Assessing the accuracy of SRTM altitude data for the hilly area in northeastern Romania

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Abstract—**SRTM data is still one of the most used data in geosciences for various purposes: geomorphometric analysis, environmental covariate modelling or geomorphic change detection. Although high resolution national/regional DEMs exist, very often accessing them is expensive, or their coverage is not complete over specific areas (only floodplains or cities are covered). Because of this SRTM still remains the best choice when elevation data is needed for regional/national or global areas. In order to assess the correctness of SRTM data to depict the real shape of Earth surface we used a regional high resolution DEM which cover a part of the hilly area of north-eastern Romanian. Both DEMs were converted to the same horizontal and vertical datum (Stereo 70 Romanian projection and the EGG97 geoid), interpolated to the same grid size and position and compared using raster algebra. The horizontal x and y components and the vertical component errors were assessed. The results show that the errors of the SRTM model are well consistent with its acquisition method (the presence of the trees and the topographic shadow) and does represent reasonably well the Earth's surface in the study area. Anyhow, the resolution of the Earth features depicted on the SRTM model is limited by the acquisition method and does not incorporate landforms which have a vertical and horizontal wavelength under 100 m.**

I. INTRODUCTION

Data on Earth's shape and elevation is the foundation of the modern geosciences [1]. Elevation is used in many geomorphological, geological and environmental modelling and analysis, and especially datasets with global coverage are of interest.

SRTM mission collected near global data in C-band using synthetic aperture radar (SAR) technology between 11 and 22 February 2000, from which NASA produced through SAR interferometry a DEM with 1 by 1 arc sec. spatial resolution (roughly 30 m at the Equator) [2, 3, 4, 1]. The system acquired the data at angles between 17° (small look angle) to 65° (large look angle) [3]. At large look angles and steep areas the lack of data (voids) is present (shadow effect) especially for steep terrains [3], voids which were filled through interpolation and altitude from other sources [5]. At small look angles, the layover and foreshortening effects affects mostly the mountainous terrains by shortening the hillslopes [3], but in general were removed by the processing [3, 4]. Small local random errors of ±4 m are present due to changes in surface local conditions [4]. The obtained elevation represent the altitude of Earth's surface and its cover: rocks, rough water, vegetation and man-made constructions [1]. Heavy vegetation canopies are not penetrated, while other vegetation features are penetrated [6, 1]. Smooth water and sand areas might not get scatter and present voids [1]. Large man-made features appear on the SRTM surface, but in urban areas the elevation represent a mean value of the height of the buildings, because of reflections, shadows and layovers [1]. Water areas (lakes, rivers, seas) were processed through flattening [1].

The system of data acquisition and processing was designed to produce errors with linear vertical absolute height error of less than 16 m, linear vertical relative height error of less than 10 m, circular absolute geolocation error of less than 20 m, and circular relative geolocation error of less than 15 m [1]. The validation has shown that the errors were under half of the pixel resolution (10-15 m and under) for both vertical and horizontal components at 90% [4] fulfilling the planned requirements.

LiDAR data was shown to model very well the earth surface (the vertical component of the altitude error is under 2 m or even better [7, 8]) and represents one of the best and available snapshots of Earth's topography (with its own shortcomings [7]), today at regional or even national scales.

II. STUDY AREA

The north-eastern Romanian (Fig. 1) is a hilly area covering a surface of around 31 000 km^2. The elevation range is of 566.3 m, from 0.3 m in the Prut channel at Galați to 566.6 m in the central part. LIDAR data with a density of 2 to 6 points per square meter is available for an area of 21 076 km^2 covering Prut and Bârlad

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catchments. The elevation of the LiDAR DEM represent the earth bare surface, the vegetation and man-made features being filtered.

Figure 1. Geographical position of the study area

III. Material and Methods

The LiDAR data was provided at 30 m resolution in order to match the SRTM1 Arc-Second Global void filled version (https://lta.cr.usgs.gov/SRTM1Arc) which was imported and mosaicked in SAGA GIS [9]. A visual inspection of the two DEMs was performed on shading maps to assess the presence of rough errors. On the LiDAR DEM several areas with missing data were identified. These areas represent 0.03% of the study areas and were masked from the analysis.

