GLL

Geomatics, Landmanagement and Landscape No. 3 • 2013, 59–66

THE STUDY OF METHODS FOR CORRECTING GLOBAL DIGITAL TERRAIN MODELS USING REMOTE SENSING DATA

Ihor Kolb, Marija Lucyshyn, Małgorzata Panek

Summary

This work describes original methods of improving the quality of Digital Elevation Models (DEM), obtained by means of satellite altimetry data. Shown are subsequent steps of geometric correction of global raster DEM, such as SRTM, SRTM DLR and ASTER GDEM, which are commonly available. According to the authors of this analysis, methods proposed here can be used in geoinformation projects.

Keywords

Digital Terrain Models (DTM) • Digital Elevation Models (DEM) • shuttle radar topographic mission (SRTM) • satellite images • Geographic Information System (GIS)

1. Introduction

Digital Terrain Models (DTM) are an important part of geographical information projects. The purpose of these projects is to study the characteristics of geosystems and DEMs are very helpful in analyzing various natural objects and phenomena.

Due to the creation of many digital models of topographic surface at global and national levels, terrain data are more accessible. Shuttle radar topographic mission (SRTM) carried out by NASA in 2000 provided data, were used to create digital terrain models (DEM) on a global scale. These data can be freely downloaded from the Internet and they are very often used in different projects [SRTM 90m Digital…]. Another similar product – ASTER GDEM – is a joint operation between METI (Ministry of Economy, Trade and Industry) and NASA. It was made according to data obtained in 1999–2000 with ASTER sensor on board the Terra satellite launched into Earth orbit by NASA [ASTER Global Digital Elevation…]. Considering expansion of mentioned DEM in different studies, it is necessary to identify the accuracy of measuring the height of points in areas with different character of terrain and type of bottom topographic surface. Therefore, the development of methodologies to assess the accuracy of the global DEM is an urgent task, as is confirming the large number of publications on this topic in professional literature [e.g. Shangmin et al. 2011, Jarvis et al. 2004] and other.

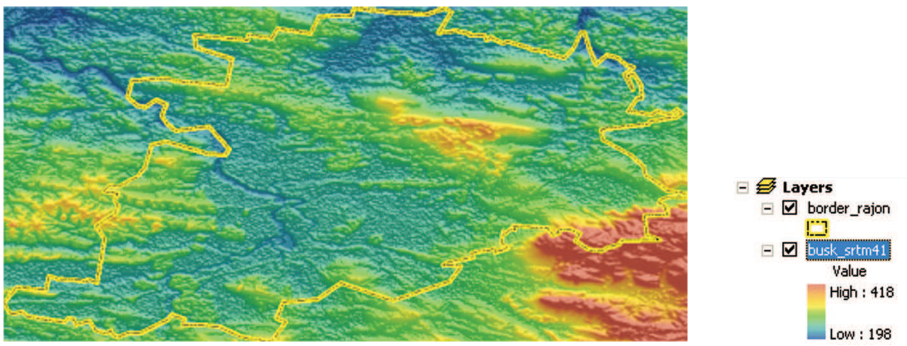
In this analysis, an attempt is made to estimate the quality of SRTM DEM and ASTER GDEM on the territory of the West Ukraine, in the basin of the Western Buh River. This river is an object of study in national and international ecological projects. We have tried to prepare a DEM correction, using multispectral satellite images by making the correction matrix of SRTM and ASTER GRID according to the height of Earth's vegetation.

2. The Procedure of DEM geometric transformation using high resolution satellite images

It is appropriate to make geometric transformation using reference points to correct the location of nodes in global DEM. These could be points in confluences of high order watercourses.

The study area is Busk Raion in Lviv Oblast. To do the experimental work, we used 8-band satellite images taken from LANDSAT 7 ETM+ sensor on April 12, 2002. Spatial resolution for bands 1–5 and 7 is 28.5 m and for panchromatic channel (8 band) is 15 m. For this territory of Lviv Oblast, we used the SRTM terrain model, 4.1. version. We have downloaded two SRTM fragments – "srtm_41_02" and „srtm_41_03", from http://srtm.csi.cgiar.org – the website of CIAT (International Center for Tropical Agriculture). CIAT has corrected this data to keep raster surface with cell size of 90 m x 90 m constant, without false or missing values. We have used interpolation methods to fill cells with "Nodata" values in input SRTM data.

