

## HORIZONTAL ACCURACY ASSESSMENT OF GOOGLE EARTH DATA OVER TYPICAL REGIONS OF AUSTRALIA USING WORLDVIEW

Jing Guo<sup>1</sup>, Hongjing Tu<sup>1</sup>, Hai Li<sup>1\*</sup>, Ying Zhao<sup>1,2</sup>, Jin Zhou<sup>1</sup>

<sup>1</sup>National Quality Inspection and Testing Center for Surveying and Mapping Products, Beijing, China - gj\_season@163.com

<sup>2</sup>Beijing Key Laboratory of Urban Spatial Information Engineering

### Commission III, ICWG III/IVb

**KEY WORDS:** Google Earth, Accuracy assessment, Remote sensing, Absolute positioning accuracy, Relative positioning accuracy

### ABSTRACT:

Since the release of Google Earth image data, it has been the most widely used remote sensing data worldwide, and its accuracy evaluation has also been the focus of historical research. However, the researchers found that Google Earth's image accuracy assessment results have obvious regional characteristics. This article uses the Australian continent as the research area and WorldView-2 remote sensing images as reference data to study the accuracy evaluation results of Google Earth data. The research shows that the overall accuracy of the assessment area in Australia is better. The areas with the best overall accuracy appear in the western coastal areas, with an accuracy range of 0.7-1.4; the accuracy assessment results in the central desert area are also better, with the accuracy range 1.4-2.2, and the areas with the worst accuracy appear in the western mountains and hills of 14.5 and 17.1

### 1. INTRODUCTION

Google Earth (GE) is a virtual earth software developed by Google, which lays out vector maps, satellite photos, and topographic maps on a three-dimensional model of the earth. His image data is not a single data source, but the integration of satellite imagery and aerial photography (CUTBERTO, 2016; GOOGLE, 2011). As a public and free global data source, Google Earth has faster data updates and higher positioning accuracy. Provided publicly available remote sensing images of different resolutions for the world, with a spatial resolution ranging from 0.1 to 15 m (Wikipedia, 2014). Since the data was made public, it has played an important role in the fields of science and engineering such as global change and cartography, geological disasters, environmental protection, water conservancy and transportation, and military. It is also the basic data for geological analysis on global and regional scales. Because of the widespread use of GE remote sensing data, the quality of its accuracy has always been a hot topic in related fields.

At present, the research on the accuracy and quality of GE remote sensing images has achieved a lot of results, which can be summarized into three aspects: 1) In terms of research content, focus on the accurate evaluation of GE, especially the evaluation of plane position accuracy. The evaluation parameters include medium error and average. Error, standard deviation, etc., as well as the accuracy difference of GE data in different regions. 2) In terms of research methods, high-precision control points (such as GPS, Lidar, etc.) or high-precision remote sensing images are used to realize the accuracy analysis and error law statistics of GE. 3) In terms of the research scope, it is mainly based on local areas such as typical geomorphic regions and specific regions (such as countries, cities, etc.), and it does not form a comprehensive coverage of the accuracy analysis of key countries and regions in the world.

The above analysis shows that the current research mainly has the following two problems: 1) Although accurate evaluation results can be obtained by using high-precision ground control points, accuracy evaluation by using high-precision ground control points is not suitable for large-scale image accuracy evaluation due to the restriction of the acquisition range, quantity and cost of control points. WorldView-2(WV) is one of the representatives of high-precision remote sensing data. It has the characteristics of high positioning accuracy, high resolution, and wide coverage. Its appearance provides a new method for large-scale GE accuracy assessment, and it has also become an ideal reference data for assessing the quality of global GE or other remote sensing image data (DU Xiao-ping, 2013). 2) There have been many research results of GE. data accuracy evaluation on a global scale. A series of researchers have carried out accuracy evaluation studies based on global and region-based accuracy. There are great differences in the accuracy results of different researchers on the global scale. Some authors proposed that GE's global level accuracy error range is 10-1500 meters (Becek, 2011). Regarding regional studies, the accuracy evaluation results are significantly better than the global accuracy evaluation results, but there are big differences in the accuracy evaluation results between different regions (FLANAGIN, 2008). The research shows that with the different evaluation regions, the error changes of GE also have large differences. Therefore, the regional-based GE accuracy assessment results have higher credibility and applicability.

