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Vertical accuracy assessment of SRTM C-band DEM data for different terrain characteristics

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ABSTRACT: Data elevation models are used in different applications but in the practice availability of good quality DEMs are often restricted by technical and economical aspects.

The ‘‘open source’’ Shuttle Radar Topographic Mission C-band (3 arc second, approx. 90 m grid size) version II data, released to the general public via the internet seems to be an alternative for several tasks although the data requires careful processing and an investigation into the quality of this dataset was considered an important task.

This paper presents the results of the tests carried out in Warsaw University of Technology to determine the quality and potential suitability of the SRTM product (version II). Three test areas (approx 10,000 km^2 each) were chosen over Poland, one in the North, the second in the centre and the third in the South. The test sites represent different terrain and landscape characteristics; moreover, representation of various classes gave a good overview of vertical accuracy of radar data. The large numbers of independent and accurate control points were used for vertical accuracy determination. The additional set of accuracy tests using a national data elevation model (25 m grid size) was done as well.

The results show that the SRTM ver. II data for the tiles tested performed better than its standard specification, and can be suitable for wide use in many applications without further processing (improvement), besides projection and datum transformations.

1 INTRODUCTION

In the last years we have observed growing interest of practical use of various information about Earth surface while at the same time the development of collecting data technology increased (in particularly form the space). One of the main sources of the surface height information is digital elevation model (DEM). Production methods of height data collection begin from direct survey, through the cartographic method based on contour lines at different scales, photogrammetric processing of aerial photos and satellite imagery, and ending with LIDAR scanning and RADAR interferometery.

The best method selection a for data elevation model production is directly related to extent of area to be processed (e.g. local or national range), expected positional and vertical accuracy of the final product and finally the cost of investment.

The "open source" SRTM C-band (3 arc second, approx. 90 m grid size) version II data, released to the general public via the internet seems to be an alternative for several tasks although the data requires careful processing and an investigation into the quality of this dataset was considered an important task. The purpose of this paper is to document the analysis that was undertaken to describe the SRTM height accuracy, based on different analyses prepared on various test sites. For the project three test sites (approx. 10 000 km^2 each) in Poland were chosen. The first test area was localized in the North-East Poland with relatively extensive forest areas and lakes; the second in the centre of Poland with the advantage of flat agriculture areas; and for the third site a mountain region, the most difficult for SRTM data (maximum altitude above 1700 m a.s.l.) localized on the south of Poland was selected. (Fig. 1)

2 DATASETS

2.1 *SRTM data*

The Shuttle Radar Topography Mission (SRTM) was a joint project between National Aeronautics and Space Administration (NASA) and NGA (National Geospatial-Intelligence Agency), with the participation of the German and Italian space agencies to

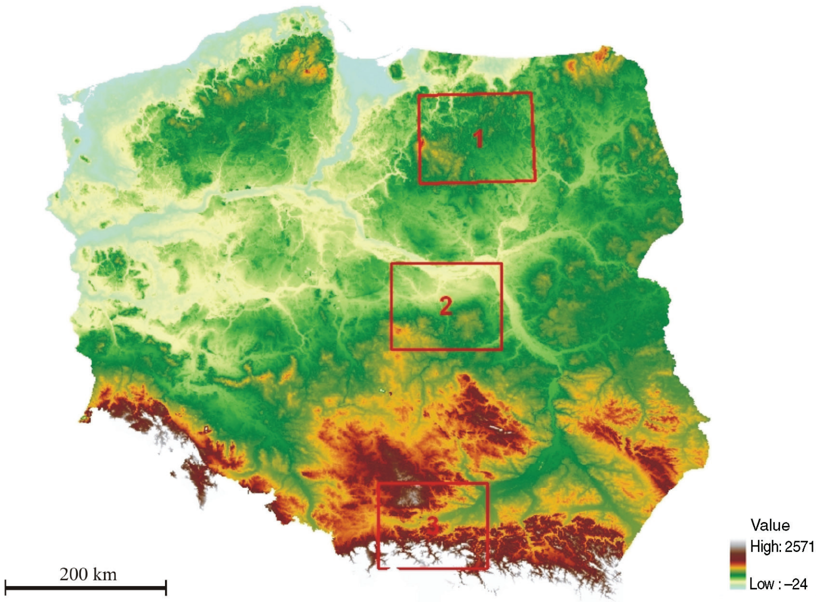

Figure 1. Test site distribution showed on the DEM colour map for Poland.

