

## COMPARATIVE ANALYSIS OF ELLIPSOIDAL ELEVATION SURVEYED BY GNSS SYSTEM, SRTM AND ASTER GDEM

R. Noetzold<sup>1,2</sup>, M.C. Alves<sup>1,3</sup>, J.A.F. Sobrinho<sup>1</sup>, R.A. Gallon, M.J.P.A. Oliveira<sup>1</sup>, H.H.T. Borges<sup>1</sup>, R.T. Silva<sup>1</sup>

<sup>1</sup> Federal University of Mato Grosso, Cuiabá - MT  
rafael\_noetzold@hotmail.com, marcelocarvalhoalves@gmail.com,  
jeziel.andre@hotmail.com, ragallon@yahoo.com.br, maicon.oliveira53@gmail.com,  
hhans\_borges@hotmail.com, rayzatrindde@rocketmail.com

<sup>2</sup> Capes Support

<sup>3</sup> CNPq Support

### Abstract

*The aim of this study was to compare the ellipsoidal height using the GNSS system, SRTM images and Aster GDEM images. The survey was conducted on the campus of Federal University of Mato Grosso, Cuiabá - MT. The static surveying was performed in 27 neighboring points, where a Global Navigation Satellite Systems (GNSS) receiver was installed as a base. Subsequently, we performed the real time kinematic survey supported on adjusted basis to obtain the correct elevation data of 3883 points. Then, the data base were processed and corrected by the Precise Point Positioning Method. The elevation data from SRTM and Aster GDEM models, extracted by the nearest neighbor technique were used for comparison. Subsequently we compared the GNSS data with the data extracted from the images, SRTM and ASTER, by linear regression, and we performed the calculation of Root Mean Square Error (RMSE). The results showed:  $R^2$  of 0,84 between Aster GDEM and GNSS; 0,86 between GNSS and SRTM and 0,83 between Aster GDEM and SRTM. A similar result was obtained by RMSE, where the biggest error occurred in the comparison between Aster GDEM and SRTM data.*

**Keywords:** Digital elevation model, Accuracy, Global navigation satellite survey.

### 1. Introduction

The digital elevation models (DEMs) can be generated based on data from the remote sensing radar. This technique uses radar waves and has the advantage of operating satisfactorily in the middle of adverse conditions of excessive cloud. After several steps of selection, correction and processing, radar are used to generate a digital elevation model.

There are several advantages using digital elevation models, including the convenience of working with data and significant savings time and money, since field visits to collect topographical information on the site are dispensed reduced. Among the various possibilities of use, one way of taking advantage of this DEM is its use on urban analysis studies. The two digital elevation models most widely used are the SRTM and ASTER GDEM.

The launch of the orbital platform ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) in space aimed to obtaining data related to processes occurring earth's surface on a regional scale. This information may be used by various branches of science such as studies related to climate, hydrological surveys, geological surveys, soil, and others.

The ASTER instrument has three spectral bands in the visible and near infrared, sixbands in the shortwave infrared region and five spectral bands in the thermal area of the electromagnetic spectrum, with 15, 30 and 90 meters of spatial resolution, respectively (YAMAGUCHI et. al., 1998).

By means of a space mission, in order to obtain information about the relief the Shuttle Radar Topography Mission (SRTM) was released in 2000. As Gorokhovich and Voustianiouk (2006), SRTM data available represent 80% of the surface in the spatial resolution of 90x90 m for Brazil.

To obtain information of the topography in an indirect way, the data obtained from SRTM and Aster GDEM, and more recently the use of automated positioning of satellite systems (GNSS), can be correlated.

The knowledge of the altitude in urban areas contributed significantly to the planning of the land use, and is one of the essential information for the preparation of construction projects and territorial planning. The attainment of these elevation data can be acquired through on-site survey, with the use of topographical equipment, or in an indirect way using the data generated by sensors installed on orbital platforms.

