ASSESMENT TO THE ALTIMETRIC ACCURACY OF DIGITAL ELEVATION MODELS OBTAINED FROM DRONE IMAGE INFORMATION

Carlos Alberto Felgueiras[1], Jussara de Oliveira Ortiz[1], Cláudia Cristina dos Santos[1], Eduardo Celso Gerbi Camargo[1], Sidnei João Siqueira Sant'Anna[1]

[1]Coordenação Geral de Observação da Terra, INPE, Av. dos Astronautas, 1758, Jardim da Granja, São José dos Campos, SP, Brasil, e-mails: {[1]carlos.felgueiras, [1]jussara.ortiz, [1]claudia.santos, [1]eduardo.camargo, [1]sidnei.santanna}@inpe.br

ABSTRACT

This research article aims to evaluate the altimetric accuracy of Digital Elevation Models (DEMs) generated from remote sensing images acquired by digital cameras transported in unmanned aerial vehicles generically known as Drones. The DEMs generation was carried out with the software Pix4D using as input the images of the drone flights and control points of high planimetric and altimetric accuracy acquired in field works by Global Positioning System (GPS) equipment. The DEMs have spatial resolution of 1 meter and their altimetric qualities were evaluated by cross validations using the set high accuracy control points. The methodology of this work was applied to actual information within three geographic regions in the municipality of Jacareí, São Paulo, Brazil. The work presents qualitative and quantitative analysis of the results considering altimetric error metrics, statistics and quadratic mean errors, for the DEMs obtained by drones and for Shuttle Radar Topography Mission (SRTM) elevation grids available at no cost on the internet. Comparative analyzes of the results considering soil cover information, observed through remote sensing images of the RapidEye satellite, were performed too. The results show that the drone DEMs have altimetric accuracy of less than 1 meter, but with different values in the three regions observed. As expected, the altimetric accuracy was lower for the SRTM data, since its spatial resolution is 30 meters.

***Keywords* —** altimetric accuracy, digital elevation models, direct and cross validations, drone images, SRTM grids.

1. INTRODUCTION

Currently the imaging technology using digital cameras coupled to Unmanned Aerial Vehicles (UAV), known generically as Drones, has been extensively used for monitoring geographical regions in various fields of applications such as: information gathering in the monitoring of areas with frequent environmental degradations; precision agricultures; monitoring of forests; real estate registrations; general mining and others. Also, the development of this technology has been increasing for the accomplishment of topographic, planimetric and altimetric mapping in a shorter period of time and at an affordable cost, allowing several studies of the same area with less temporal and spatial resolutions [1], [2]. The validation, meaning precision and accuracy assessment, of the drone image derived products is an important research issue as it allows one to qualify and to determine the application fields of them [3-6].

In this context the objective of this work is to evaluate the altimetric accuracy of DEMs generated from remote sensing images obtained by digital cameras carried by drones. It was used the Pix4D Mapper software [7], along with a set of high-resolution sample points, to process the drone images for generating the DEMs. Three different real geographic regions were considered, as a case study, to assess the accuracies. The work presents qualitative and quantitative analyzes of the results considering cross validations with the high accuracy control points, hereafter referred as hard samples. Also compares the results with direct validation performed in SRTM data [8] obtained on the internet with the additional support of a web application available at https://earthexplorer.usgs.gov/. Comparative analyzes of the results considering soil cover information, observed through remote sensing images of the RapidEye satellite, were performed too.

2. MATERIAL AND METHODS

In this work it was used the drone Phantom 3 Advanced [9] in order to obtain the images of the regions of interest. The Phantom shoots 12-megapixel JPEG and even DNG RAW image files. It contains a photographic camera with a 1/2.3" sensor, fast f/2.8 prime lens, focal length 3.61mm, generating images with 4000x3000 pixels, and it is GPS assisted hover. The acquired images were processed with software Pix4D mapper. The planimetric and altimetric survey to obtain a set of high-resolution control points were accomplished making use of a TOPCON/Hiper GGD GPS [10] that records the data in double frequency. The validation procedures, as well, the spatial data managements and displays were performed using the geographical information system software known as SPRING [11].

