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Reply on RC1

Qiong Zhang et al.

Author comment on "Leveling airborne geophysical data using a unidirectional variational model" by Qiong Zhang et al., Geosci. Instrum. Method. Data Syst. Discuss., https://doi.org/10.5194/gi-2021-33-AC1, 2022

Many thanks for your significant comments on our paper. The response to each comment is listed as followings:

(1) A native speaker is helping us to modify the grammar and expression of the manuscript. We will carefully and repeatedly check the manuscript to improve the quality of English language.

(2) As the referee suggested, we have modified the introduction in the manuscript. We summed up the published methods in a more efficient way and supplied the advantage of proposed method. The supplied introductions are given as below shown.

This paper describes a new leveling technique based on image space properties of leveling error. Firstly, we studied the leveling error characteristic, including directional distribution property and amplitude variety property. Then the proposed leveling method is described based on the property analysis. A smooth field is constructed to obtain the real data level of the nonanomalous area in advance. Based on the directional distribution property, the leveling method extracts the leveling errors by combining unidirectional variational model with spatially adaptive multi-scale model.

The leveling method can protect the integrity of anomaly data by separating the potential anomaly points and constructed smooth field. More importantly, the geophysical area data are leveled as a whole which avoids the possible error transfer. The method is adaptive and automatic without parameter setting. The technology is applied to three types of field datasets to show the stability and robustness of the method.

(3) In the manuscript, we leveled the geophysical data based on image space properties. The leveling errors are often visible as stripe patterns (Huang, 2008; Fan, 2016). When we studied the data leveling, we found that the stripe noise effects severely degrade the image quality in similar way. And the variety of destriping algorithms are proposed in the literature (Bouali and Ladjal, 2011; Zhou et al., 2014; Guan et al., 2019). Then we tried to consider the properties of leveling errors in the image space. In the manuscript, the gradient is calculated and understood from the point of image processing.

Mathematically, the gradient is defined as vector and only applicable to continuous functions. In digital image processing, image is deemed as two-dimensional discrete function. The image gradient is approximately calculated by the finite difference method. The gradient image shows the difference between adjacent pixels. So the unit of gradient is nT in Fig. 2.

(4) In Fig.1, x axe is the horizontal axe. Let **D** be the survey area data, the corresponding horizontal gradient $\mathbf{G}_x$ is

$$\mathbf{G}_x(i+1,j)=\mathbf{D}(i+1,j)-\mathbf{D}(i,j).$$

That is, the horizontal gradient is equivalent to difference data between the adjacent flight lines. The vertical gradient is equivalent to difference data between the adjacent pseudo tie lines. In line 177, $\mathbf{TV}_x$ and $\mathbf{TV}_y$ are defined as horizontal and vertical variations for consistency. The similar definition is given in Reference [3]. The Reference firstly proposed unidirectional variational model to remove stripe noise in moderate resolution imaging spectroradiometer data.

We have supplied the calculation formulas of horizontal gradient and vertical gradient to better explain the method. The supplied introductions are given as below shown.

Assuming there are L flight lines and N survey points in each line, expressed as

$\mathbf{D}(N\times L)=[\mathbf{D}^1\mathbf{D}^2\ldots\ \mathbf{D}^L]=[\mathbf{D}_1\mathbf{D}_2\ldots\ \mathbf{D}_N]^{\mathrm{T}}$,

where $\mathbf{D}^L$ are the Lth flight line data, $\mathbf{D}_N$ are the Nth pseudo tie-line data, and T abbreviates transpose.

The gradient of the survey data in horizontal direction is $\mathbf{G}_x=[0\ \mathbf{D}^2\text{-}\mathbf{D}^1\ \ldots\ \mathbf{D}^L\text{-}\mathbf{D}^{L-1}]$.

The gradient of the survey data in vertical direction is $\mathbf{G}_y=[0\ \mathbf{D}_2\text{-}\mathbf{D}_1\ldots\mathbf{D}_N\text{-}\mathbf{D}_{N-1}]^{\mathrm{T}}$.

(5) There are three advantages of proposed method compared with existing leveling methods.

(a). The manuscript proposed a general model for leveling preprocessing. The leveling preprocessing has important significances. A synthetic model is established in **Appendix** to state why we need a leveling preprocessing model to separate the anomalous and nonanomalous data. The Appendix part explains the necessity of moving anomalous area data before leveling. The details have been published in another paper of mine in Reference [6].

In the manuscript, the leveling preprocessing model is constructed based on characteristic analysis of leveling errors. It is available and general for airborne geophysical data leveling.

