Oasis montaj Best Practice Guide

VOXI Earth Modelling - Rules of Thumb for Voxel Element Sizes

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Rules of Thumb for Voxel Element Sizes

Introduction

Voxel inversion, by definition, divides the earth into a number of voxel elements and solves for their associated physical properties. Ideally, the output from a voxel inversion should be free from discretization artefacts, i.e. it will depend only on the data and the regularization method and not on the specific locations of voxel elements or their finite sizes. To approximate this ideal, the geoscientist performing the inversion must ensure that certain relationships are satisfied on the proximity of data points to voxel elements. These relationships are the focus of the following discussion.

Vertical Discretization

Consider a single EW line of observations over a voxel model, with NS strike, no terrain, and a surface half layer, as shown in section in *Fig. 1*.

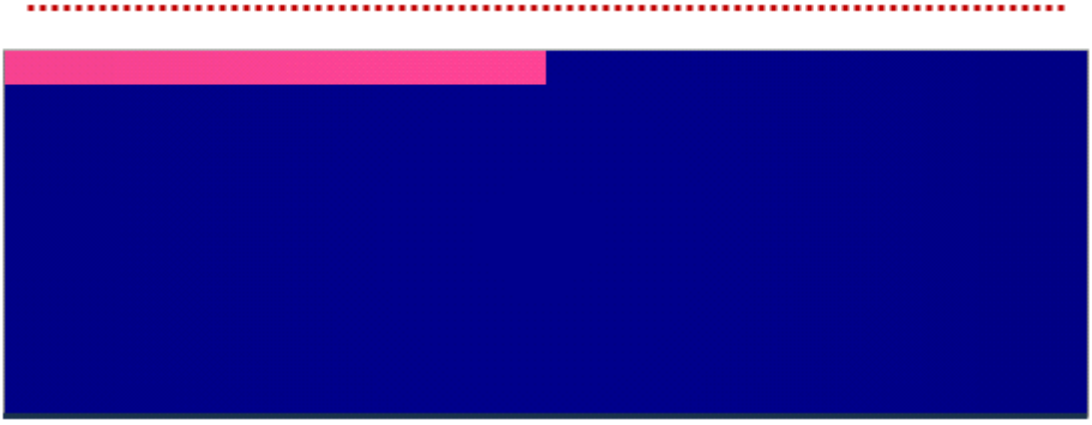

Fig. 1: The half layer voxel model

Computing the TMI response, at the magnetic pole, yields the responses for increasing clearance above the surface, as shown in *Fig. 2*. The vertical scale is defined in terms of the thickness of the half layer, d_{HL}. We can see that, as the clearance above the surface increases, the "edge effect" decreases. This must be balanced off against losing resolution in the inversion result. *Fig. 2* suggest that a suitable balance point is when the observations are approximately d_{HL} above the surface. Therefore, to avoid discretization errors in an inversion, the surface voxel element thicknesses should be less than the clearance of the survey. This can be achieved by using sufficiently small voxel element thickness, or by upward continuing the data prior to inversion.

- **Rule of Thumb**: To avoid discretization artefacts, the thickness of the surface voxel elements must be less than the clearance between the observations and the surface. Surface measurements should be upward continued prior to inversion.