Through the above analysis, in order to accurately evaluate the accuracy of the GE high-resolution remote sensing image plane position, this paper uses WV data to evaluate the GE position accuracy, which can more scientifically and objectively verify the accuracy quality of GE. The accuracy assessment area is the typical landforms of central, eastern,

\* Corresponding author

and Western Australia. Plain, hilly, and mountain areas are selected for accuracy assessment, and in important cities, Accuracy assessment is carried out in coastal and desert areas. According to the geometric quality index system of high-resolution optical satellite remote sensing images, the position accuracy is evaluated from two aspects: absolute positioning accuracy and relative positioning accuracy within the area.

## 2. DATA AND STUDY AREAS

### 2.1 Study Areas

Select 23 geomorphic areas in Australia as the experimental plots (Figure 1). Australia is located between the South Pacific and the Indian Ocean, surrounded by the sea, and is the only country in the world whose land covers an entire continent. Compared with other continents, Australia has the smallest proportion of high mountain areas. It is a continent with low and flat terrain and gentle undulations. The mainland can be clearly divided into three major terrain areas from west to east. The western part is the plateau and the main terrain is the Victoria Desert. The landforms are mainly deserts. This area accounts for about half of Australia's national area, with an average elevation of about 200-500 meters. The main cities are Perth and Darwin. The central part is plain, with an elevation generally below 200 meters. The main cities are Amon Ryde and Port Pirie. The eastern part is mountainous, with an average elevation of 800-1000 meters. At its peak, Kosciusko Mountain, at an elevation of 2,230 meters, is also the highest point in Australia. The main cities are Sydney, Canberra, Melbourne, Brisbane, and Newcastle. About 70% of Australia's land belongs to arid or semi-arid areas, and most of the central part is not suitable for human habitation. The country's population is highly urbanized. Nearly half of its citizens live in the two major cities of Sydney and Melbourne. The 23 research areas selected in this paper include flat land, hills and mountains, and other different types of landforms. The research areas involve coastal urban areas on the east and west, central desert areas, and western coastal mountains.

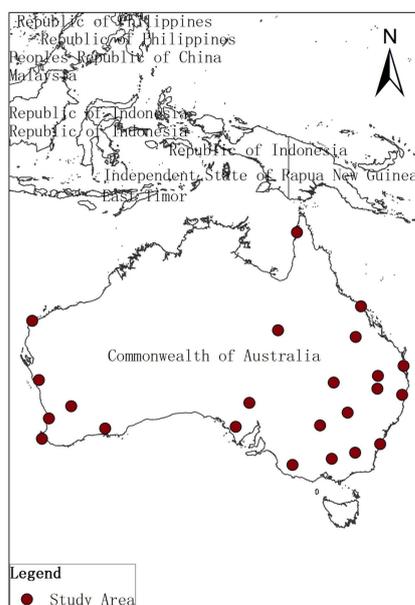


Figure 1. Location diagram of the study area

### 2.2 Data

As a popular image map software, GE's image spatial resolution has been continuously improved in recent years. It can reach a resolution of 0.5m in some countries and urban areas. In places with high spatial resolution, its relative positioning accuracy can even reach the requirements of 1:2000 mapping specification. The image evaluated in this paper is the 17th-level satellite image downloaded from GE. The higher the level of the data, the higher the resolution of the image, but the smaller the area of the image that can be obtained. The spatial resolution of GE images is better than 2 meters, using WGS-84 ellipsoid parameters and UTM projection.

In this paper, high-resolution remote sensing image WV-2 data is selected as reference data to test the location accuracy of GE data. The manufacturer of the WorldView-2 satellite is DigitalGlobe. It was launched in 2009. Its satellite-borne multispectral remote sensor has four industry-standard spectrum bands (red, green, blue, and near-infrared), as well as four additional (coast, yellow, Near-infrared, and near-infrared 2) spectral bands, of which the coastal band (Wavelength: 400-450 nanometers)(Anderson,2012) Under good conditions, it can penetrate water vertically downward for about 15 meters, its panchromatic resolution reaches 0.46 meters, and the matching multi-spectral resolution is 1.84 meters. WorldView-2 has a large-scale acquisition capability of 770km, the sub-satellite point width is 16.4km, the revisit cycle is very short, and the same place can be visited twice within 1.1 days. This article uses WV's pre-ortho standard imaging products (Ortho • Ready • Standard 2A), without terrain correction, only radiation correction, error correction caused by sensors and satellite platforms, with map projection.