Further, the SRTM data was resampled and reprojected to match the LiDAR DEM at 30 spatial resolution and Stereo 70 projection (EPSG:3844) using the GDAL gdalwarp function. The proj4 option of the gdalwarp function was used to translate the LiDAR elevation data in .ASC format from the EGG97 (European Gravimetric Geoid Model 1997) to EGM96 (Earth Gravitational Model 1996), which is the geoid model used by SRTM data. The absolute differences between the data in the two geoid models are in the range of ±0.5 m.

The raster algebra was performed in R statistical software using the raster package (https://cran.r-project.org/web/packages/raster/index.html). R stat base functions and several packages (lattice, rgdal) were used for the manipulation, the statistical analysis and for the plotting.

IV. Results and Discussions

At the first look the histogram of the difference between LiDAR DEM and the SRTM DEM (Fig. 2 – thick black line) show that SRTM data is under the LIDAR surface, because the majority of the differences are positive. This is similar with other areas around the Globe [6]. Over forested areas the SRTM data is over the LiDAR bare ground, but under the canopy top, because of the radar signal penetration the canopy.

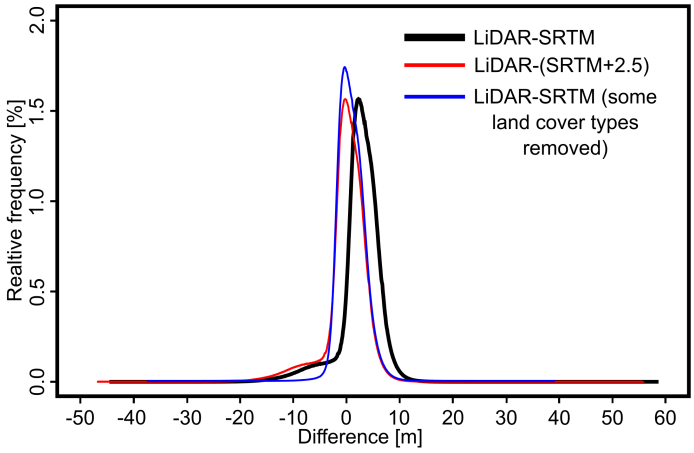

Figure 2. The histograms of the LiDAR DEM and SRTM DEM difference

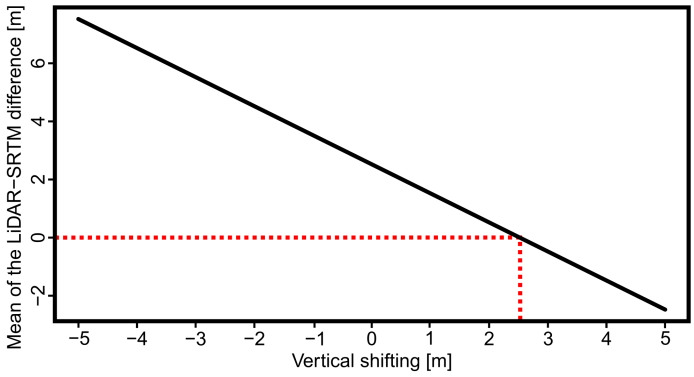

Figure 3. The variation of the mean of the difference at different spatial shifts

In the first error estimation approach of the error we shifted vertically the SRTM DEM from -5 to +5 m in 1 m steps and computed the mean values of the differences between the LiDAR DEM and SRTM DEM. The results are shown in Fig. 3 and reveal that by shifting vertically the SRTM with +2.5 m we obtain a mean of the differences close to 0 (Fig. 2 – thin red line), meaning that the negative and positive differences are symmetrically distributed around 0 m and represent the best fit between the two models. This value will be considered as the

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main vertical trend component of the SRTM error. The following error estimation approach consisted on the horizontal shifting of the SRTM DEM on all 8 principal cardinal directions with 1, 2 and 3 pixels (30, 60 and 90 m respectively). The analysis of the mean and standard deviation of the differences between the LiDAR data and the shifted SRTM DEMs show that the shifting increase the values of these two statistical measures (Fig. 4), so there it seems there is no horizontal mismatch between the two DEMs.