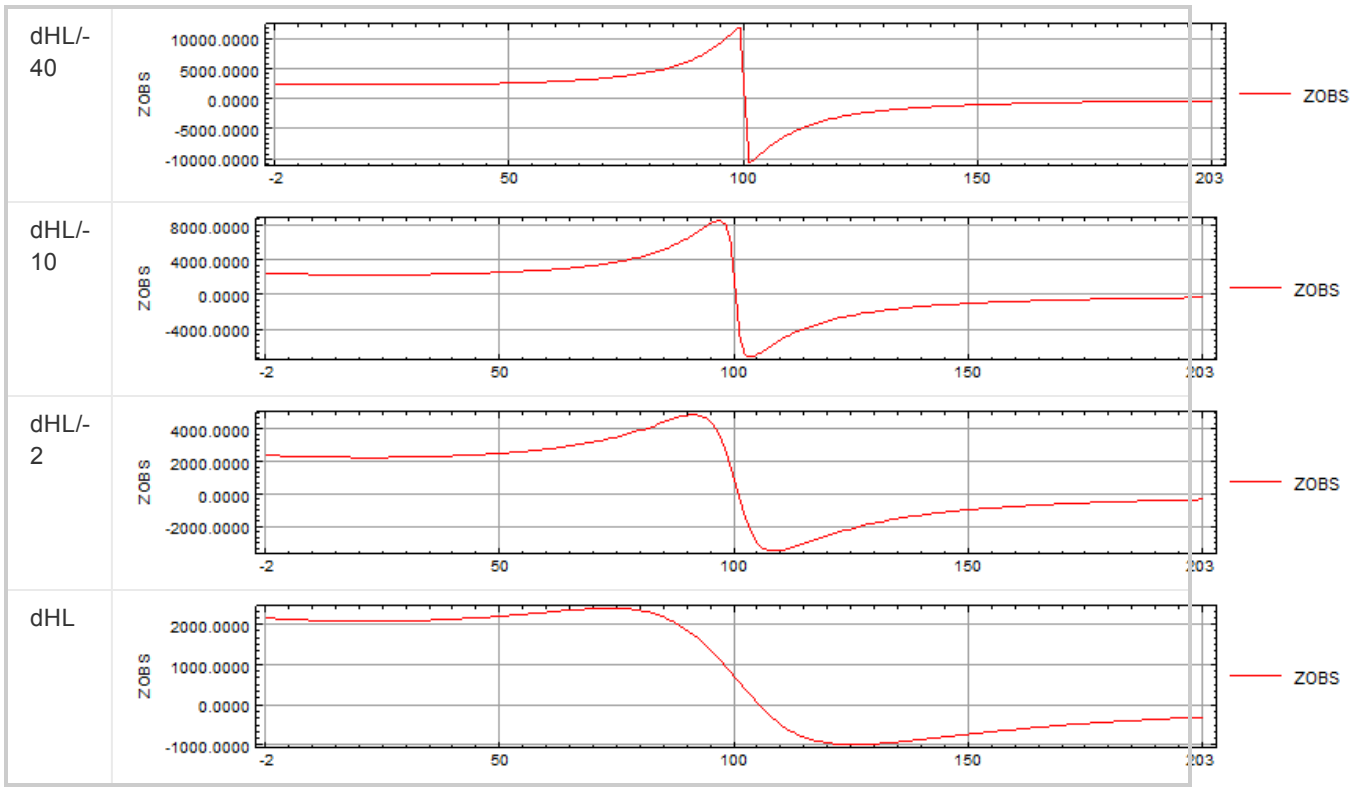

Fig. 2: The TMI response over the half layer voxel model with increasing clearance.

Terrain

Consider a single EW line of observations at constant clearance over a uniform voxel model with a sloping terrain, as shown in *Fig. 3*. The true terrain is shown by the dashed line, but since the voxel model is composed of discrete voxel elements on a regular mesh, the true terrain can only be approximated in a stepwise fashion. The expected response at the red dotted points over such an incline is expected to be linear, however this expectation will only be realized if there is sufficient clearance between the stepwise terrain and the observation points.