## 3. METHODOLOGY

This paper uses the high-resolution optical satellite remote sensing image geometric quality index system to evaluate the position accuracy from two aspects: absolute positioning accuracy and relative positioning accuracy within the scene. Absolute positioning accuracy refers to the statistical value of the difference between the geographic coordinates of points on high-resolution remote sensing images and the real geographic coordinates, including positioning accuracy without ground control points and positioning accuracy with ground control points. The positioning accuracy without ground control points is the statistical value of the error between the geometric positioning results and the real coordinates based on the ground positioning model established based on the high-resolution satellite orbit ephemeris, attitude, and sensors. This indicator can not only evaluate the accuracy of the positioning model, It can also reflect the overall reliability and stability of the high-resolution satellite remote sensing platform and imaging system.

The absolute positioning accuracy adopts the medium error evaluation index, and evaluates the position accuracy through the root mean square (Root Mean Squared Error, RESM) of the statistical checkpoint plane error. Intermediate error is a commonly used index to measure the accuracy of data. It can reflect the influence of larger errors on the reliability of geometric correction results, so it has become a widely used index for evaluating accuracy.

The reference image WV and the evaluated image GE adopt the method of automatic matching to select the same object points, as shown in Figure 2. During the registration process, the software can calculate the errors of all the same points in the X and Y axes of the evaluated GE image and WV image, and then calculate the corresponding plane error parameters to get the errors in the X direction, Y direction and the plane.

$$RMSE_x = \sqrt{\frac{\sum_{i=1}^N (X_i^0 - X_i)^2}{N}} \quad (1)$$

$$RMSE_y = \sqrt{\frac{\sum_{i=1}^N (Y_i^0 - Y_i)^2}{N}} \quad (2)$$

$$RMSE_{xy} = \sqrt{\frac{\sum_{i=1}^N (X_i^0 - X_i)^2 + \sum_{i=1}^N (Y_i^0 - Y_i)^2}{N}} \quad (3)$$

In the formula, RMSE<sub>x</sub> RMSE<sub>y</sub> is the mean square error in the X-axis direction and Y-axis direction respectively; RMSE<sub>xy</sub> is the horizontal mean square error; n is the number of matching points.

The above formula shows the impact of larger errors on the accuracy and reliability of the results. The mean square error is a representative value of a group of absolute errors. When the absolute error of a group of data is greater, the mean square error is also greater, and its accuracy is lower. The smaller the error, the smaller the mean square error and the higher the accuracy.

Relative positioning accuracy is an important indicator for evaluating the relative geometric positioning accuracy of high-resolution remote sensing images(Guojing,2020). It reflects the error relationship between the field distance and the distance on the map. The field distance is the measured distance, and the distance on the map is directly measured on the image. The distance between two points with the same name corresponding to the field. The actual distance in this article is the sum of the distances between the WV checkpoints of the reference image, and the distance on the map is the sum of the distances of the corresponding points on the GE remote sensing image. The smaller the relative error, the higher the geometric accuracy of GE.

Specific steps are as follows:

(1) Suppose the measured coordinates of the two points M and N on the image are respectively (X<sub>M</sub>, Y<sub>M</sub>), (X<sub>N</sub>, Y<sub>N</sub>), and their real coordinates are (X'<sub>M</sub>, Y'<sub>M</sub>), (X'<sub>N</sub>, Y'<sub>N</sub>);

(2) Calculate the measured distance of the two points  $A_i = \sqrt{(X_N - X_M)^2 + (Y_N - Y_M)^2}$  and the true distance  $B_i = \sqrt{(X'_N - X'_M)^2 + (Y'_N - Y'_M)^2}$ , then the absolute distance error  $C_i = |A_i - B_i|$ ;

