

Solid Earth Discuss., referee comment RC2
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Comment on se-2021-65

Anonymous Referee #2

Referee comment on "Constraining 3D geometric gravity inversion with a 2D reflection seismic profile using a generalized level set approach: application to the eastern Yilgarn Craton" by Mahtab Rashidifard et al., Solid Earth Discuss.,
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This paper describes an application of a level set method to the problem of reconstruction density from gravity data in 3D with additional constraints obtained from 2D seismic survey. The constraints are implemented as a regularization penalizing the evolution of the level set functions where the model is deemed to reliably constrained by from prior information, in this case an inverted 2D seismic section. The method is applied in synthetic examples and to a field data set from Yilgarn Craton in Western Australia.

I think the main contribution of this paper is the adaptation of the methodology to the specifics of the area studied in the field data example and the specific kinds of data available there. I recommend accepting the paper with some revisions.

Comments on the substance of the paper:

I think the theory section is adequate, considering that a previous paper by the authors where the methodology is explained in more details is referenced. Examples section is adequate in scope, however some results were a bit difficult to interpret. I believe that several figures might benefit from editing and some additional comments would help. Specifically, I have the following suggestions:

Lines 106-108: The meaning of the sentence is hard to understand, I suggest reformulation for clarity. Gravity level set inversion actually is quite well-posed when gravity values are known and does not need much regularization, in my experience. When

minimum length/area regularisation is used, usually it does not lead to overly simplified shapes when the data constrain the problem well.

Lines 125-126: It would be nice to reformulate the sentence, because its meaning is hard to understand.

Line 129: What exactly does "uniform" mean here?

Line 135: Could you please elaborate a little bit on the difference of the effect of W_s and W_p ?

Lines 141-142: Could you please make it clearer, what is meant by "arrays", also what the "sample section" means here.

Lines 148-150: The meaning of the sentence is not clear.

Line 165, Figure 1: The top two images on this figure need labels, captions and more explanation. How do the bottom figures, especially figure 1b fit into the right top image? Why do images (a) and (b) show two different plots of the same matrix W_s ?

Section 2.4. As far as I understand, this regularization prevents small pieces of one lithology to be isolated inside another lithology, reducing fragmentation of the model, but it's not quite clear why such a constraint needs to be applied. What is meant by "nucleation"?

Line 218: I wouldn't call the starting disc model random. Maybe it is better to use a different word to describe the choice of the initial model.

Lines 254-255: The sentence seems to contradict later sentences: it says that the seismic section is only applied in the construction of the initial model. However, around line 260 it is said that the reflectivity from the seismic section is also used as a constraint during inversion.

Line 286: "The difference between the structural similarities" and "an indication of the applicability of the approach to spatially distributed constraints in the level-set inversion" -- these two phrases are hard to take in and could be simplified for clarity.

Line 295, Figure 5: It might be nice to show the true and inverted models from the same angle.

Line 440, Figure 12: Compared to the starting model, Figure 10b, it appears that the green, blue and brown units have switched places and moved away from their original locations quite a lot. It is usually hard to recover the shape of a unit if there isn't some overlap between the initial and true unit location, so such a result doesn't look plausible. Considering that also the evolution of the level set function was suppressed at the seismic section, this final reconfiguration of the facies is very unlikely.

Are you sure that the units are plotted in the correct color? The color bar from Figure 15 would make the models on Figure 12 much more plausible and consistent with Figure 10 and the discussion. This needs to be fixed or explained. It would be helpful if Figures 10, 12 and 15 used the same color scheme, so I suggest replotting Figures 12 and 15 using the color scheme of Figure 10.

Also, it would help to plot the final models on the same set of axes as the initial model in Figure 10a, to better visualize the shape changes of the bodies. It would also help to plot the initial and both final models along the seismic section overlain on the seismic image as in Figure 9d.

Lines 443-444: Again, it's a bit difficult to compare the initial and final models and also see how well the final models fit the constraints. If Figures 12 (a) and (b) were plotted on the same kind of axes as Figure 10, perhaps this would make understanding the changes in the model after the inversions easier.

Lines 448-449: The fact that the models differ in constrained parts and do not much differ elsewhere seems to indicate that the information in the constraints does not quite agree with the information in the gravity data. I wonder if it might indicate that the constrained inversion result is incorrect elsewhere, or that the constraints themselves are incorrect? Could the authors comment on this? Have you tried a synthetic, in which the constraints were assumed correct, while they weren't, to see how robust the inversion is to such errors? There is a relevant comment on uncertainty in the conclusion section, but it is a bit far below and hard to tie to this particular place, so it would be nice to make a comment here.

Line 465, Figure 15: The numbers and colors on the color bar are out of order and inconsistent with Figures 10 and 12. Could this figure be replotted in the color scheme of Figure 10, for easier understanding? How does the unconstrained inverted model compare with the prior interpretations? Could you perhaps show an example?

Line 505: Could Yamarna Greenstone unit be marked on Figure 12b? It would probably help to better appreciate the shape changes, if this body were plotted in 3D.

Line 509-510. Again, this is a bit difficult to see from the plots on Figure 12, I think a 3D plot of this body would help.

Technical comments:

Lines 111-112: "in the same fashion as that smallness terms regularize inversion problems (Calvetti et al., 2000)", remove "that".

Line 118: I suggest using small "w" if the sentence is continued, or start a new sentence with "Here" with the capital "H".

Line 145: "as follow:" -> "as follows:"

Lines 161-162: Word "plausible" seems to be out of place here. It's not quite clear what this sentence grammatically means.

Line 165, Figure 1: In the caption, second line remove "of" from "Distribution of constraint matrix of from lithology 2".

Line 256: Replace "area. In" by "area, in", otherwise the second sentence is grammatically incomplete.

Lines 480-482: The first sentence grammatically needs improvement. The next small sentence needs to be reformulated for style.