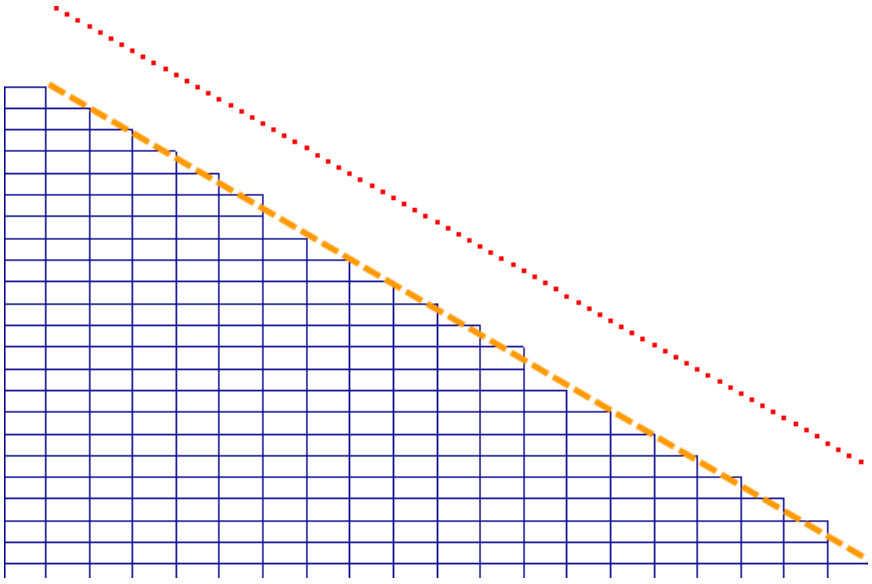

Fig. 3: The sloping terrain voxel model.

To illustrate the effect of clearance over a stepwise terrain, let us define a characteristic measure of the voxel size to be the average voxel dimension, d_P. *Fig. 4* shows the effect of increasing the clearance perpendicular to the terrain surface. When the clearance is less than d_P the observation locations can come very close to voxel edges, and eventually, the locations will even fall inside voxel elements. At a clearance of $3*d_P$, the worst terrain discretization artefacts are mitigated.

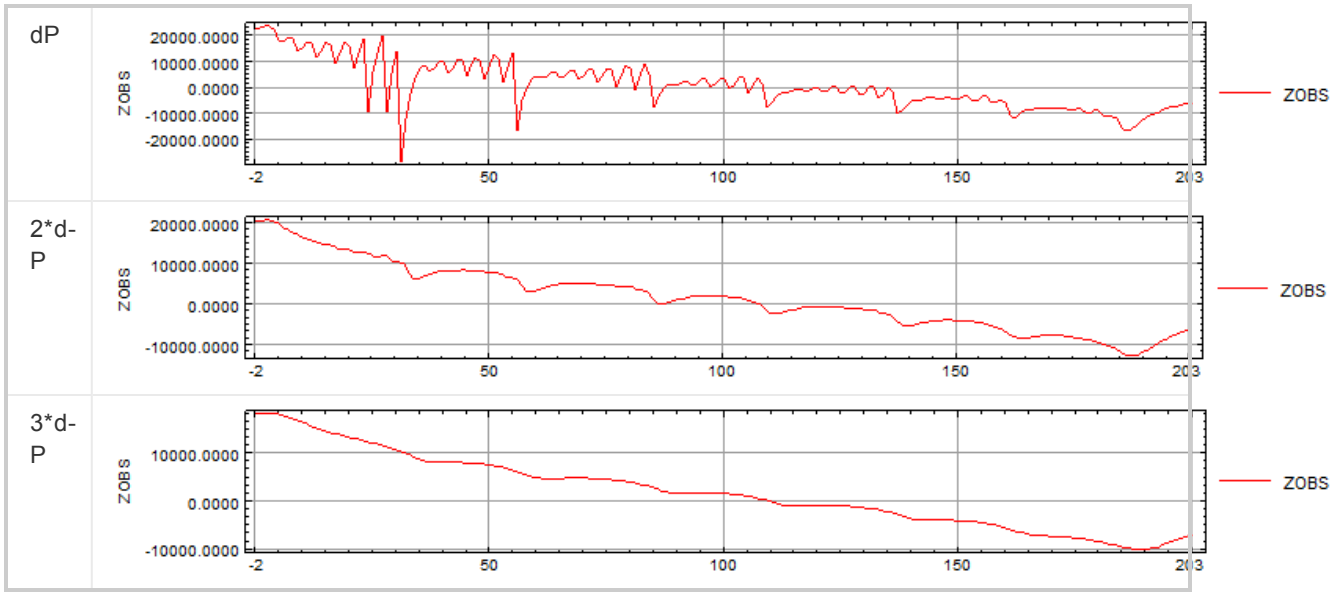

Fig. 4: The TMI response over the sloping terrain model with increasing clearance

- **Rule of Thumb**: To avoid terrain artefacts, the average dimension of the surface voxel elements must be less than one third of the clearance between the observations and the terrain surface. Measurements may need to be upward continued prior to inversion.

