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Comparation to the Methods of Interpolation with ASTER GDEM V2 Based on ICESat/GLA14 Lvliang Mountains in Shanxi Province

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ICESat/GLA14, a series of altitude points with high accuracy, it can be used for ASTER GDEM data's accuracy correction, while the rational interpolation method is the important guarantee for the quality of ASTER GDEM data correction results. IDW, Simple Kriging, Ordinary Kriging and Universal Kriging are used in this research to make an accuracy correction for ASTER GDEM V2 based on the ICESat, and compared with the large scale topographic map of Shuiyuguan in Lvliang Mountains. Results show that the Simple Kriging is the best in the four interpolation methods. So, we hold our opinion that the Simple Kriging interpolation is more suitable for the study area of ASTER data accuracy correction.

1. Introduction

Digital elevation model (DEM) is the core data for terrain analysis (G.X. Wang, 2005). For studying the effects of different interpolation methods, many scholars did the corresponding research (X.S. Yi et al. 2010). For example, Q.A. Zhu made a interpolation research based on GIS, and the result pointed out that in order to get the desired research result, the research areas should be studied individually, the data should be analyzed and compared sufficiently, the interpolation algorithm should be improved (Q.A. Zhu et al., 2004). And at the same time, an appropriate spatial interpolation method should be chosen (Q.P. Liu et al., 2009). H.E. Zeng studied spatial interpolation based on Kriging method, compared with the IDW through example, which proved the advantages of Kriging (H.E. Zeng, 2007). ZIMMERMAN D studied the differences between Kriging Interpolation and IDW, and the result showed that Kriging had a better estimation precision than IDW due to its consideration of spatial structure of the sampling point without considering the terrain and the type of sampling method case (ZIMMERMAN D et al., 1999). Kerane-henko studied the differences between IDW, Ordinary Kriging and Logarithmic Kriging, and the result showed that if there were less than 200 sampling points and the data set had a logarithmic distribution, the Logarithmic Kriging played the best performance, otherwise the Ordinary Kriging was better (KERANC-HENKO A N, 1999).
Although the above research compared of different interpolation methods, there is no interpolation methods that is suitable for all the research areas (J.B. Nie, 2007). So there is no doubt that it is necessary to explore the optimal spatial interpolation method for specific topography (X. Li et al., 2007). The paper analyzes and compares various interpolation methods with the data of ICESat/GLA14 and large scale topographic map of Shuiyuguan town, Lvliang Mountain area in Shanxi Province, the results of interpolation research show the improvement in the precision of ASTER GDEM V2 on one hand, and it also offers a certain reference value for the following spatial interpolation research in this region on the other hand (Y.H. Fu et al., 2013).

2. Material and method

2.1 Study area

Lvliang Mountain is located in the west of Shanxi province, it is NE-trending, and its length is about 400 km. Lvliang Mountain is close to, but separated by the Yellow River to Yulin city in Shanxi province in the west, bounded with Datong Basin and Xinding Basin in the north, connected with Taiyuan Basin in the east and Linfen Basin in the south. Guandi Mountain, in the middle part of Lvliang Mountain, is a vault dome. The mountain is divided by radical water system, its relative height is more than 1000 m, the main peak is 2831 m

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above sea level. The northern part of Lvliang Mountain is divided into two parallel columns in east-west direction, Yunzhong Mountain is in the east, and Luya Mountain and Guanqin Mountain is in the west. Many peaks are over 2700 m, it is watershed of Fen river system and Shangqian river system. The height of south part of Lvliang Mountain declined to 1000 m~1500 m, and the trend of southwest section of Lvliang Mountain turns to NE. The distribution and topographic features which are shown in Figure 1.