generate a near-global three dimensional dataset. SRTM utilized dual Spaceborne Imaging Radar (SIR-C) and dual X-band Synthetic Aperture Radar (X-SAR) configured as a baseline interferometer (60 meters long) (Farr & Kobrick 2000), acquiring two images at the same time. Those two images, when combined, can produce a single 3-D image (Bamler *et al*. 2003). SRTM was the primary payload on the STS-99 mission of the Space Shuttle Endeavour, which launched on February 11, 2000. The goal was to image each terrain segment at least twice from different angles (on ascending, or north-going, and descending orbit passes) to fill in areas shadowed from the radar beam by terrain. SRTM successfully collected data over 80% of the Earth's land surface, for the most of the area between 60°N and 56° S latitude (USGS 2006). The study object of the present paper was radar data processed and published by NGA in the middle of 2005. Version II of SRTM data included improvements for water bodies (NGA 2003).

SRTM data has been used to generate a digital topographic map of the Earth's land surface with data points spaced every 3 arc second for global coverage of latitude and longitude (approx. 90 meters). The absolute horizontal and vertical accuracy is 20 meters (circular error at 90% confidence) and 16 meters (linear error at 90% confidence), respectively (USGS 2006).

2.2 *Reference input data*

In the present project two types of input data were used: independent control points, and a national elevation model DEM (namely DTED level 2). In total, more than 6600 evenly distributed independent points from 1st and 2nd order network delivered in the Polish national projection PUWG 1992 were used. Basic vertical accuracy of mentioned points were not worse than 0,1 meter and positional accuracy 0,05 meter. For the project, the independent control points were established as ground truth (error-free) and used in vertical absolute accuracy assessment processes of SRTM and DTED data.

The National elevation model available in Poland (DTED level 2), produced from topographic maps at the scale 1:50 000, was used as well. The input data of the test sites were delivered with a pixel size of 1 arc second in the geographic projection (Lat/Lon) WGS 84. The absolute vertical accuracy of national DEM data was analyzed. The test raster (DTED) data was superimposed with a set of independent control points and the elevation delivered form the test raster using bilinear interpolation. On the basis of the difference between the calculated Z-coordinates from data and control points, the RMSE are calculated separately for each test site (Kay *et al*. 2005). In summary the absolute vertical accuracy (RMSE) of national DEM data were for the first test site 1,9 m, for the second 1,4 m, and for the third mountain test site 2,8 m.

3 STUDY METHODOLOGY

The fundamental aim of the presented project was to make vertical accuracy assessment of SRTM data for various land cover classes respectively, taking into consideration the height terrain characteristic based on three test sites over Poland.

In the first stage of evaluation, absolute vertical accuracy of the radar data based on a large number of independent control points were prepared. The test raster (SRTM or

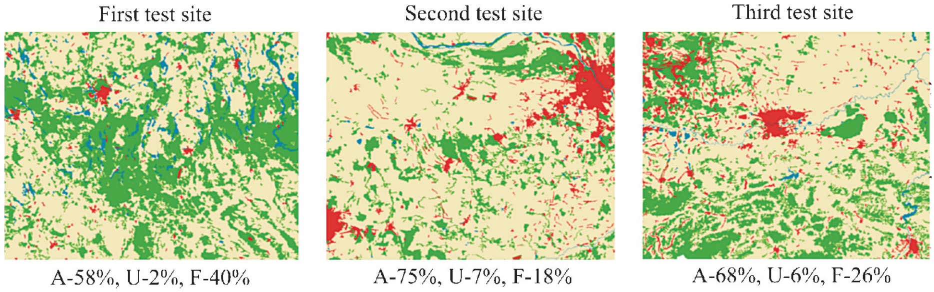

Figure 2. Graphical and percentage land corer stratification of three test sites selected. (A) – Arable-beige colour, (U) – Urban-red colour, (F) – Forest-green colour and Water-blue colour.