DEM data were placed together in one raster structure within the borders of Busk Raion using Arc GIS program. In this way, we have a SRTM model without "no value" cells (Figure 1).



Source: authors' study

Fig. 1. Input SRTM model of Busk Raion

As is known, in GIS environment you can make a geometric correction of raster data using a dataset of reference points. In this case it was proposed to use confluence points which can be clearly identified on satellite images and which one can get from a hydrological analysis of DEM. For geometric correction of the position of SRTM raster, it is necessary to identify points of significant watercourse confluence. According to our technology, these points will be used as reference points in the polynomial transformation of raster image. To create an orographic network, one can use suitable program modules of hydrological modeling in GIS packets. There are such modules in ArcGIS, gvSIG, SAGA programs and so forth. Figure 2 shows the result of geoprocessing – automatically separated orographic network keeping high order thalwegs (each cell has an runoff accumulation parameter of no less than 1000). Watercourses and their confluences are clearly visible.

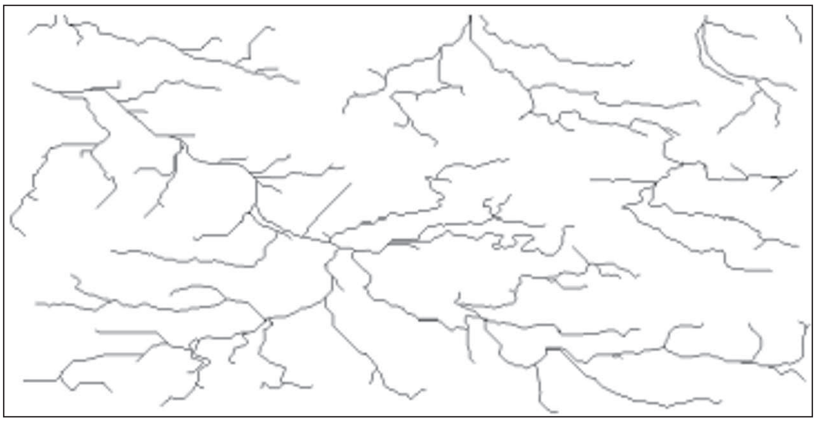


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Fig. 2. The orographic network in the study area

The next stage of the analysis is, the geometric transformation of SRTM raster which has been made in ArcGIS with the Georeferencing toolbar (Figure 3). We have taken 9 points in, the survey which were clearly shown in the watercourse model and in the satellite image. Deviation of proper point locations is ranges from 6 to 57 m. The mean square error of checkpoints on the model SRTM, computed after the second order polynomial transformation, is ± 27.5 m in a planned position.

In Figure 3 it can be seen the geometrically corrected DEM which has been created using the ArcMAP Georeferencing toolbar.

Summing up this stage of analysis, we can state that the accuracy in a planned position of SRTM model on the territory of Busk raion corresponds to the top margin of range, notably ± 50 m in the worst determined places. This figure can be improved almost by a factor of 2 to ± 30 m, by making the correction according to the proposed technique, using a satellite image with a 30 m resolution.

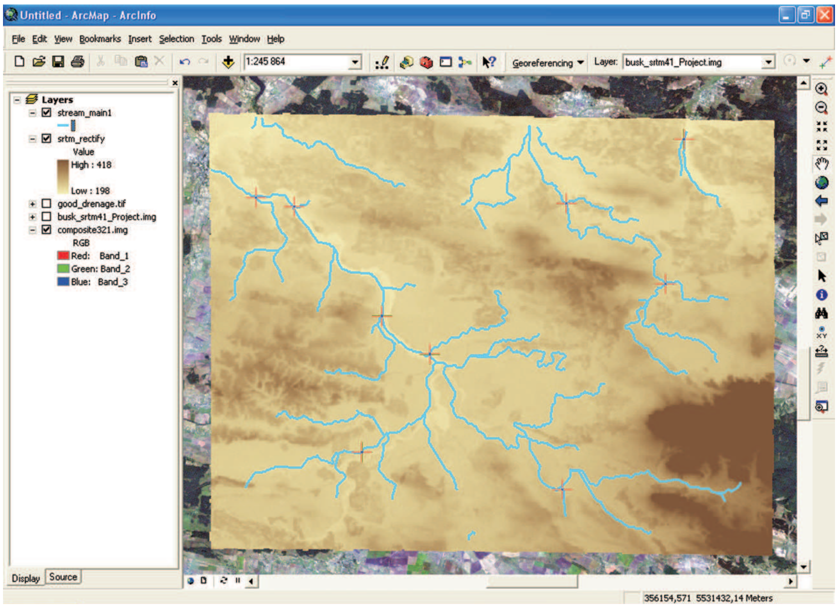

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Fig. 3. Geometrically corrected DEM SRTM