(3) Calculate the mean value of distance difference based on the calculation results of multiple control point pairs;

(4)The relative positioning accuracy in the m area is:  $\frac{1}{m} \sum_{i=1}^m \overline{C_i}$

| Study Area | Absolute Positioning Accuracy | Relative Positioning Accuracy (along track) | Relative Positioning Accuracy (vertica track) | Absolute Positioning Accuracy (along track) | Absolute Positioning Accuracy (vertica track) |
|------------|-------------------------------|---|---|---|---|
| Australia  | 1.08                          | 1.97  | 1.13  | -2.26                                       | 0.49  |
|            | 3.60                          | 0.60  | 1.05  | -0.92                                       | -11.78  |
|            | 14.51                         | 7.31  | 6.48  | -19.06                                      | 16.18   |
|            | 1.78                          | 3.02  | 1.85  | 1.59  | -3.83   |
|            | 4.31                          | 3.20  | 7.18  | 11.14                                       | -3.90   |
|            | 8.70                          | 5.07  | 6.17  | -5.56                                       | -11.03  |
|            | 10.40                         | 17.64                                       | 4.57  | 8.15  | -3.65   |
|            | 1.39                          | 1.15  | 1.35  | 1.50  | -2.74   |
|            | 3.29                          | 4.05  | 2.48  | 6.77  | -2.92   |
|            | 3.44                          | 0.70  | 0.93  | 0.50  | -6.68   |
|            | 3.45                          | 0.70  | 0.92  | 0.49  | -6.70   |
|            | 3.35                          | 1.67  | 2.60  | 8.72  | -3.85   |
|            | 1.43                          | 0.70  | 1.03  | -3.78                                       | -2.50   |
|            | 1.43                          | 1.29  | 1.44  | 0.70  | -4.09   |
|            | 1.46                          | 0.79  | 0.94  | -1.88                                       | -4.04   |
|            | 1.95                          | 2.07  | 1.42  | 1.00  | -1.08   |
|            | 2.24                          | 2.53  | 1.25  | -2.29                                       | -0.90   |
|            | 17.12                         | 2.16  | 2.95  | 17.30                                       | 28.82   |
|            | 0.71                          | 0.79  | 1.39  | -1.11                                       | 1.14  |
|            | 1.15                          | 0.86  | 1.11  | -1.72                                       | 2.74  |
| 0.84       | 1.33                          | 1.00  | -1.68   | -1.23                                       |   |
| 1.97       | 1.00                          | 1.20  | 5.20  | 2.67  |   |
| 0.84       | 1.33                          | 1.00  | -1.68   | -1.23                                       |   |

**Table 1.** Statistics by the mean square error of horizontal positional accuracy in Australia study area

#### 4. RESULT

In this study, the WorldView image data was used as the hypothetical true value, and the absolute positioning accuracy and relative positioning accuracy were evaluated on the GE image data of 23 regions selected in Australia. The self-developed software was used to match the WV data and GE data pixel by pixel, and the accuracy evaluation method introduced in Section 3.2 was used to obtain the accuracy results of WV and GE data in each study area in Australia, so as to study the quality of GE position accuracy ,as shown in figure3.

