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Evaluation of hydrological consistency of DEMs derived from SRTM and ASTER2 in three levels of interpolation

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Abstract

This study evaluated the accuracy of drainage models generated from the interpolation of SRTM and ASTER2 by Topo to Raster in three levels for a basin in Viçosa (MG). The standard used to classify the mapping quality was the PEC (Cartographic Accuracy Standards). We also evaluated the proportional representation of drainage in relation to reference database (IBGE) and the total area of sinks in each DEM generated interpolated. The interpolation increased the planimetric accuracy of generated drainage networks and the addition of hydrographic contributed to its better design. The PEC scale 1:100.000 for ASTER2 and SRTM was Class B and C, respectively. The representation of the drainage of the models compared to reference responded positively to the interpolation, but the maximum value reached was 59.8% for treatment 3 in ASTER2.

Keywords: Accuracy, ASTER 2, SRTM, interpolation, PEC, drainage network.

1. Introduction

Topographic data has importance to society for several purposes, which require three-dimensional perspective view. Achieving these data through remote sensing using satellites began in the 80's (Hirano *et al*., 2003) and has since been improved by generating more accurate cartographic products on a global scale. Among them are Digital Elevation Models (DEMs), which represent the surface of the land through point data of known three-dimensional coordinates (Algarni and Hassan, 2001).

Currently two databases widely used came from sensors SRTM (Shuttle Radar Topography Mission/NASA) and ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer). The second version of the latter was released in October 2011 with the promise of correcting inconsistencies present in the first one. Images of these sensors are available for Brazilian territory with spatial resolution of 90 and 30 m for SRTM and ASTER, respectively. Thus, there is still lack of a topographic database of remote sensing in resolution higher than 30 m. One consequence is to limit the work scale, which does not reach values higher than 1:100.000 and 1:250.000 in DEMs of 30 and 90 m resolution (Altoé, 2011). For DEMs with 15 m resolution, available in other countries, the scale of 1:50,000 (or less) was adequate, and may be used to generate contours at intervals of 40 m (Hirano *et al*., 2003). In addition to the limitation in scale, the resolution of the DEM affects the accuracy of the features of the landscape and drainage networks generated from them (Clarke *et al*., 2003).

The sources of errors in DEMs arise from collection of data (which depends on the technology used), the spatial structure of altitude, the interpolation technique used to generate the DEM and density of data (Chaplot *et al*., 2006; Erdogan 2009). Through geostatistical interpolation is possible estimate values for the intervals between sampled data present on the surface. Although the issue is widely discussed in literature, there is no agreement on which method is more accurate. For example, Chaplot *et al*. (2006), found that for each geomorphology investigated there was an interpolator with better performance if the data density was low, and the Kriging was the best if the structure of altitude was strong. However, Guedes *et al*. (2011) compared the quality of the DEMs generated by interpolation using ordinary kriging and Topo to Raster. The authors observed that the kriging tended to a greater smoothing of the relief with reduction in extreme altitudes, including serious topological errors. Chaplot *et al*. (2006) suggests that impact of interpolation is possibly more visible in derivations of the DEM, as drainage network, than in altitude itself.

This study aimed to evaluate the accuracy of drainage networks models generated from the interpolation of SRTM and ASTER2 DEMs through the Topo to Raster interpolator in three levels of interpolation to a watershed in Viçosa (MG). We used the “PEC”, Cartographic Accuracy Standards (Brasil, 1984) to access the mapping quality. We also evaluated the proportional representation of drainage network in relation to the reference database (IBGE) in 1:50.000 scale and the total area of sinks in each DEM interpolated.

2. Methods

2.1 Study area

The study area was the watershed of São Bartolomeu River, located in Viçosa/MG, standing between the geographical coordinates 20° 44’ and 20° 51' South latitude and e 42° 50’ and 42° 55’ West longitude. The city is inserted in domain of "Mares de Morros", featured by a rough relief. Total area of watershed is about 55.1 km², representing 18.4% of city area, which is inserted in Doce River basin.

2.2. Database

As reference, we used the topographic and hydrographic charts by Brazilian Institute of Geography and Statistics (IBGE) available in vector format at institute's website (www.ibge.gov.br) in 1:50.000 scale for the region. For generating the drainage network models we used DEMs obtained from the sensors and SRTM ASTER2. All databases have been projected for the UTM coordinate system, Datum WGS 84.

Data processing was performed at ArcGIS 10 (ESRI) and PEC was obtained using software GeoPEC (Santos, 2008).

2.3 Data handling

Each DEM was converted into a grid of points containing altitude information of each pixel on it. In Topo To Raster, the points listed and IBGE hydrography were used as input data to the interpolator as drainage enforcement. This same procedure was used for all interpolations.