After the availability of SRTM, several studies using this data can be done in different areas, for example, in surveying applications (Koch and Lohmann, 2000; Smith and Sandwell, 2003; Falorni *et al.*, 2005). Koch and Lohmann (2000) mentioned that the possible sources of error in SRTM data can be divided in the characterization of parameters for SAR data acquisition, processing, and the influences of vegetation.

Arefi and Reinartz (2011) stated that the data obtained by Aster GDEM include many artifacts and errors that diminish the quality and accuracy significantly. To solve this problem they developed an algorithm to improve the quality of these data.

Kervyn *et al.* (2006) present the advantages and limitations of Aster and SRTM topographic mapping in a volcanic. However, the overall assessment of the accuracy of these products requires more studies at local scales involving control of ground truth and accuracy of test methods with higher precision and accuracy, as the GNSS system.

Stevens *et al.* (2004) observed better representation of the topography of active volcanoes with Aster data than with the SRTM data.

In this sense, the objective of this research was to compare the ellipsoidal height using the GNSS, SRTM images and Aster GDEM images.

## 2. Methodology

The research was conducted on the campus of Federal University of Mato Grosso (UFMT), Cuiabá, Mato Grosso (Figure 1). Primarily, 27 marks were fixed in the soil with 0.60m in length and 0.10m in diameter surrounded by concrete PVC pipe, in the edge of the study area. Subsequently, the static survey was made at each point with the GNSS receiver set to WGS-84 datum, UTM Zone 21 South, remained for about one hour, recording data every 15 seconds.

Later, survey was conducted by RTK, setting the basis of marks at strategic points, and recorded data every 15 seconds and the collector switch was recorded every 5 times under fixed signal between base and rover.

The benchmarks were set mainly in the median field and the limits of UFMT. Data were collected along roads, curb, running track, sports courts, soccer field, scale steps, sidewalks and right foot of building constructions aiming to capture the details of the study area to obtain a greater data accuracy.

After data collection, processing was done to correct the coordinates 13 days after data collection in order to obtain precise orbits. The method of Precise Point Positioning (PPP) was used with the help of data provided by IBGE through free online service for post-processing data from GNSS. With this, users who use data from GNSS can obtain coordinates with satisfactory precision in Geocentric Reference System for the Americas.

The elevation data were extracted by the technique of nearest neighbor in the Aster GDEM and SRTM models and, together with the data obtained by GNSS, was realized the non-spatial exploratory analysis, calculating maximum, minimum, mean, standard deviation, kurtosis and asymmetry values. The relationship between each model was also performed to get altitude, represented by graphs. The root mean square error was also calculated.

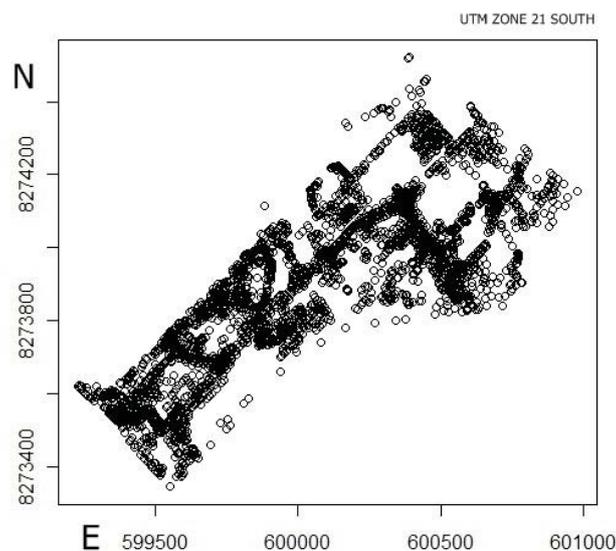


Figure 1: Study area with the altitude points

### 3. Preliminary results

Based on the non-spatial exploratory analysis of the data, there was less difference between the maximum and minimum elevation values of the SRTM model and greater difference in data obtained by the GNSS. Mean and median values of altitude were very near. The kurtosis presented distribution with platykurtic curve for both models tested. The asymmetry values were close to zero, and for data obtained by the GNSS and SRTM was observed little asymmetrical distribution on the right while the Aster data showed a slight asymmetry at left (Table 1).