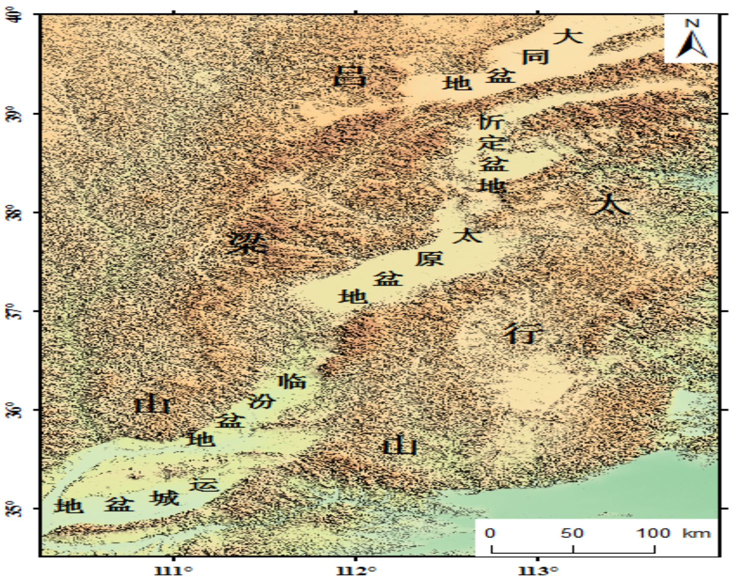


Figure 1: Distribution and Topological Feature of Lvliang Mountain

2.2 Data

This research focuses on the analysis of elevation of the Lvliang Mountain, so the data source is adopted from ASTER GDEM V2 and ICESat/GLA14.

2.2.1 ASTER GDEM V2

On June 30th, 2009, NASA and METI jointly launched the Global Digital Elevation Model via Advanced Spaceborne Thermal Emission and Reflection Radiometer, and its abbreviation was ASTER GDEM. The data was covered with all land area from 83°N to 83°S, it was wider than any other topography before and covered 99% of the Earth's land surface. Using UTM/WGS84 as the reference ellipsoid, the level precision reached 30 m (about one second) and the vertical precision reached 20 m. The data (Figure 2) adopted in this research were downloaded from https://wist.echo.nasa.gov/wist/api/imswelcome.

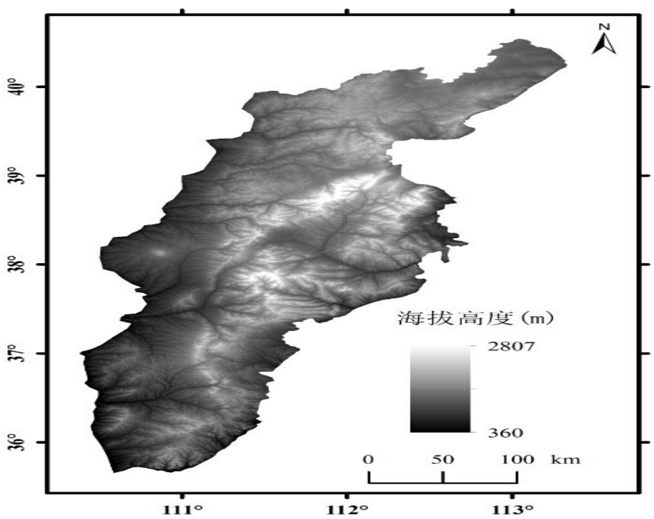


Figure 2: ASTER GDEM V2

2.2.2 ICESat/GLA14

Since January 2003, NASA has launched the first satellite which is specially used to measure the volume of the polar ice - Ice, Cloud, and land Elevation Satellite/Geoscience Laser Altimeter System (ICESat/GLAS for short). The flight altitude of ICESat is 600 km, the inclination angle is 94°, the cycle is 91 days, it's a accurate repeat orbit, and it adopts an intended low earth orbit echo observation to measure altitude variation. ICESat has a precise orbit and the ability to control orientation, it also launches a precise measurement of the surface topography and elevation changes in ice sheet by high spatial resolution along-track. ICESat has the most advanced GLAS, it has three laser device, each wavelength is 532 nm in visible light and 1064nm in near infrared laser pulse. Terrestrial laser spot diameter is about 70 m, the distance of each spot in the track direction is 172 m, the vertical resolution of the Laser Radar altimeter is 14 cm. During continuous operation mode, the design life of each laser is 18 months, and the launch implement can work 5 years continually (Wally H J et al., 2002). In this research, the data (Figure 3) is achieved from the NSIDC (http://nsidc.org/data/ICESat/).