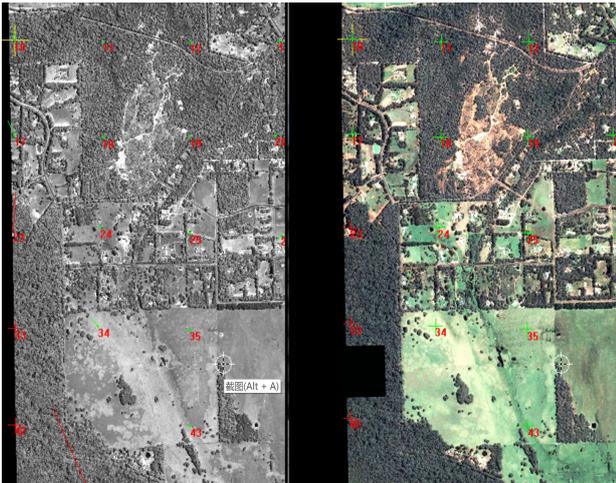


Figure 2. Image matching point distribution

##### 4.1 Accuracy trend analysis

The areas with the best accuracy appear in the coastal areas of southern Australia, and most of the areas with better accuracy appear in the eastern and western coastal areas. In particular, the accuracy of the western coastal areas is better than the eastern and central research areas, and its accuracy is better than 2 meters (Table 1). The results of the study show that the overall positioning accuracy of the central and east-central non-coastal areas of Australia is better than that of the eastern coastal areas, with an accuracy range of 1.43-2.24 meters. On the contrary, the location accuracy of the eastern coastal area is quite different. The location accuracy of the area with better accuracy is better than 4 meters, the accuracy result of the area with the worst accuracy is (8.7-17.1 meters), and the 3 areas with the worst accuracy are adjacent to each other. The study also found that the accuracy assessment results of the central desert area are generally better. The worst accuracy occurs in mountainous areas, and the accuracy is 17.1 m RMSE (RESx: 2.2 RESy:3pixels) and 10.4 m RMSE(RESx: 17.6, RESy: 4.6 pixels)(Figure 3), which shows that the positioning accuracy of GE image data The deviation may be caused by the geometric distortion of the mountain area. Another reason for the large horizontal error to be found may be due to the low relative position accuracy in the x-direction. The author also found that there is a systematic deviation between the Google Earth image and the WV image in the two regions with poor accuracy.

The worst accuracy among the 23 study areas is 17.1 meters RMSE (RESx: 2.163, RESy: 2.954 pixels). Although the relative positioning accuracy results are relatively good, we found that the Google Earth image data in this area has a horizontal error in the y direction that is significantly greater than x Horizontal error of direction (RMSEx: 17.3, RMSEy:

28.817 pixels). The study found that the above-mentioned areas with poor accuracy mainly occur in the mountainous regions of eastern Australia, which further proves that plains and hills usually have better accuracy than mountains.

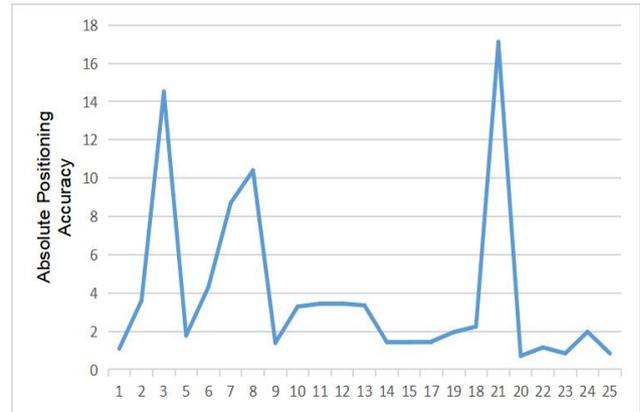


Figure 3. Absolute accuracy variation for Australia

##### 4.2 Accuracy analysis for terrain

It can be seen from Figure 4 that the accuracy evaluation results of GE based on WV have different accuracy performances in different geomorphological types. This paper analyzes the three types of landforms: flat land, hilly land, and mountainous land. The accuracy of the flat area is the highest for the flat area, followed by the hilly area, and the mountain area has the worst accuracy result. Although the accuracy results in flat and hilly areas are better, it can be found that the accuracy results in flat areas are basically within 2 meters, and half of the accuracy results in hilly areas exceed 2 meters. Within 5 meters, an area with an accuracy assessment deviation of 17.1 meters also appeared. The overall accuracy assessment results of mountain areas are low (8.7-14.5 meters), but there are also some areas with high accuracy of 1.8 and 3.6 meters, respectively. From the perspective of the selected research areas, they are all in coastal areas and have rich information of features, which can be excluded as matching. The reasons for the possibility of large differences in accuracy can be combined with the results of relative positioning accuracy to analyze the reasons for the large differences in accuracy.