DTED) data was superimposed with the set of approximately 6,600 check points and the elevation derived from the test raster using bilinear interpolation. On the basis of the differences between the calculated Z-coordinates derived from test data and the check points, the RMSE, standard deviation and mean values are calculated.

Secondly, discrepancies between surface represented by two independent height models (DTED – national DEM, SRTM) were calculated separately for each test site. The method is based on direct comparison of two raster data sets (DTED and SRTM) by superimposing equivalent raster matrices. Common pixel size, projection system and matrix size are the necessary conditions for comparing two data sets. The overlay resulted in values that quantify the discrepancies between the two data sets with height differences calculated for every pixel. For these discrepancies RMS, standard deviation and mean values are calculated. (Kay *et al.* 2005, Zieliński 2004).

The land cover stratification (placed below Fig. 2) showed the proportional contribution of individual land cover categories for each test sites processed using the Corine Land Cover 2000 map (Bielecka & Ciolkosz 2004). Three broad categories (Urban, Agriculture, Forest,) reflecting the land cover characteristic of the test sites were produced. The water classes were excluded from the analyses. The domination of the agriculture and forest class for each test site directly corresponded to general land cover characteristic of Poland.

Additionally, elevation slope masks were made from the national data (DTED). This slope mask was classed into 4 levels: between 0% and 10 %, 10%–20%, 20% –40% and more than 40% corresponding with the stated performance classification of commercial height data product. The above mentioned test areas selected for this project characterized the differentiation of terrain relief characteristics. The first two test sites were classified as rather flat areas with little varied terrain. Moreover selected slope classes for the range (0–10%) covered above 96% of the two test areas. However, contribution of slope classes for the third (heterogeneous) mountain test site were as follows (0–10%) – 62%, (10–20%) – 22%, (20–40%) – 14%, (more than 40%) – 2%, respectively.

4 RESULTS

The received results are related to the representative test sites selected for Poland and presented in the figures shown below. The first three figures (Fig. 3–5) show final results

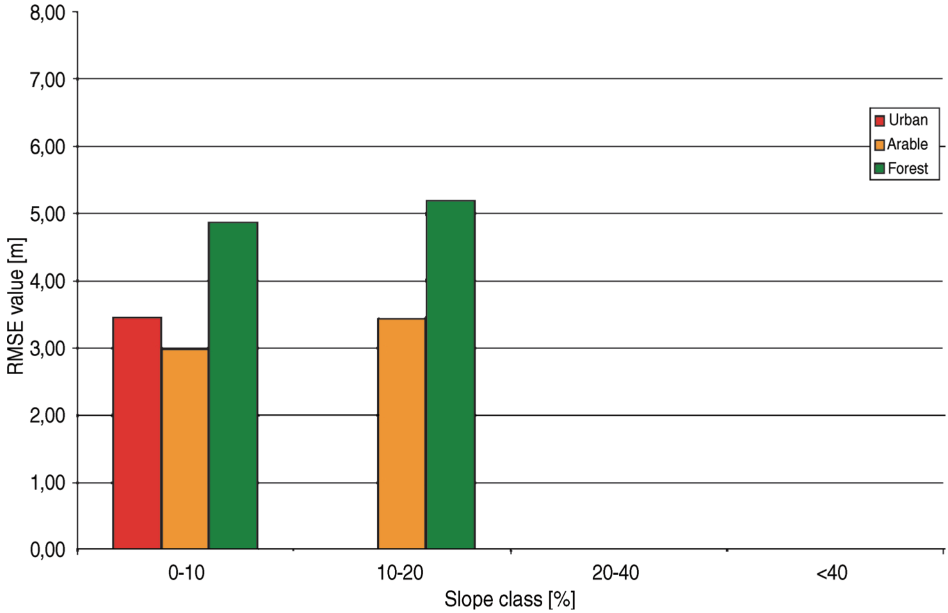

Figure 3. Summary results of absolute accuracy of SRTM data for the first test site.

of vertical absolute accuracy assessment of SRTM for selected land classes in the sites (agricultural land, urban zones, forest areas) and the slope categories for each test site separately. In addition, the figures (Fig. 6–8) contain final results of heights discrepancies (between DTED and SRTM) in the comparable form for each site separately as well.