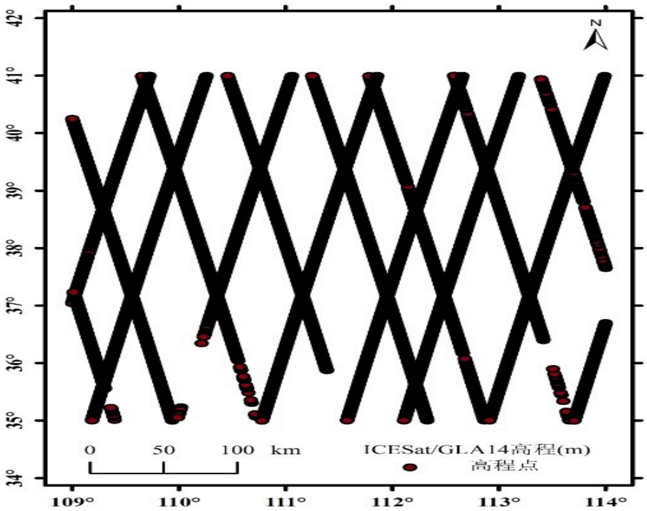


Figure 3: ICESat/GLA14

2.3 Methodology

The first step of research is to process the data, and the results are interpolating data; the second step is to compare different interpolation methods and set up parameters; the final step is to validate and analyze the interpolation results.

2.3.1 ICESat/GLA14 data processing

In this paper, 19 stages data were selected as research data from Feb 21st, 2003 to July 17th, 2009. With the NGAT height extraction tool, the height can be read from the original binary file data, and transformed to the height under WGS84 coordinate system by Formula 1(X.P. Du et al., 2013).

$$H_{WGS84} = h - N - 0.7 \quad (1)$$

H is the height which is relative to the reference ellipsoid, N is geoid height, it means the distance of geoid surface and surface of reference ellipsoid, according to the fluctuation of the sea level, the value is negative or positive. H is orthometric height, which is the length of gravity line between a spots to the geoid.

With the help of 3D analysis tool in GIS software, the function "Add Surface Information" can be implemented, which can extract raster data elevation values in DEM to ICESat/GLAS vector data points as an attribute values, and unify the format of both ICESat/GLAS vector data points and DEM raster data (T. Zhao, 2014). In addition, origin ICESat/GLAS data exist gross error which should be reduced, it means, if the value of differences between GLAS and DEM lager than ±60 m, it should be reduced as gross error (Webster, R., 1990).

2.3.2 Validation

Analyzing the interpolation results by mask method and overlapping ASTER data by raster calculator, setting the large scale map of Shuiyuguan area as a benchmark, extracting the control point elevation values for interpolation results and analyzing its RSME, the calculation is given by the following formula (formula 2).

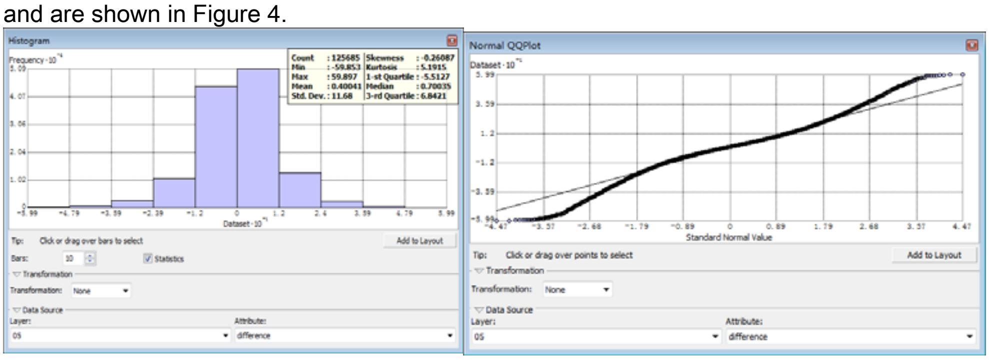
$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(Z_{oi} - Z_{pi})^2} \quad (2)$$

Zoi represents the measured value; Zpi represents the predicted value, n represents sample capacity.