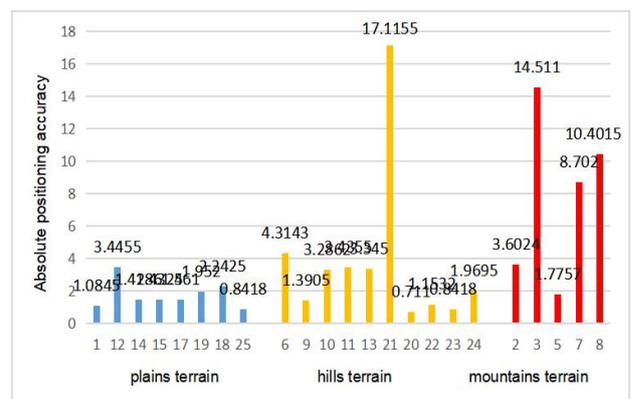


Figure 4. Absolute positioning accuracy distribution on plains (blue columns), hills (yellow columns), and mountain (red columns) terrain

### 4.3 Comparison of relative position accuracy

Through the results of relative positioning accuracy, you can find out whether there are systematic errors in the image. Table X reflects the relative position accuracy results of the 23 study areas in the vertical and along with the rail directions. It can be seen from the figure 4 that most of the study areas with better absolute position accuracy results have a strong correlation between the relative position accuracy in the vertical and along the rail direction. The absolute positioning accuracy results of the areas with small offset and strong correlation in the vertical rail and along the rail direction are both better than 2 meters.

In the study area this time, it was found that individual areas exhibited more obvious systematic errors. When the deviation between the vertical and along the rail directions is large, the corresponding absolute positioning accuracy is also poor. For example, the absolute positioning accuracy is 14.51 and 10.4 meters. Corresponding vertical track directions all have large deviations, which are more than 7 pixels and 17 pixels, respectively, and their deviations along the track direction are relatively small. Another area with poor absolute positioning accuracy is 8.7 meters, and its corresponding relative positioning accuracy has a large deviation in both vertical and along rail directions, exceeding 5 and 6 pixels respectively. This may be due to the system error of the strict imaging model due to the satellite attitude angle and the camera according to the angle, which in turn leads to the system error of the fitted parameters. Another area worth noting is the area with the worst absolute positioning accuracy of 17.12 meters, and its corresponding relative positioning accuracy is not large in the vertical and along-track directions. Therefore, it is necessary to analyze the deviation of the absolute positioning accuracy in the vertical rail and along the rail direction.

### 4.4 Comparison of absolute position accuracy

The absolute positioning accuracy index can not only evaluate the accuracy of the positioning model but also reflect the overall reliability and stability of the high-resolution satellite remote sensing platform and imaging system. Through further analysis of the absolute positioning accuracy in the vertical rail direction and along the rail direction, we found that the regions with good absolute positioning accuracy evaluation results (better than 2 meters) have very small deviations in the vertical the track, but

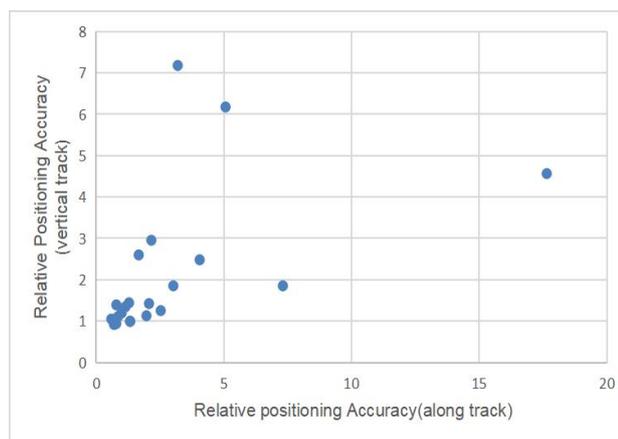


Figure 5. Spatial distribution of relative positioning accuracy

absolute positioning accuracy evaluation result is better than 4 meters, there will be a shift of 6-8 pixels in the vertical or along

the track, but there will not be a large shift in both directions at the same time. The areas with the worst absolute positioning accuracy have large deviations in the vertical and along the orbit, and the maximum deviation exceeds 28 pixels. This may be related to the attitude roll angle and attitude pitch angle (Figure 6).