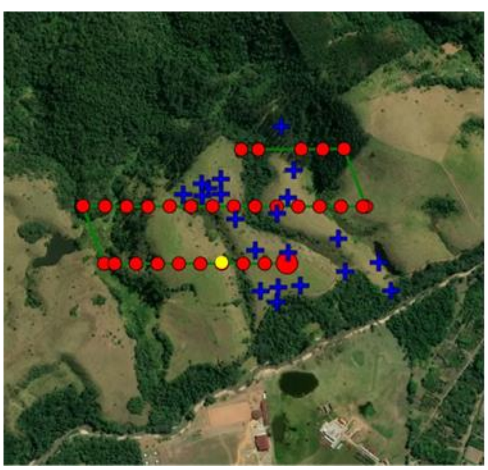
The methodology used in this work involved the following steps: i) choice of geographic regions of interest; ii) obtaining a set of high accuracy GPS control points, the hard samples; iii) acquisition of drone images; iv) processing the drone images in the Pix4D software to obtain the local DEMs; v) acquisition of SRTM information available at the internet; vi) evaluation of the accuracy of the drone and the

SRTM DEMs by assessment to general statistics, as mean and standard deviation values, and by Root Mean Squared (RMS) errors; vii) quantitative and qualitative analyzes of the results considering also the land cover information extracted from RapidEye satellite images.

Figure 1 illustrates the acquisition process of the hard samples. GPS information are measured for the blue target previously established for the field team. This target is later identified in the images acquired by the drone.

Figure 1: Illustration of the hard samples measuring process.

Figure 2 shows the arrangement of the waypoints of drone photos (red circle marks) in the flight path and also the distribution of hard samples in one of the studied regions. The main characteristics of the drone flight mission are: altitude of 200m leading to GSD of about 9cm; cover area of 25ha; 40 waypoints and front and side overlap ratio of 80% and 60%, respectively.



(a)

(b)

Figure 2: (a) Points of the drone acquisition images (red circles) and hard sample (blue cross) distribution and (b) A drone image (relative to the point acquisition highlighted by yellow circle) showing the hard samples location (blue circle).

3. RESULTS

The methodology of this work was applied, as a case study with actual data, in a geographic region of the Jacareí city, São Paulo, Brazil. The studied region has the following geographical bounding box: W 46º 4’ 4.98’’ to W 46º 0’ 2.82’’ and S 23º 16’ 2.91’’ to S 23º 12’ 47.23’’. Figure 3 presents the geographical location of the considered region, with a 5-meters planimetric resolution RapidEye image composition as a background. Also, the Figure 3 shows the Paratei river, in cyan line, the high accurate sample data, in white plus symbols, and the drone flight areas, in brown polygons, used in this case study. The background image is a composition of bands 3, 4 and 5 assigned to the color channels blue, red and green respectively.

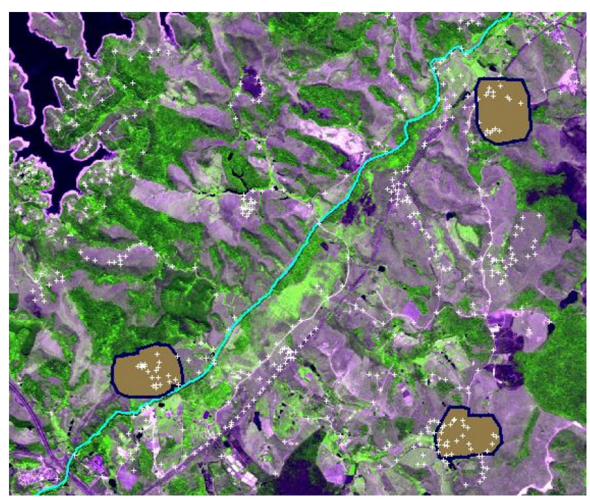


Figure 3. Geographic region of study showing the Paratei river, the hard samples and the drone flight areas.

In this work, for each brown region of Figure 3, many drone images, around 40 for each flight region, were acquired during field works accomplished in the region. The drone images were processed, in the Pix4D software, considering the hard samples and stereoscopy approaches for generating the orthomosaics (true orthophotos), based on orthorectification. This process creates the drone DEMs with 1 meter of planimetric resolution. Figure 4 illustrates a mosaic of the lower left polygon area showed in Figure 3.

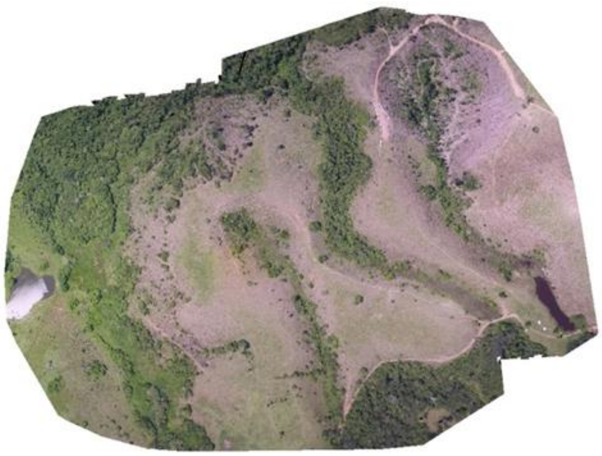


Figure 4. Mosaic of images acquired by drone flights in the Lower Left location of the Jacareí region.