3. Results

3.1 Data analysis

Histogram and normal QQ graph are the two methods adopted in this research to explore 19 stages data. The result shows that three stages in 2005 obey normal distribution, and is suitable to do Inverse Distance Weighted and Kriging interpolation. The analysis results are produced by overlaying these three phase data and are shown in Figure 4.



(a) *(b)*

Figure 4: ICESat/GLA14 exploring (a). 2005 annual histogram; (b). 2005 pnual normal QQ plot

3.2 Parameter settings

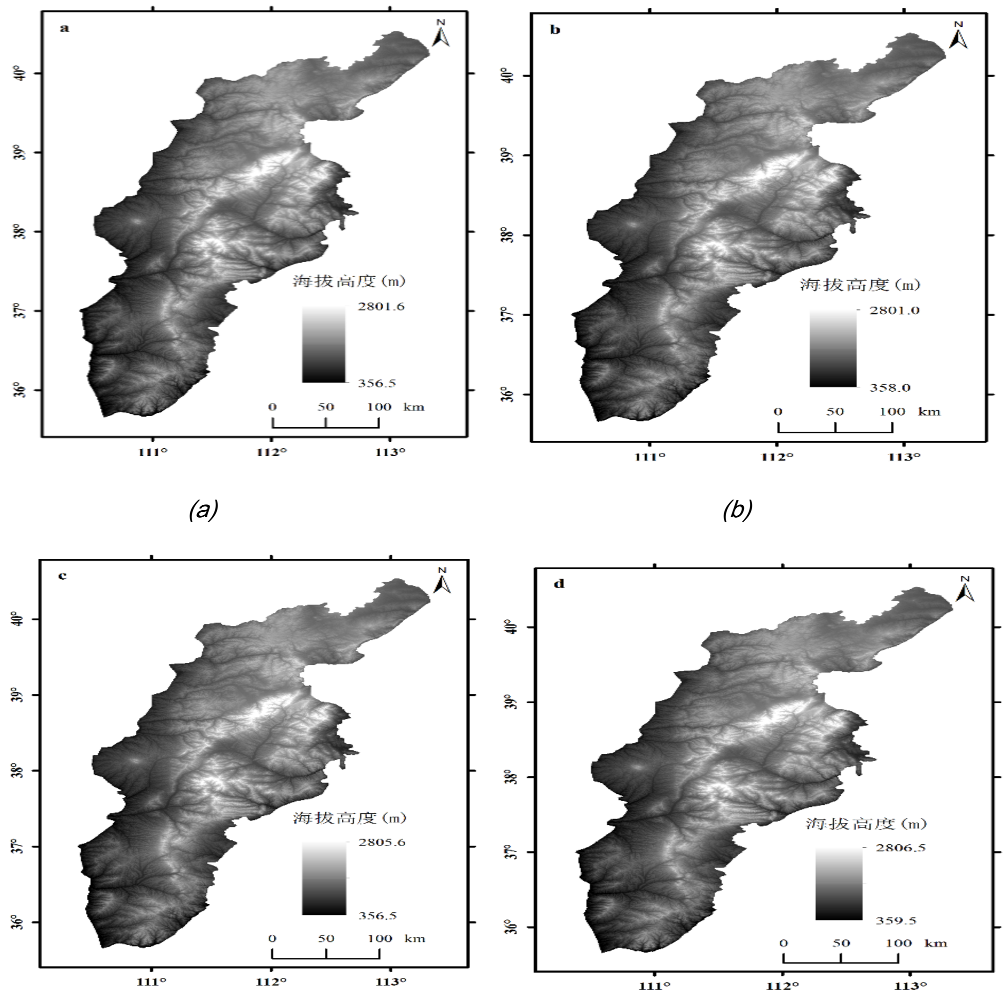
In this paper the parameter settings of interpolation method through trial and error, the evaluation criteria of repeated researches us the average value is close to 0 as well as a smaller RMSE. There are two main parameters affecting the Inverse Distance Weighted Interpolation, the first is the power value of distance – P, and the second is the number of control point – n, which can affect unknown points. The larger the value of P, the points that closer to the unknown points will weight greater, and the further points will weight smaller. Too large value of P may result in a condition that only a small part of known points effect the results of interpolation, the value of P is 2 in this research, and the large part known points are just doing some local linear interpolation. When the P value has been determined, a small n cannot reflect the macro landform nicely, a large n, however, may introduce some poor related control points, this step will increase the error, so it is necessary to obtain n by trial and error. The results show that when the value of n is between 10 to 15, the interpolation effect is the best, so the minimum value of n is 10, and the maximum is 15. The data in this research has the properties of autocorrelation and anisotropy, and the average value and RMSE of interpolation results are shown in the Table 1.