4.1 *Absolute accuracy of SRTM data*

The tested SRTM version II product has an estimated vertical absolute accuracy better than official product specifications. The results (Fig. 3–5) show that the tested radar product works better on the less difficult terrain (lower slope angles of terrain), corresponding to the specifics of radar acquisition (Eineder & Holzner 2000). Moreover, the product dataset typically included surface information (e.g. for forest and urban classes) height values.

For instance, for the lower slope angles (slope between 0 and 10%) the data has RMSE values in the range 1,7 – 3,0 meter for agriculture land, from 2,2 – 3,9 meter for urban zone and for forest area 3,6 – 5,2 meter.

For the highest slope classes (<20%) SRTM has an RMSE value not bigger than 3,4 meter for agriculture land, for urban zone 2,5 meter and for forest area 5,2 meter.

Furthermore, for the most difficult slope classes above 20%, the reference data slightly meets the stratification criteria only in one test site (mountains region) for agriculture land and forest area, the RMSE value received up to 6 meter for mentioned land classes.

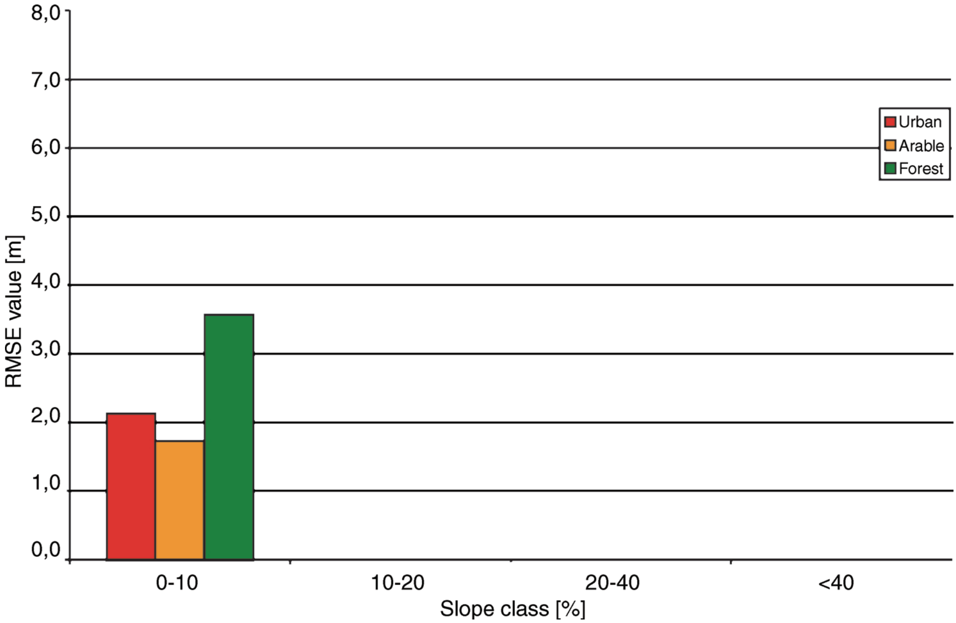

Figure 4. Summary results of absolute accuracy of SRTM data for the second test site.