⚠ *Caveat: Given the wide variety of possible terrains and clearances, it may be necessary to do some preliminary forward modelling using a constant property voxel model and to compare the response with the discretized terrain to confirm that there are no terrain artefacts.*

Horizontal Discretization

The horizontal dimensions of the voxel elements used in an inversion should be optimized to produce the smallest number of elements while still preserving the resolution of the data and avoiding artefacts. Geophysical data are often characterized by oversampling along survey lines and undersampling across lines which makes an appropriate choice of horizontal voxel dimension difficult. To motivate an appropriate rule of thumb, consider a checkerboard voxel model with dimensions of each square being d_{CB}. Flight line separation is set d_{CB} with flight lines over the centres of the squares, as shown in *Fig. 5*, and TMI data, at the pole, are simulated (*Fig. 6*).

To test the effect of horizontal voxel size[1], we invert the checkerboard data using a suite of voxel sizes. The corresponding plan view slices through the recovered models are shown in *Fig. 7*. It is evident that

[1]This example is overly favourable for size $d_{CB}/2$ because the voxel element boundaries align.

the minimum horizontal element size is ~ $d_{CB}/2$ and that $d_{CB}/4$ is a better choice. Going to smaller horizontal sizes dramatically increases processing requirements and yields a smoother model, but doesn't significantly increase the interpretation value of the result.

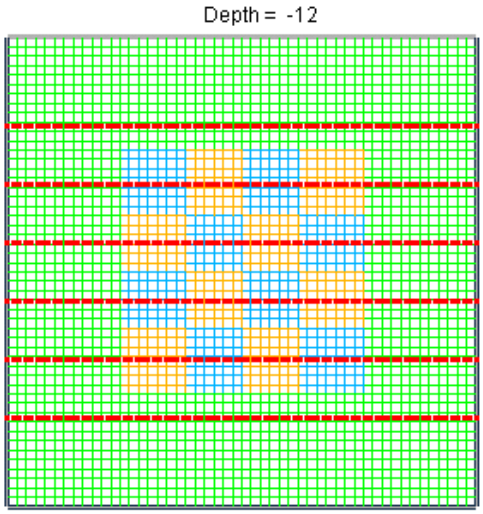

Fig. 5: The checkerboard voxel model

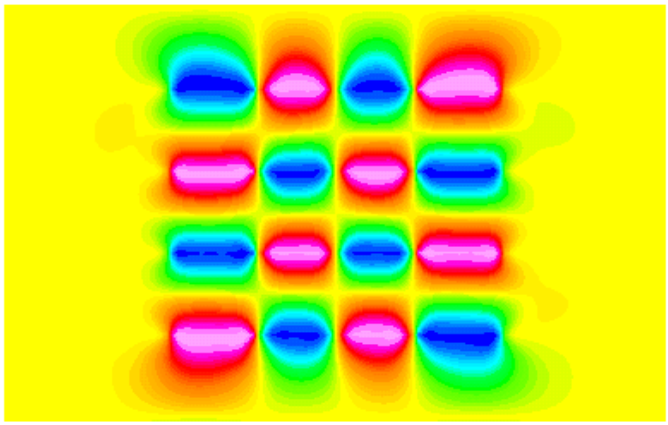

Fig. 6: The TMI data over the checkerboard model

- **Rule of Thumb**: To avoid horizontal discretization artefacts, the horizontal size of voxel elements should be approximately one quarter, or less, of the line spacing.