The original DEMs were submitted to three levels of interpolation. For ASTER2 was used the original DEM treated with a mean filter (for reasons that will be further addressed) and interpolated to 30, 20 and 10 m resolution (i.e., the interpolation to 30 m did not change the original resolution of the database, but it is expected that the addition of hydrography improve the quality of the model). For SRTM, the original DEM and those interpolated to 30, 20 and 10 m resolution was used. In this work we discuss these as levels 0, 1, 2 and 3 respectively to the following treatments: original DEM, 30 m, 20 m and 10 m.

For generation of the drainage network, first the DEM has submitted to a circular mean filter with 3 cell radius. Simultaneously were generated a raster of sinks. Then a fill command was used to remove the sinks and created file was used to determine the flow direction and subsequently flow accumulation. An arbitrary amount of cells were selected from flow accumulation raster to represent the drainage according to the observations made. The proportion of 50 contributing cells to a pixel of 90x90 m was used as threshold (Table 1).

Table 1: Number of contributing cells used as threshold for formation of channels in each resolution of DEMs.

Resolution	Contributing cells
90x90m	50
30x30m	450
20x20m	1012
10x10m	4050

The numerical drainage generated was then converted to vector format, allowing the calculation of its length and setting of control points.

For the analysis of drainage models and determination of Cartographic Accuracy Standards (PEC), were created 17 points in IBGE hydrography that could be easily identified in drainage generated by the models, located at the junction of two streams (Figure 3). The determination of PEC was made as described in Decree-Law No. 89.817 (Brasil, 1984) using software GeoPEC. Were also compared area of sinks and proportional representation of drainage network derived from each DEM in relation to the reference database (IBGE), dividing the total length of the drainage generated in the model by the total length of reference drainage.

For comparison, a 30m resolution DEM was generated based on the digital topographic map of IBGE. Through this, a topographic profile was drawn for visual evaluation of interpolation effect on surface and estimate altimetric RMS (RMSz).

3. Results and discussion

When ASTER2 DEM was initially processed, the result was a drainage network with many artifacts (feathering) and unconnected fractions, as observed by Altoé (2011) and Clarke *et al*. (2003) in other databases. Clarke *et al.* (2003) used hydrography and contour interpolation, generating a DEM with a 10 m resolution that met the specifications required for the particular case. Furthermore, these authors argue that data from hydrographic supplement hypsometry generating a more natural surface and drains better defined. However, these authors had a hydrography in the scale of 1:24.000 for a DEM of 30 m. In this study, these flaws were corrected using the mean filter, although this process may cause loss in data quality (Garbrecht and Stark, 1995).

In topographic profile created to evaluate the smoothing effect by the use of filter, it was observed that there are major differences at lower resolutions, which is expected, since the greater pixel area cause a higher smoothing. Also, a low resolution DEM has naturally a smoother surface. Through data of topographic profile was possible to compare the models with 30 m resolution (treatments 0 and 1 of ASTER and treatment 1 of SRTM) calculating the RMSz. We observed that the filter decreased the RMSz in both databases in 30 m resolution (Table 2) and RMSz found is within standards stated for both databases. However, it is important to note that the isolated analysis of RMSz does not expose systematic errors in the database (Clarke *et al*., 2003).

Table 2: Analysis of the mean filter effect in the RMSz. Treatments with 30 m resolution (ASTER 1 and 2, SRTM 2). F = filter, NF = no filter.

	ibge-srtm30NF	ibge-srtm30F	ibge-asterorigNF	ibge-asterorigF	ibge-aster30NF	ibge-aster30F
Mean	-4,5191824	-3,6834368	-6,258956	-6,2608448	-7,9788984	-6,3431752
Var	63,27749346	60,33896659	56,60437445	44,27524154	45,39775969	46,86996334
Desv.Pad	7,954715171	7,767816076	7,523587871	6,653964348	6,737785964	6,846164133
Min	-7,9652	-11,1729	-12,1558	-13,1541	-12,0978	-11,974
Max	-4,926	-6,4044	-5,1199	-6,7628	-3,2651	-6,4026
RMS	9,121090016	**8,568778298**	9,763507037	**9,116974126**	10,4258044	**9,312941278**

Regarding accuracy of drainage network, the interpolation was positive for ASTER2 and SRTM with progressive reduction of planimetric RMS (Figure 1). This reduction seems to stabilize to SRTM at level 3 of interpolation (10 m). We observed a more uniform distribution of deviations for drainages derived of ASTER2 DEM in all treatments, and a greater RMS in N axis to SRTM.