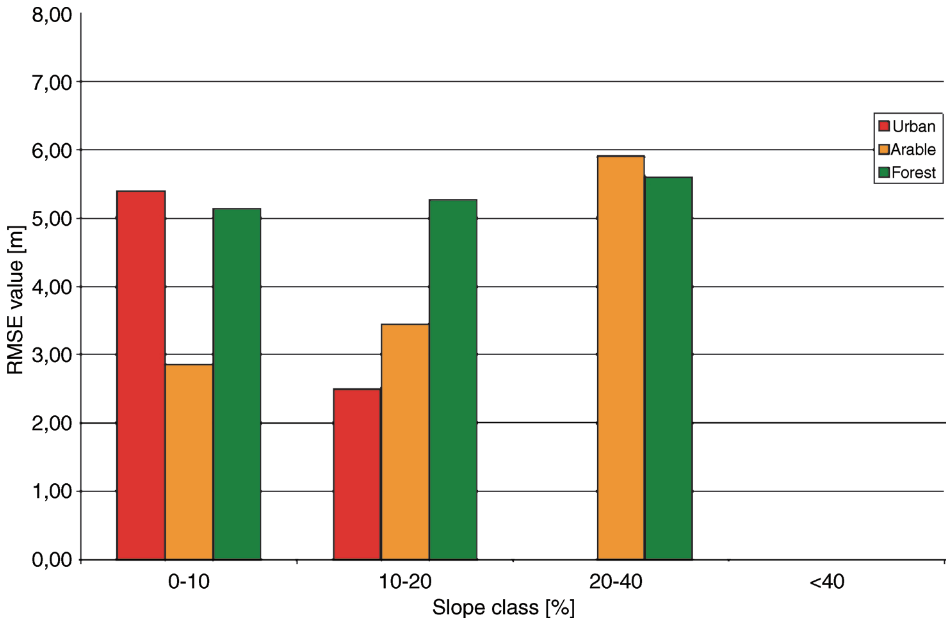

Figure 5. Summary results of absolute accuracy of SRTM data for the third test site.

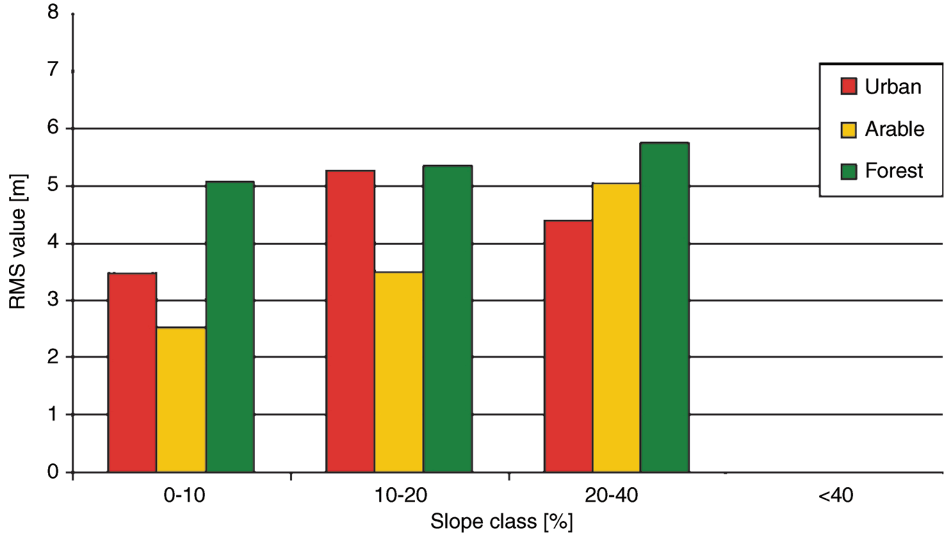

Figure 6. Summary results of discrepancies (SRTM v DTED) for the first test site.

4.2 *DTED ver. SRTM*

Further assessment of SRTM data show that the discrepancies between radar product and independent elevation models data (DTED) found similar results of RMS value calculated from common pixel height differences of two datasets (Fig. 6–8). However, the RMS values contained the additional error (heights) factors from DTED dataset.