Cross validations, using the hard sample points, were performed for assessing the altimetric accuracy of the DEMs' drone data. In the cross validation process the actual altimetry value of each hard sample, measured in the work field, is compared with that estimated altimetry from the DEMs generated with all the samples, inside the region, but itself. The method of cross validation is applied here, instead of direct validations, in order to avoid bias because the hard samples were considered also to assess the drone DEMs. Table1 presents the error metrics related to the cross validations applied to the 3-drone flight regions considered.

Table 1. Error metrics of the drone DEMs validations

Flight area	Number of hard samples	Mean (m)	Variance (m^2)	Standard Deviation (m)	RMS
Lower Left	17	-0.012	0.026	0.162	0.162
Upper Right	12	-0.011	0.042	0.205	0.205
Lower Right	15	0.026	0.018	0.134	0.137

For comparison purposes, SRTM data were gathered from the internet for the 3 drone flight regions. Table 2 reports the error metrics of SRTM DEMs direct validations assessed for the considered regions. In this case it was applied direct validations, cross validations were not necessary as the SRTM were not generated considering the hard sample data.

Table 2. Error metrics of the SRTM DEMs validations

Flight area	Number of hard samples	Mean (m)	Variance (m^2)	Standard Deviation (m)	RMS (m)
Lower Left	20	2.746	15.894	3.987	4.841
Upper Right	20	1.382	17.328	4.163	4.38
Lower Right	22	3.297	20.205	4.495	5.575

Figures 5, 6 and 7 show the land cover, using the RapidEye image composition, inside of each drone flight region. These figures will be useful to analyses of the altimetry accuracies related to the land cover of each region, mainly the vegetation and bare areas.

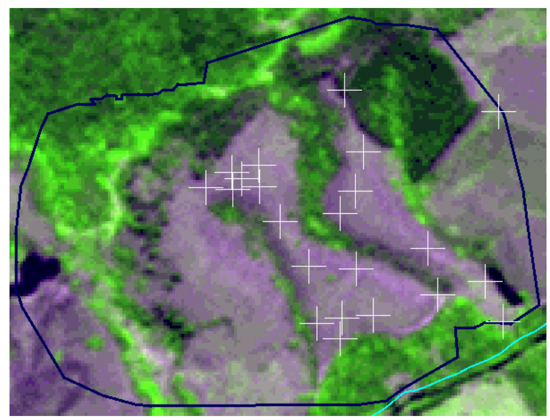


Figure 5. Land cover of the Lower Left drone flight area.

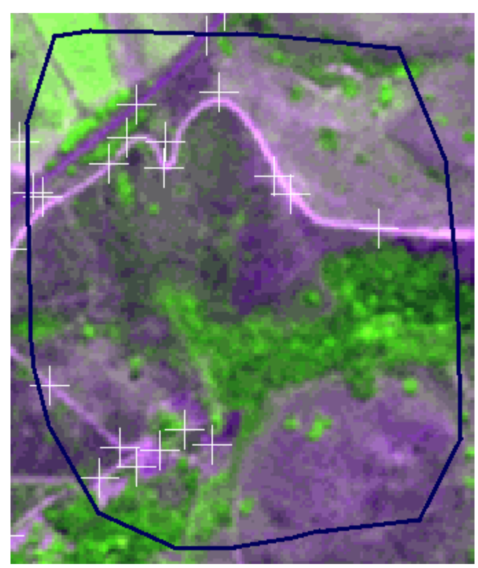


Figure 6. Land cover of the Upper Right drone flight area.

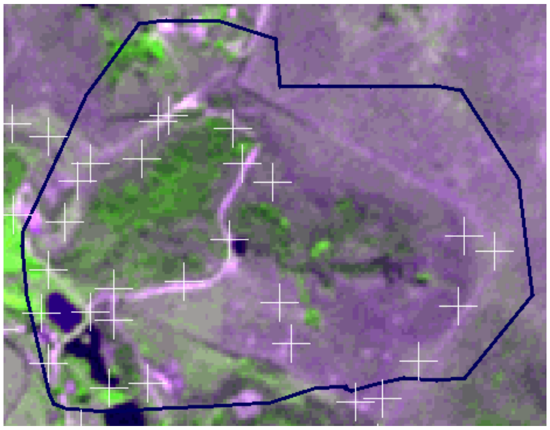


Figure 7. Land cover of the Lower Right drone flight area.