## 5. CONCLUSION

Radiational remote sensing image accuracy assessment requires the help of ground-measured control points, and the acquisition cost is relatively high. This paper uses WV high-precision remote sensing images as reference data to evaluate the accuracy of GE data in Australia's southwestern coastal areas, eastern coastal areas, and central, southern, and northern regions. The results show that the overall accuracy of the assessment area in Australia is good, and there is no obvious systematic deviation in GE images in most of the study areas. This paper finds that in the study area with poor accuracy evaluation results, GE image data and WV have obvious characteristics of systematic deviation. Since this feature is not universal, it has no significant impact on the results of this assessment. Combining the results of relative positioning accuracy and absolute positioning accuracy, this paper also finds that the larger error may be due to the satellite attitude angle, camera angle and other errors that make the strict imaging model have systematic errors and the attitude roll angle is related to the attitude pitch angle.

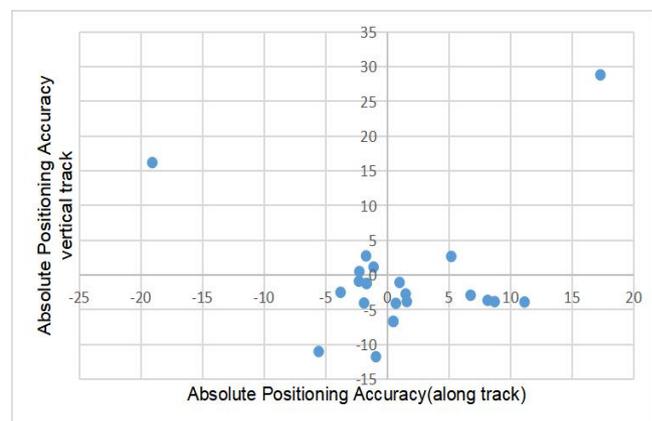


Figure 6. Spatial distribution of absolute positioning accuracy

## ACKNOWLEDGEMENTS

This work has been supported by Mapping Global Program. This paper is funded by Beijing Key Laboratory of Urban Spatial Information Engineering, NO. 20210223. The authors also acknowledge the WorldView. for accessing available data from Google Earth.

## REFERENCES

Becek, K., Ibrahim, K., On the positional accuracy of the Googleearth imagery. TS051-Spatial Information Processing Ipaper no.4947. In:FIG Working Week 2011, Marrakech, Morocco, 18-22 May 2011.

Cutbert., Uriel., HORIZONTAL., POSITIONAL ACCURACY OF GOOGLE EARTH ' S IMAGERY OVER RURAL AREAS: A STUDY CASE IN TAMAULIPAS, MEXICO. BCG - Boletim de Ciências Geodésicas - On-Line

version, ISSN 1982-2170 ,<http://dx.doi.org/10.1590/S1982-21702013000400005>.

Du Xiaoping, 2013. Vertical Accuracy Assessment of SRTM and ASTER GDEM over Typical Regions of China Using ICESat/GLAS. *Earth Science-Journal of China University of Geosciences*, 2013, Vol.38 No.4, doi:10.3799/dqkx.2013.087

FLANAGIN, A.J., MERZGER, M.J., The credibility of volunteered geographic information. *GeoJournal*, 72, 137-148, 2008.

Guo Jing, 2020. *Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci.*, XLIII-B3-2020, 1333 - 1338, <https://doi.org/10.5194/isprs-archives-XLIII-B3-2020-1333-2020>, 2020

Google. Source for elevation data. Google Product Forums. 2008. Available at: <https://groups.google.com/forum/?fromgroups=#!topic/earthdata/KsRTsXULRNk>. Accessed: 20 March 2013.

Google Developers. What is the Google Earth API? [EB/OL] (2012-02-24) [2014-05-27] <https://developers.google.com/earth/?hl=en>.

Potere D (2008) Horizontal positional accuracy of Google Earth's high-resolution imagery archive. *Sensors* 8: 7973–7981. <https://doi.org/10.3390/s8127973> PMID: 27873970

Wikipedia. Google Earth [EB/OL] . ( 2012-12-18) [ 2014-05-27] [http://en.wikipedia.org/wiki/Google\\_Earth](http://en.wikipedia.org/wiki/Google_Earth).