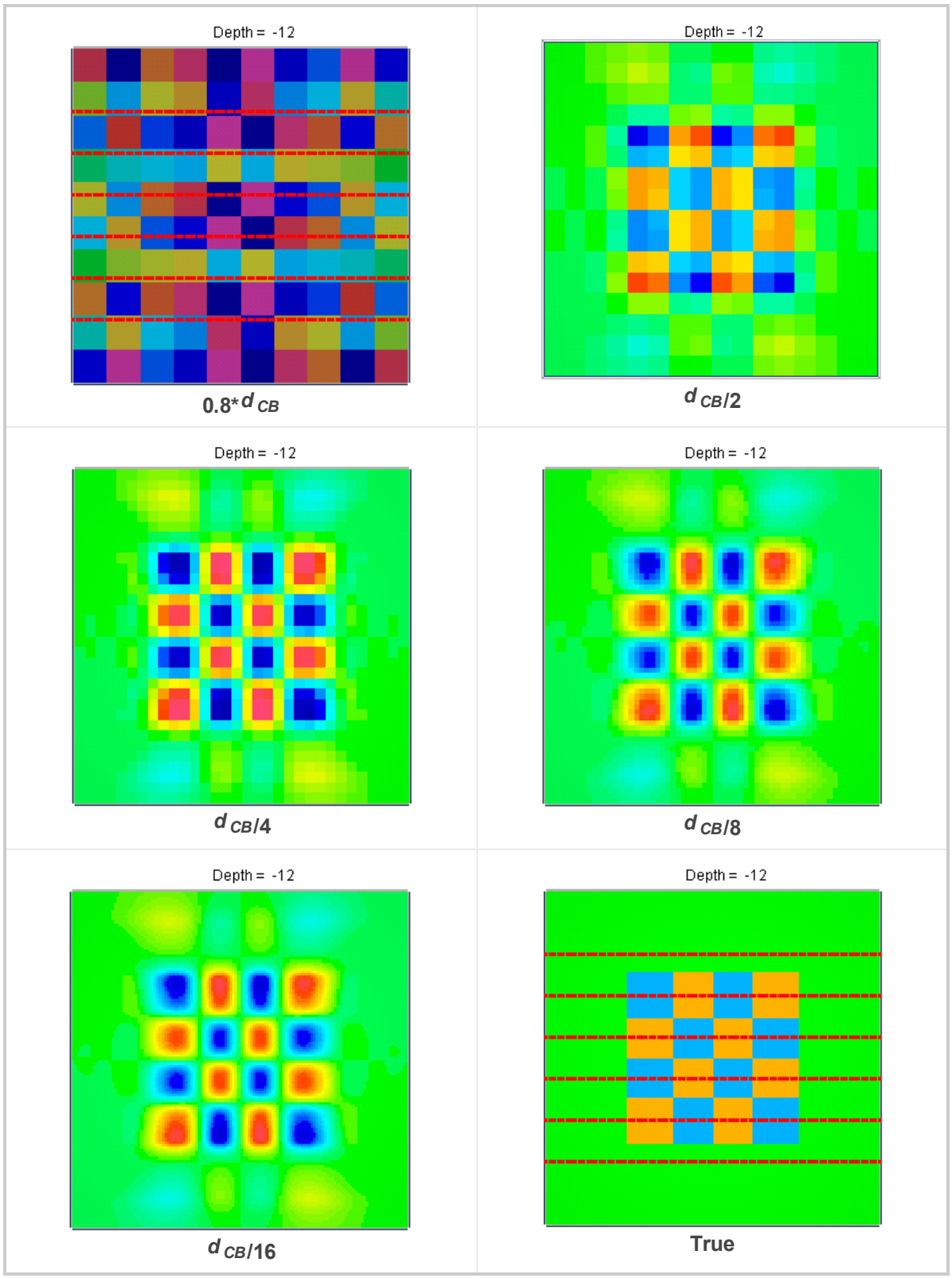

Fig. 7: Plan view slices through the checkerboard model for decreasing horizontal voxel element sizes