**Table 1:** Descriptive statistics referring to altitude values of the campus UFMT obtained by GNSS, Aster GDEM and SRTM models.

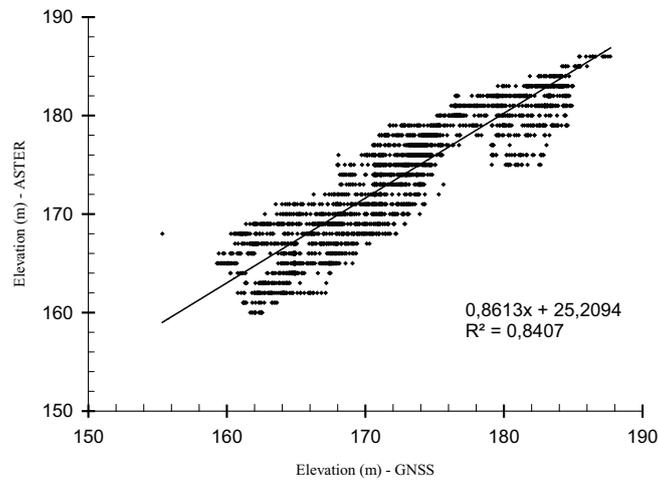
Statistical indices	Models		
	GNSS	ASTER-GDEM	SRTM
Maximum	187.68	186.00	189.00
Minimum	155.34	160.00	164.00
Mean	172.32	173.63	176.20
Median	172.29	174.00	176.00
Kurtosis	-0.81	-1.05	-0.99
Asymmetry	0.20	-0.13	0.07
Standard Deviation	6.58	6.18	7.01
Coefficient of variation (%)	3.82	3.56	3.98

The coefficients of variation below 4% were explained by the smooth topography of the study area.

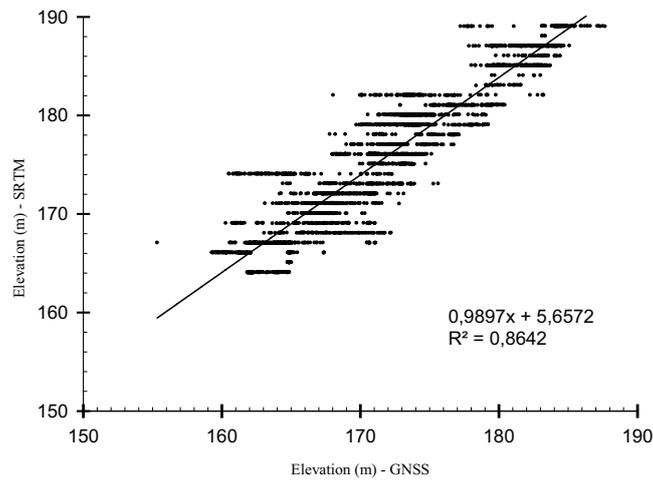
Through the relationship of elevation data between the models studied, we observed a coefficient of determination from GNSS and Aster GDEM, GNSS and SRTM, Aster GDEM and SRTM of 0.84, 0.86 and 0.83, respectively (Figures 2, 3 and 3).

Observed values of root mean square error were 2.94, 3.86 and 4.66 for GNSS and Aster, GNSS and SRTM, Aster and SRTM, respectively. Consequently, the elevation data obtained by GNSS represented more accurately the study area.