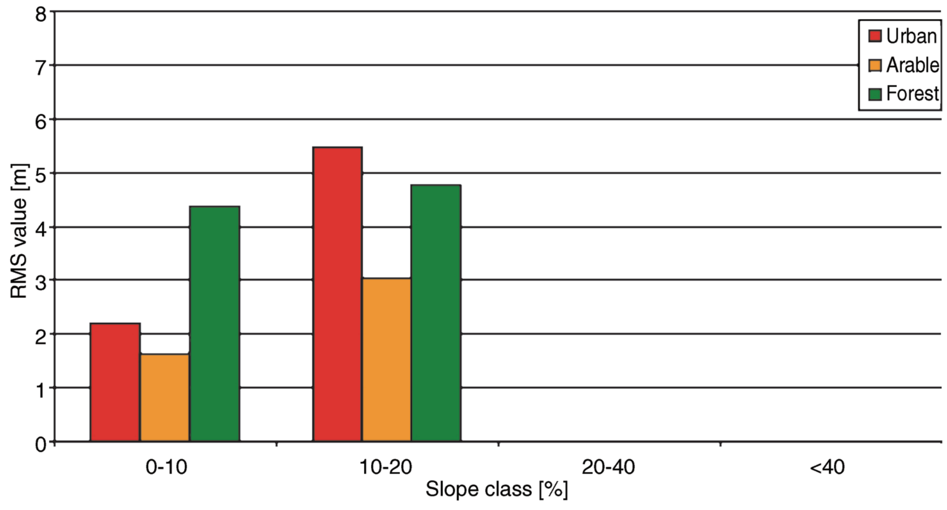

Figure 7. Summary results of discrepancies (SRTM v DTED) for the second test site.

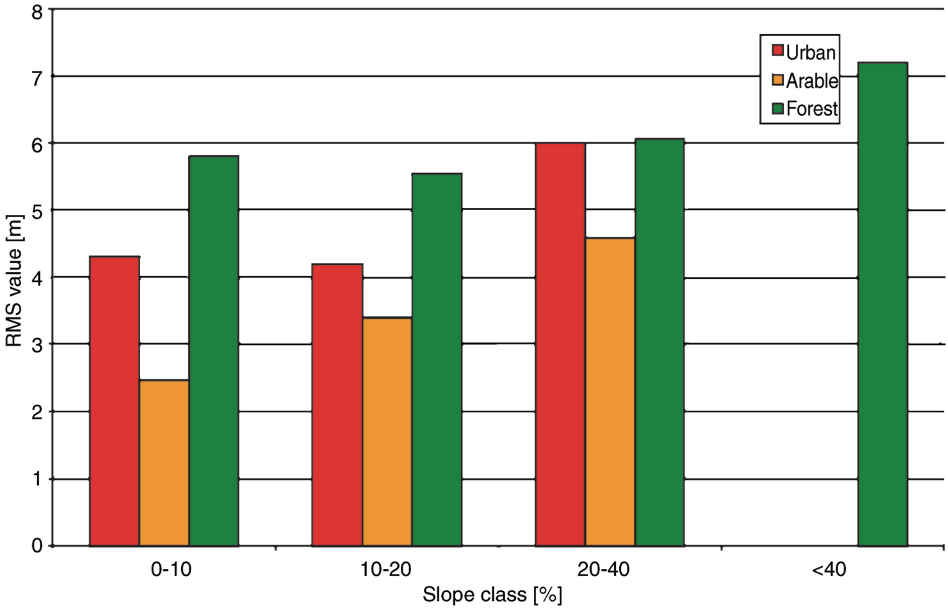

Figure 8. Summary results of discrepancies (SRTM v DTED) for the third test site.

In summary, the RMS values of the data compared for the lower slope angles (0–10%) has obtained for agriculture land up to 2,5 meter, urban zone up to 4,4 meter and for forest area up 5,8 meter.

For highest slope angles (<20%) for agriculture land, urban zone and forest areas – up to 3,4 meter, up to 5,5 meter and about 5,3 meter, respectively. Consequently, for the slope angles above 20% the representation of samples into selected classes were limited and RMS value for agriculture land and forest areas obtained up to 5 meter and up to 7 meter.

The following figures describe results of the different accuracy analyses of the SRTM product. The three land categories (Arable-beige colour, Urban-red colour and Forest-green colour) are split into four slope angle classes (0–10%, 10–20%, 20–40%, <40%). The lack of results shown in the charts means that representation of particular land cover stratification classes were limited for selected test sites.

5 CONCLUSIONS

The results show that, for all the applied test sites, SRTM products performed better than their standard specification, with rather stable results for the selected land classes in the site (agricultural land, urban zones, and forest areas) and the corresponding slope categories. On this basis, it was concluded that "open source" SRTM C-band (3 arc second, approx. 90 m grid size) version II data products is suitable for several tasks, such as rectification of most VHR imagery without further processing, besides projection/datum transformations.

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