We can conclude that the better resolution and the higher level of georeference accuracy of a satellite image, the better results of the geometric correction of the DEM.

3. Correction of the part of global DEM according to vegetation height

The next stage of the research is the creation and analysis of corrections maps by the height of vegetation [e.g. Austin and Gallant 2010, SRTM DEM processing…]. To achieve this, can create adjustment layers according to the vegetation height in DEM using multispectral satellite images. This is proposed in order to build a vegetation index map (for instance NDVI map) and to classify it by biomass size. Due to this, one can easily find areas with different vegetation height – forests, bushes, meadows etc. On this map, values of heights, typical for each kind of greenery, are assigned to cells. Thus, we get the map with adjustments for vegetation height.

We have taken images with band 3 (red) and band 4 (near infrared) of Landsat 7 scene to calculate the NDVI. The result of this calculation is a raster map (the fragment of this map is shown Figure 4). One can estimate the condition of vegetative cover, water areas, open ground etc. We have used such classification parameters of NDVI map to form the map with adjustments for vegetation height (considering the types of vegetation, present in the investigated area) in DEM:

- 0.7 and more – forests – correction in DEM is −10 m,
- 0.3–0.7 – open woodlands and bushes – correction in DEM is −5 m,
- 0.15–0.3 – high grass, bushes – correction in DEM is −1 m,
- −1–0.3 – open areas, water areas, artificial surfaces – without correction.

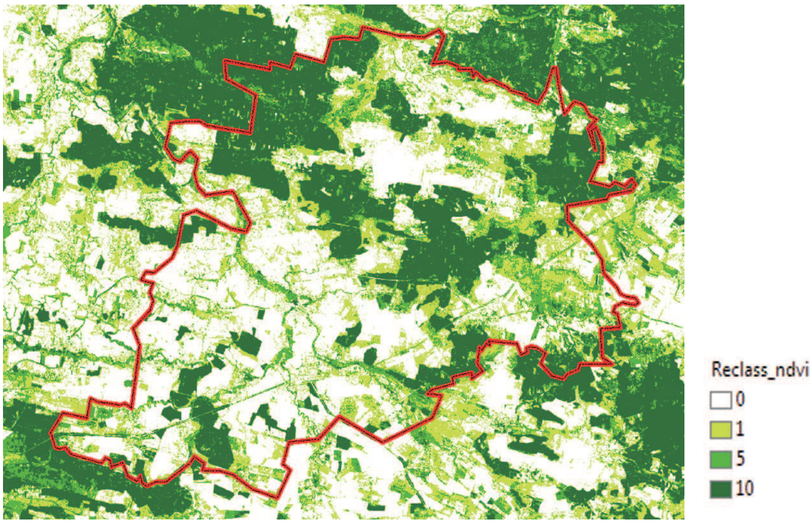

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Fig. 4. Classified NDVI map

We have placed corrections in SRTM data, adding a DEM raster layers and maps with corrections. We have achieved the new DEM with adjustments for vegetation height.

In the next pictures (Figure 5) the fragment of the satellite image and the fragment of SRTM DLR are shown. They both show the area of study. One can see that vegetation is highly influence on the high of DEM nodes – local surface growths match contours of forests. After making adjustments for the vegetation, the picture changes considerably – such artifacts disappeared (Figure 6).