(b). In the leveling method, the survey data are leveled as a whole. The leveling errors are extract at once rather than block processing. The integrated processing avoids the regional error caused by strong noise, missing data, or error transfer in the common leveling process.

(c). Many leveling methods perform the correction process with the assistance of extra tie-line data, a selected standard level, or configured filter parameters. The proposed leveling method is an adaptive and automatic correction without tie-line data. There are massive data collected in geophysical exploration. It is important to maintain the data processing efficiency.

We will sum up and supply the advantages of proposed method in the revised manuscript.

(6) As the referee suggested, a reasonable simulation model can help to validate the efficiency of a new algorithm. Thank you for your comments. This opinion is of great value for our future research.

Because the polishing of the paper is not over yet. We cannot upload the latest revision now. We tried our best to improve the manuscript and made some revisions in the manuscript. These revisions will not influence the content and framework of the paper. Once again, thank you very much for your comments and suggestions.

Appendix

Synthetic model

Huang (2008) proposed an effective leveling method based on line-to-line correlations that has been tested on airborne geophysical data without tie-lines. By selecting a reference line, the level errors in the adjacent line are determined from the differences between the line data and the reference line data in a least-squares sense. Leveled line serves as new reference line to level its adjacent line until all lines are leveled. However, the leveling process may be influenced by anomalies along tie-line direction. In addition, the single-channel leveling algorithm might cause channel data distortion in some cases.

Figure 1 shows a synthetic airborne time-domain electromagnetic (ATEM) model with a rectangular anomaly and no level error is added to the synthetic ATEM data. We apply line-to-line correlation leveling on the synthetic data, selecting Line 3 as the reference line and the first order polynomial as the level error function. Figure 2 shows the leveling results of Line 4, including channel 14 and channel 15. We expect the fitted level errors are approximately zero, however, fake level problem is caused in the fitted level errors as Fig. 2 shown. More importantly, the leveling results are distorting at channel 14 and channel 15 (marked by the dashed black circle in Fig. 2). As shown in Fig. 1, Line 4 is located on the edge of the anomaly that has gradient variation with Line 3. The difference data (see Fig. 2) between Line 4 and its reference line (Line 3) are dominated by the sharp anomaly variation, as well as the fitted level errors in Line 4. The between-line differences of anomaly area lead to fake level in the fitted level errors. Moreover, because the differences between the fitted level errors at the adjacent channels are bigger than the differences that of the raw data at the adjacent channels, the leveling results between channels are distorting. Therefore, we deem it is necessary to separate the smooth nonanomalous data from the anomalous areas data in advance.

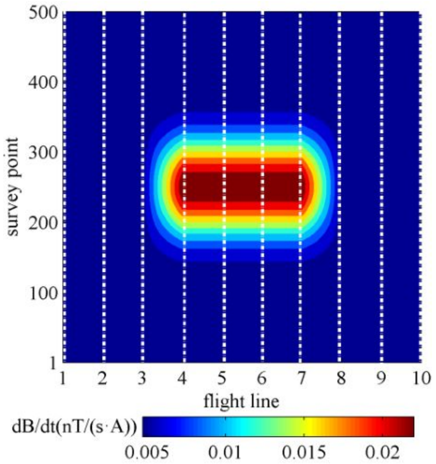

Fig. 1. The synthetic ATEM model without level errors.

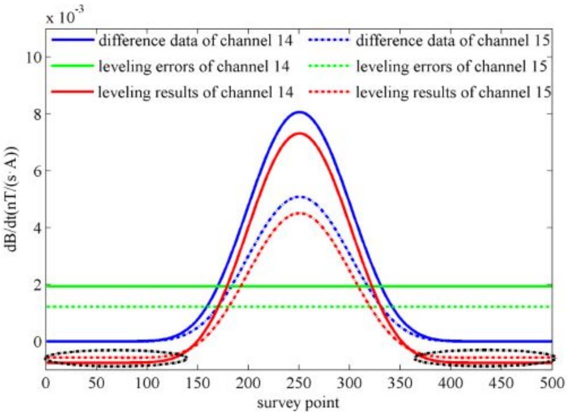

Fig. 2. The data from Line 4 in Fig. 1. The difference data between Line 4 and the reference line of channel 14 (solid blue) and channel 15 (dashed blue), the level errors of channel 14 (solid green) and channel 15 (dashed green), and the leveling results of channel 14 (solid red) and channel 15 (dashed red).

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