Table 1: Interpolation Result (m)

Method	IDW	Ordinary	Simple	Universal
Mean	0.007	0.0002	0.043	0.0002
Root-Mean	10.53	11.26	10.77	11.26

3.3 Overlap results

The results of overlap are shown in the Figure 5, and the validation results are shown in Table 2.



(a) (b)

(c) (d)

Figure 5: Interpolation Results (a. Ordinary; b. Universal; c. IDW; d. Simple)

Table 2: RMSE Statistics (m)

	Ordinary	Simple	Universal	IDW
RMSE	21.76	21.43	26.99	22.35

It can be concluded from the table 2 that the interpolation results of Simple Kriging Interpolation is the best with the data on October 10th, 2005. Compared with Simple Kriging, the Ordinary Kriging has a difference of 0.33 m, the IDW has a difference of 0.56 m, and the Universal Kriging has a difference of 1.55 m, it’s the worst in these 4 methods. After comprehensive consideration, the research suggests that in Lvliang Mountain research area, Simple Kriging Interpolation method is more suitable for spatial interpolation analysis study.

4. Conclusion

This paper sets Lvliang Mountain in Shanxi Province as research area, it discusses the comparison of several interpolation methods via ICESat/GLA14 data which is corrected by ASTER GDEM v2 data. After exploring data by normal QQ chart and histogram, the three phase data in 2005 are overlaid and the elevation difference between overlaid data are obtained, the differences are interpolated by IDW, Simple Kriging, Ordinary Kriging and Universal Kriging, and the optimal parameters of each method are been explored and chosen, the p value is 2 in IDW, 3 in Simple and Ordinary Kriging and 0 in Universal Kriging, the maximum and minimum predicted point are 15 and 10, the trend type of Ordinary Kriging and Simple Kriging is 3, and the Universal Kriging is const.

Through the precision analysis in Lvliang as a benchmark, the results of Simple Kriging, 21.80 meters in the 2005 full-year, is the most optimal of the four interpolation methods. Therefore it may provide a better interpolation algorithm for the study area.

At present, the interpolation study in domestic and overseas are tend to compare the difference methods but not explore the parameter settings in depth (Price D T et al., 2000). In this paper, the research tests the parameters and obtains the optimal parameters in each interpolation methods, meanwhile, the best interpolation method is also obtained, which provides certain reference value in interpolation parameter settings in this research area. There is a lot of inperfection, the first is that some geological factors are not analyzed in this research, such as slope and aspect, which will impact the precision; the second is that there are many mines in the Lvliang Mountain area, and the terrain changes largely here, so the maps used in this research may have some errors with the real landform in 2005.

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