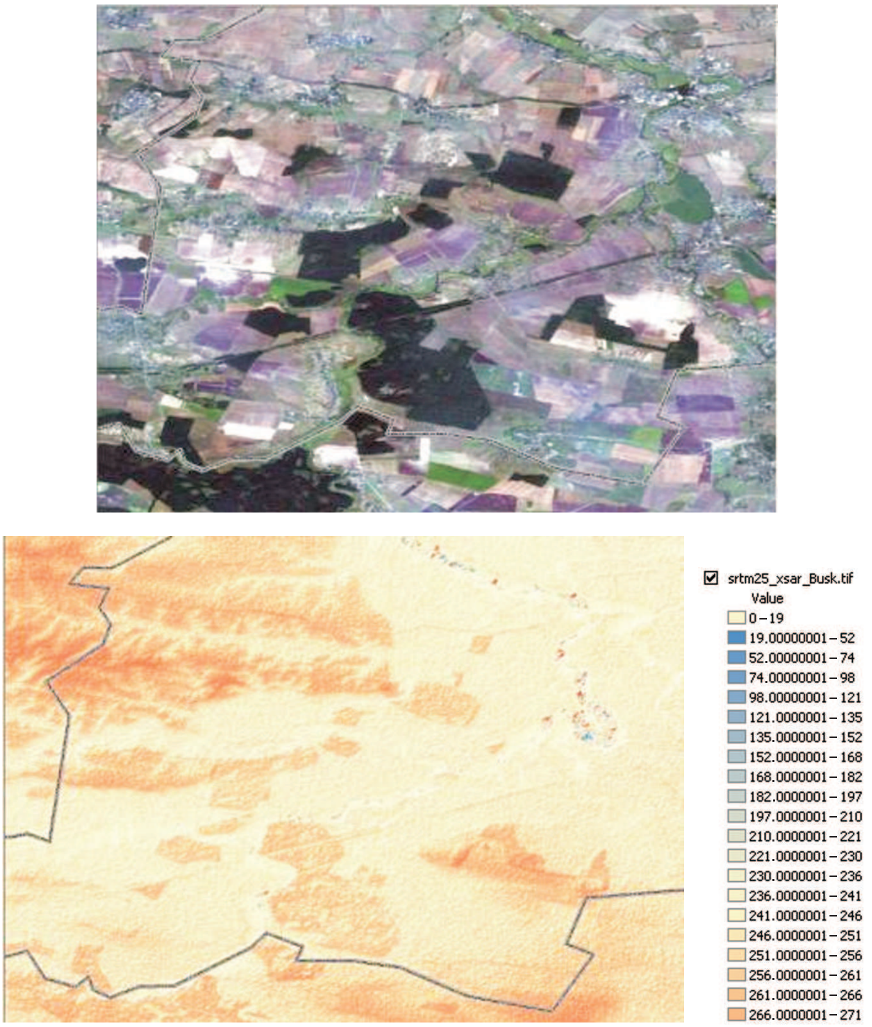

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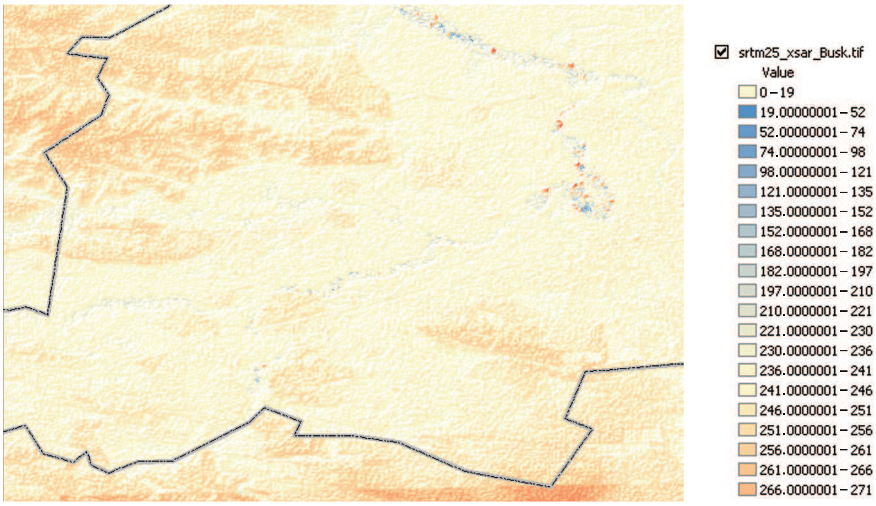
Fig. 5. The satellite image and the SRTM DLR of the Busk Raion

4. The analysis of study results

To create and improve the geometric quality of surface models on a local level, is appropriate to do geometric transformations of cartographic model areas and of higher resolution satellite images. We propose the use of methods which are commonly applied in GIS for hydrologic analyses. These methods can form a basis for separating the network of reference points which are necessary for doing the geometric transformation.