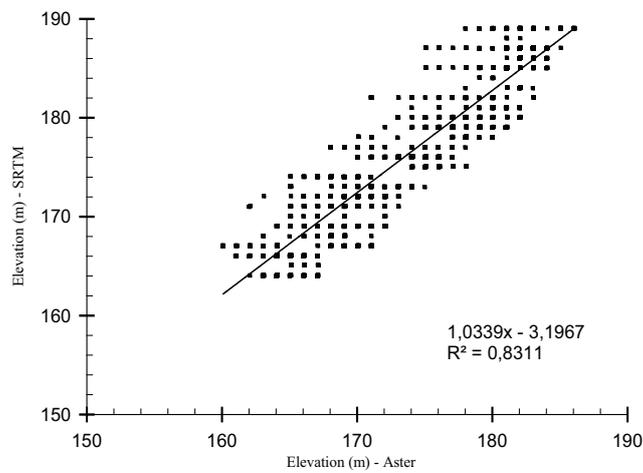
Research performed with Aster and SRTM data show important information such as those described by Carvalho *et al.* (2004). The authors observed that the results obtained by SRTM relief were satisfactory in areas with mountainous terrain, but created problems in determining slopes in flat areas. In the case study of Schunemann and Novacovski (2011), the option of using the products Aster GDEM (surface model) had an advantage over SRTM products (elevation model).



**Figure 2:** Relationship between altitude values obtained by GNSS and Aster GDEM.



**Figure 3:** Relationship between altitude values obtained by GNSS and SRTM.



**Figure 4:** Relationship between altitude values obtained by Aster GDEM and SRTM.

#### 4. Conclusion

The results of  $R^2$  and accuracy were higher than 0.83 between the elevation data obtained by Aster GDEM, GNSS and SRTM.

The data obtained by GNSS altitude represented more accurately the studied area.

#### References

- AREFI, H., REINARTZ, P. (2011), "Accuracy enhancement of Aster global digital elevation models using ICESat data". *Remote Sensing*. Vol. 3:1323-1343.
- CARVALHO, T.M., LATRUBESSE, E.M. (2004), "Aplicação de modelos digitais do terreno (MDT) em análises macrogeomorfológicas: o caso da bacia hidrográfica do Araguaia". *Revista Brasileira de Geomorfologia*. Nº1: 85-93.
- FALORNI, G., TELES, V., VIVONI, E. R., BRAS, R. L., AMARATUNGA, K. (2005), "Analysis and characterization of the vertical accuracy of digital elevation models from the shuttle radar topography mission". *Journal of Geophysical Research*. Vol. 110, F02005, doi:10.1029/2003JF000113.
- GOROKHOVICH, Y., VOUSTIANIOUK, A. (2006), "Accuracy assessment of the processed SRTM-based elevation data by CGIAR using field data from USA and Thailand and its relation to the terrain characteristics". *Remote Sensing of Environment*, 104 pp 409–415.
- KERVYN, M., GOOSSENS, R., JACOBS, P., ERNST, G.G.J. Mapping volcano topography with remote sensing: ASTER vs SRTM. *International Journal of Remote Sensing*, Vol. X, No. X, 2006.
- KOCH, A., e LOHMANN, P. (2000). "Quality assessment and validation of digital surface models derived from the shuttle radar topography mission (SRTM)". Proceedings, IAPRS, Vol. XXXIII, Amsterdam, 2000.
- SCHUNEMANN, F. F., NOVACOVSKI, C. (2011), Avaliação visual de modelos 3D gerados através de produtos ASTER GDEM, SRTM e carta topográfica em relação a fotos do relevo. In: XV Simpósio Brasileiro de Sensoriamento Remoto, 2011, Curitiba. *XV Simpósio Brasileiro de Sensoriamento Remoto*, p. 5737-5744.
- SMITH, B., SANDWELL, D. (2003). Accuracy and resolution of shuttle radar topography mission data. *Geophysical Research Letters*, 30(9), 1467.
- STEVENS, N. F., GARBEIL, H., MOUGINIS-MARK, P.J. (2004), NASA EOS Terra ASTER: Volcanic topographic mapping and capability. *Remote Sensing of Environment*. Vol. 90: 405-414.
- YAMAGUCHI, Y., KAHLE, A. B., TSU, H., KAWAKAMI, T., PNIEL, M. (1998), "Overview of Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER). *Geoscience and Remote Sensing*". Vol. 36:1062-1071.