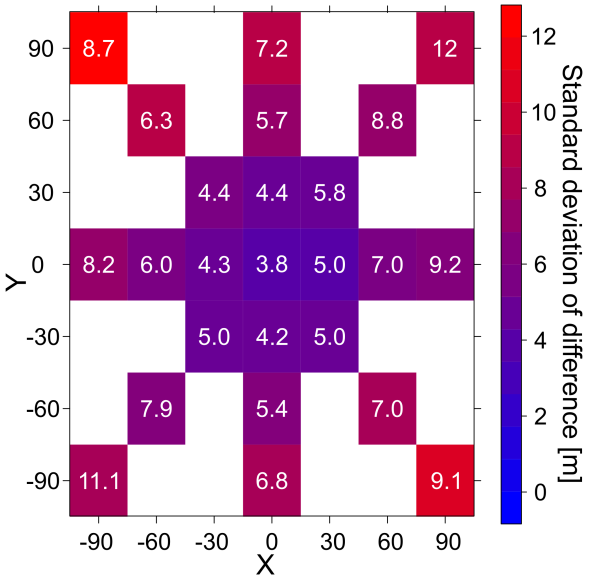

Figure 4. Matrix of the standard deviation of difference between the LiDAR DEM and the shifted SRTM DEM

After the vertical and horizontal adjustments were performed we examined the distribution of the differences (Fig. 5) by land cover type (Fig. 6). It can be seen that the biggest differences appear in the urban and forest classes, which can be explained by the characteristics of the SRTM DEM method of acquisition. The areas covered by these land cover types and other types which showed big differences (orchards, water areas, river areas, dump sites) were removed from the analysis which was performed further, in order to assess the two DEM in areas were both show the bare land surface. The distribution of the difference in this case is represented in Fig. 2 by a blue thin line and show the decrease of outlier data, but still reveal that SRTM DEM is lower in elevation than LiDAR DEM.

Differences were analyzed on aspect and slope classes computed from the LiDAR DEM in SAGA GIS (Fig. 7) to investigate the influence of these parameters on the SAR signal during SRTM data acquisition. It appears that SW to NE aspect classes have the biggest positive differences and as the slope increase the differences are the biggest. This is consistent with a shadowing of the NW hillslopes which are prevalent in the study area [10] and with the general conclusion that SRTM elevation is under the LiDAR elevation.