Source: authors' study

Fig. 6. The SRTM DLR surface after making adjustments for vegetation height

It is recommended, that satellite image processing methods are used to make adjustments for vegetation height to elevation models, if there are no high quality vegetation maps. A relatively easy method for this, is the classification of vegetation types based on the NDVI map.

In order to analyze the results of a terrain model correction we have compared corrected SRTM V.4 and SRTM DLR models with tested DEM, obtained from vectorized plans with a scale of 1 : 10000 and 1 m contour interval. Histograms with error distribution of height point values for corrected SRTM V.4 have shown, a normal error distribution with mathematical expectation of –4.6 m and a tendency to underestimate the height values in the error range of –10–12m. The general error range is from –27.6 to +19.5m. This picture can be explained by the presence of many water surfaces in the study area. It is generally known, that water areas have some peculiarities, in the way that they reflect radar emission (water and ice underestimate the height values).

The overall view of the error distribution gradient shows systematic underestimation (blue color) along terrain depressions (ravines, gullies, ditches) and inversely, overestimation in positive forms of relief (tops of hills).

A similar picture is observed in the making and evaluation of SRTM DLR models only with a much larger error range from –281 m to +178m. The mathematical expectation of the error is +23.7 m.

5. Conclusion

This analysis shows, that there is an opportunity to correct topographic surface models, which are commonly available and are permanently being improved.

Use orographic network as a source of reference and control points is a robust way to perform geometric matching of the fragments global DTM from maps and satellite images.

Present this methodology using of vegetation indices maps to search for corrections in altitude points can be used for any global DEMs and, in our opinion, provides an opportunity to improve their quality.

References

ASTER Global Digital Elevation Model Version 2: Summary of validation results, August 31, 2011, http://www.jspacesystems.or.jp/ersdac/GDEM/ver2Validation/Summary_GDEM2_validation_report_final.pdf.

Austin J.M., Gallant J.C. 2010. Comparison of Intermap 5 m DTM with SRTM 1 second DEM. CSIRO: Water for a healthy country national research flagship. Report to Murray Darling Basin Authority, 18.

Jarvis A., Rubiano J., Nelson A., Farrow A., Mulligan M. 2004. Practical use of SRTM data in the tropics: Comparisons with digital elevation models generated from cartographic data. Centro Internacional de Agricultura Tropical (CIAT), 198.

Koch A., Heipke C., Lohmann P. 2002. Analysis of SRTM DTM. Methodology and practical results. Symposium on Geospatial Theory, Processing and Applications, Symposium sur la théorie, les traitements et les applications des données Géospatiales. Commission IV, WG IV/6, Ottawa.

Shangmin Z., Weiming C., Chenghu Z., Xi C., Shifang Z., Zengpo Z., Haijiang L., Huixia C. 2011. Accuracy assessment of the ASTER GDEM and SRTM3 DEM: an example in the Loess Plateau and North China Plain of China, Intern. J. Remote Sens.

SRTM 90m Digital Elevation Data, http://srtm.csi.cgiar.org/.

SRTM DEM processing and elimination of artifacts, http://www.esoter.net/?q=content/srtm-dem-processing-and-elimination-artefacts.

http://dx.doi.org/10.1080/01431161.2010.532176.

Associate Professor, a candidate of technical sciences Ihor Kolb
Lviv Polytechnic National University
Department of Photogrammetry and Geoinformatics
Ukraine, 79013 Lviv, Bandera Str. 12
e-mail: i_kolb@rambler.ru

MSc Marija Lutcyschyn
Lviv Polytechnic National University
Department of Photogrammetry and Geoinformatics
Ukraine, 79013 Lviv, Bandera Str. 12
e-mail: luc_mariya@ukr.net

Student Małgorzata Panek
Lviv Polytechnic National University
Department of Photogrammetry and Geoinformatics
Ukraine, 79013 Lviv, Bandera Str. 12
e-mail: panusiek@vp.pl