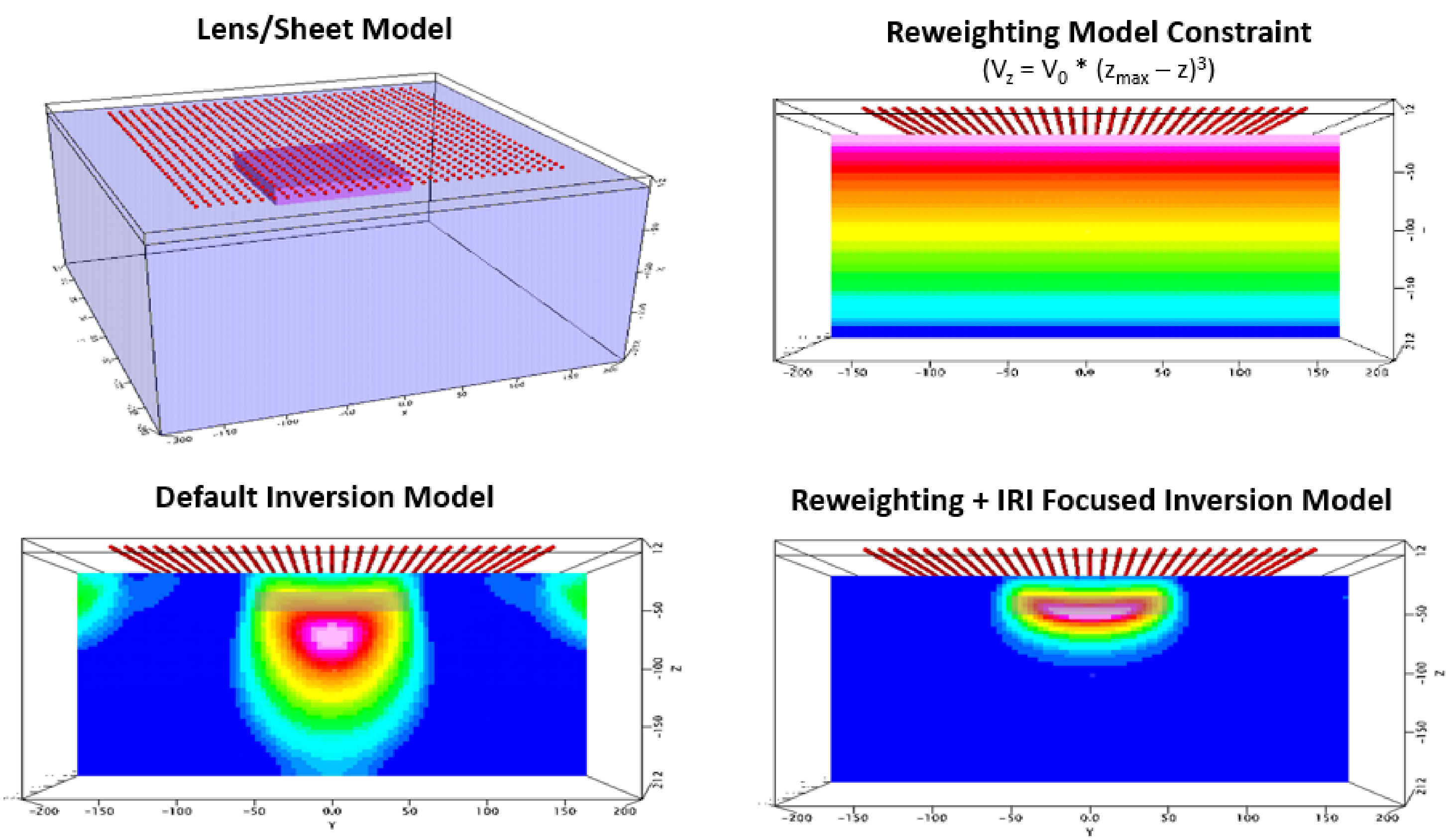

Fig. 5: A lens or sheet type model is shown at top left, along with vertical slices through the unconstrained inversion (bottom left), reweighting voxel (top right) and constrained inversion (bottom right), which closely appromiates the original model geometry.

Appendix

Here are the steps used to create and apply a reweighting model constraint:

1. Set up a VOXI session for your area of interest
2. Export the padded mesh as voxel V_0
3. Use voxel math to generate the depth dependent voxel V_z, for example V_z = V_0 * z to produce a deep model like that shown in *Fig. 4*, bottom panel.
4. Use V_z as the Reweighting model constraint in VOXI.
5. Run the inversion.

To change the depthand shape of the recovered target in the inversion, modify the depth weighting (z) component of the voxel math expression in step 3, as shown in Figure 4.