4. DISCUSSION

Analyzing the values of Table 1 it can be observed that, although the validation metrics among the flight areas are different, they are very similar. Their mean values are very low, close to zero, indicating low bias for these metrics. This is the reason for having similar values for the standard deviation and RMS metrics inside each flight area. Table 1 reports, also, that the highest error metric of standard deviation and RMS values were obtained for the upper right flight region. This can be explained by the small number of hard samples and their worst distribution within this region.

The accuracies can be affected also by the altitude of the drone flight that can change according to the relief. For vegetation regions the sensor of the drone camera will get images of the vegetation canopies instead of the actual terrain surface. Nevertheless, in our case study, the vegetation does not seem to have influenced the accuracy metrics as the hard samples, used in the drone DEMs generations and validations, were located mostly in non-vegetation areas.

As pointed out above, SRTM DEMs were also validated. As expected, and reported in Table 2 the accuracy of these DEMs are lower than those assessed for the drone DEMs. This is explained, mainly, by the poor spatial resolution of the SRTM DEMs, 30x30m, compared to the drone DEMs, 1x1meter, i. e. the SRTM information is more generalized.

5. CONCLUSIONS

In this work it was explored validation processes to assess altimetry accuracy of DEMs. Drone and SRTM DEMs obtained in different spatial regions have been considered. The drone DEMs obtained in this work present high accurate elevation values, less than 21 centimeters, that suggests they are good options for general environmental monitoring and cartographic mapping for high scales at low cost.

Future researches related to altimetry accuracy of DEMs can include investigation of other spatial regions with distinct land covers using different drone acquisition and process methods.

6. REFERENCES

[1] Pereira, W.S.; Magalhães, J.R.G.; Cardoso, A.L. "Obtenção de Modelo Digital de Terreno e Ortomosaico na Região Sub-bacia Riacho do Machado, Cruz das Alma/BA: Percepções a partir do Processamento de Dados de Veículos Aéreos Não Tripulados", *Anais do Simpósio Regional de Geoprocessamento e Sensoriamento Remoto* – GEONORDESTE 2017 – Salvador /BA – Brasil, 03-06 de Outubro 2017.

[2] Remondino, F.; Barazzetti, L.; Nex, F.; Scaioni, M.; Sarazzi D. "UAV Photogrammetry for Mapping and 3D Modeling – Current Status and Future Perspectives", *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, Volume XXXVIII-1/C22, 2011 ISPRS Zurich Workshop, Zurich, Switzerland, 14-16 Sept. 2011.

[3] Holler, W. A.; Serrato, R.J.; Graça, N.L.S. S.; Cruz, W.; Cristo, D.P. "Avaliação de Acurácia e Precisão de Modelos Digitais de Superfície a partir de Diferentes Aeronaves Remotamente Pilotadas*"*, *Revista Técnico-Científica do CREA-PR* - ISSN 2358-5420, 13ª Edition, pp: 1-20, September, 2018.

[4] Santos, L.F.B. "Avaliação de Modelo Digital de Terreno Gerado Através de VANT em Planícies Pantaneiras"**,** *Monografia Curso de Engenharia Florestal*, Universidade Federal de Mato Grosso, Cuiabá, 52p., 2016.

[5] Santise, M.; Fornari, M.; Forlani, G.; Roncell, R. "Evaluation of DEM Generation Accuracy from UAS Imagery", *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, Vol. XL-5, 2014 ISPRS Technical Commission V Symposium, Riva del Garda, Italy, 23–25 June 2014.

[6] Küng, O.; Strecha, C.; Beyeler, A.; Zufferey, J-C.; Floreano, D.; Fua, P.; Gervaix F. "The Accuracy of Automatic Photogrammetric Techniques on Ultra-Light UAV Imagery", *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, Vol. XXXVIII-1/C22, 2011-ISPRS Zurich Workshop, Zurich, Switzerland, 14-16 Sept. 2011.

[7] Pix4D SA, "Pix4Dmapper: Professional photogrammetry software", Available at https://pix4d.com/, 2018.

[8] USGS., "Shuttle Radar Topography Mission (SRTM)", Available at https://lta.cr.usgs.gov/SRTM, 2000. Accessed in October, 2018.

[9] DJI Innovation Technology Co. Available at https://www.dji.com. Accessed in October, 2018.

[10] Hiper GD & Hiper GGD Operator's manual available at: http://www.phoenix-ms.ca/dat/phoenix/productFiles/472.pdf, Accessed in December, 2018.

[11] Camara, G.; Souza, R.C.M.; Freitas, U.M. and Garrido, J. "SPRING: Integrating remote sensing and GIS by object-oriented data modelling", *Computers & Graphics*, v. 20: n. 3, pp. 395-403, May-Jun 1996.