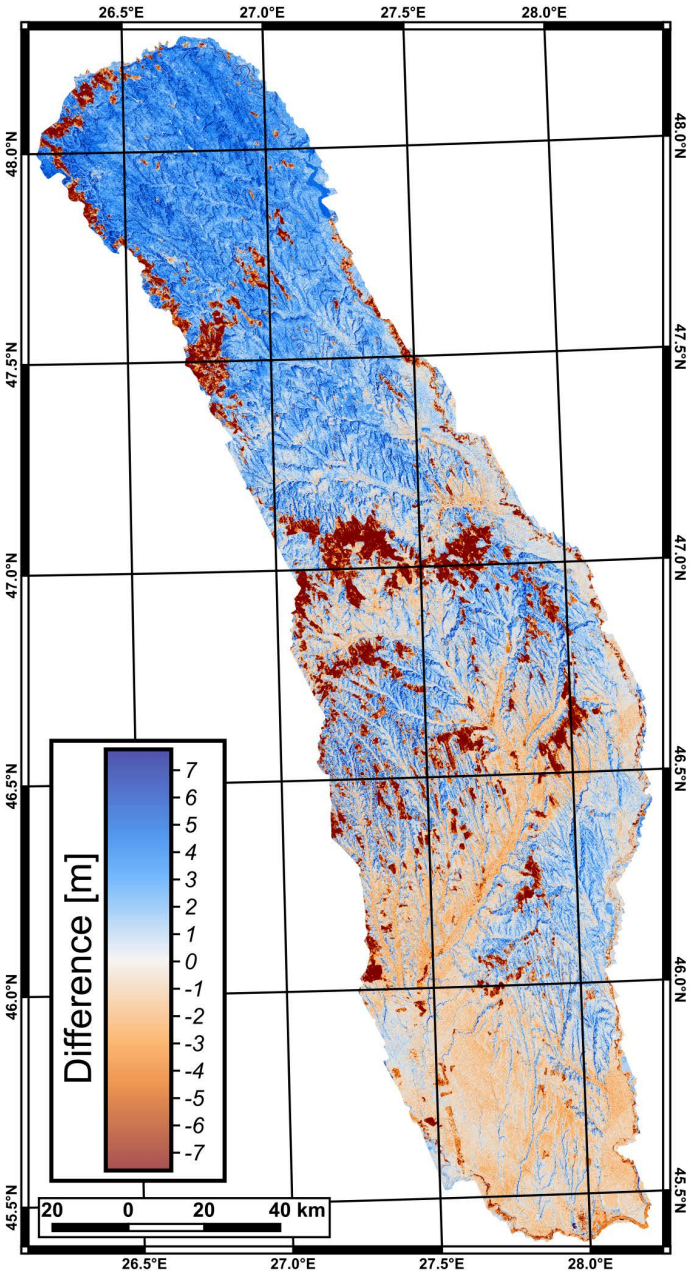

Figure 5. The spatial distribution of the difference between LiDAR DEM and SRTM DEM

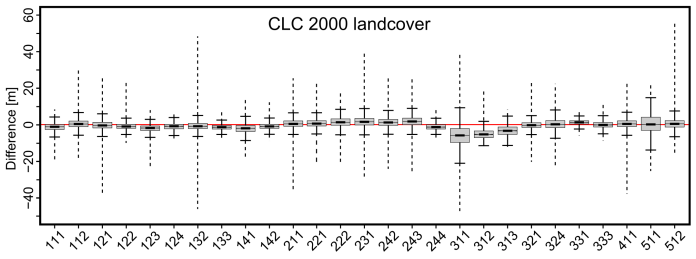

Figure 6. Boxplots of the difference between the LiDAR DEM and SRTM DEM by land use (Corine Landcover 2000 data)

The distribution of difference by aspect show

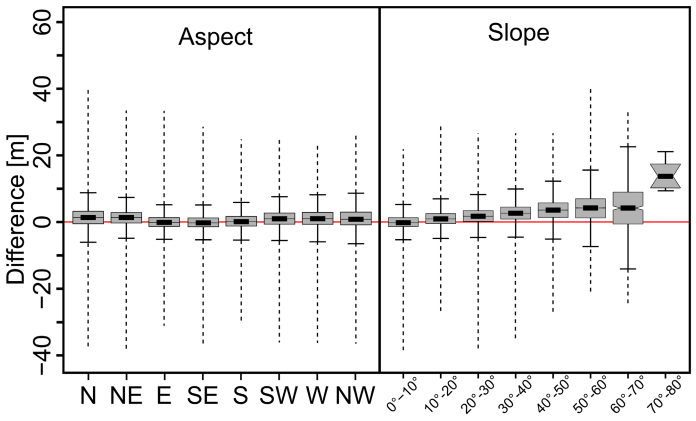

Figure 7. Boxplots of the difference between the LiDAR DEM and SRTM DEM by LiDAR aspect

V. Conclusions

In this study the SRTM DEM model was compared with LiDAR data in a raster algebra setting in order to test the correctness of portraying the Earth's surface shape. As a general conclusion we observed that SRTM elevation data is in general under the LiDAR surface. The mean value of the differences between the two surfaces is 1.52 m. If the SRTM is risen with 2.5 m this mean difference normalize to 0.02278395 m. The differences correlate well with the land-use, with slope and aspect, indicating that majority of the differences are due to the SRTM acquisition. These predictive patterns of errors can be used to improve the correctness of the SRTM DEM and could argue for its use in geomorphological change detection [11].

Acknowledgment

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