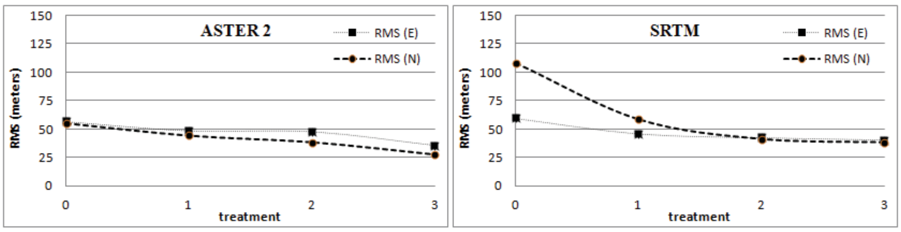

Figure 1: Planimetric RMS of drainage networks generated in each treatment.

The classification of PEC and other statistics are listed in Table 3. Although the SRTM has been classified as non-biased, it showed a greater trend than ASTER2, which showed more random errors. The drainage network from original SRTM was validated with 14 points because three of the 17 validation points did not have correspondent. To ASTER2 and SRTM the best quality of the drainage network was for treatment 3, classified in Class B and C on the scale 1:100.000, respectively.

Table 3: Statistics on planimetric accuracy of drainage network in the four treatments.

SRTM								
Treatment	**Mean (E)**	**Mean (N)**	**Std. Dev. (E)**	**Std. Dev. (E)**	**1/500000**	**1/250000**	**1/100000**	**CP's used**
0	23,9052	59,1868	54,2121	88,2297	Classe A	Classe B	REPROVADO	14
1	7,4393	28,6373	45,1781	50,3956	Classe A+	Classe A	REPROVADO	17
2	11,5569	27,4608	40,7356	30,1183	Classe A+	Classe A	Classe C	17
3	7,4393	23,3431	39,6762	29,9365	Classe A+	Classe A	Classe C	17
ASTER								
Treatment	**Mean (E)**	**Mean (N)**	**Std. Dev. (E)**	**Std. Dev. (E)**	**1/500000**	**1/250000**	**1/100000**	**CP's used**
0	10,2206	-6,1807	55,5524	54,894	Classe A	Classe B	REPROVADO	17
1	7,5608	-6,6568	47,7964	43,7263	Classe A+	Classe A	REPROVADO	17
2	2,2669	-0,7745	47,5638	38,4001	Classe A+	Classe A	REPROVADO	17
3	1,6787	6,2843	35,3817	26,6356	Classe A+	Classe A	Classe B	17

Delineation of first order drainage (headwaters) is presented as a difficulty of modeling. We must choose between not representing them to generate fewer artifacts, setting a larger number of contribution cells, or use a smaller number of cells as threshold, and accept large amounts of featherings. The most reliable way to measure this quality is visually, which is subjective and not measurable. There is no automated process to check how accurate the design of the drainage network from the model is.

The proportional representation of drainage network produced by ASTER2 has closest values to the reference. This because the morphology of these drainages represent more accurately the windings and bends of natural drainage, while SRTM produced more straight ones, even with drainage enforcement. The interpolation increased the relative representation of the drainage network. However, the values did not exceed 60% in both databases (Figure 3b). The total area of sinks decreased more significantly among treatments 0 and the others (Figure 3a).

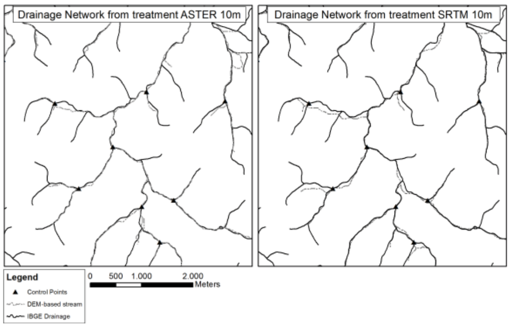

Figure 2: Representation of control points and drainage networks generated in more accurate models.

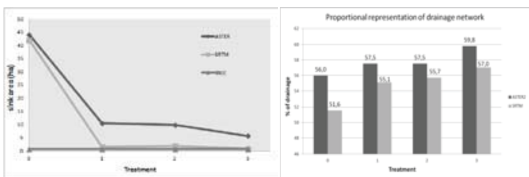

Figure 3: a) area sinks generated in each treatment, b) proportional representation of drainage compared to the reference.

4. Conclusion

The interpolation with Topo to Raster increased the planimetric accuracy of the generated drainage networks and the addition of hydrographic contributed to its better design. The PEC scale 1:100.000 for ASTER2 and SRTM was, respectively, Class B and C. Representation of drainage models in relation to reference responded positively to the interpolation, but the maximum value achieved with the used method was 59.8% for the treatment of 3 ASTER2. We must develop ways to improve drainage representation in qualitative and quantitative terms, minimizing the generation of feathered artifacts. The RMSz of DEMs was reduced in treatments where a mean filter was used, compared to those where it wasn't. It is recommended a new approach to measure this effect on the levels of interpolation, which here were not an object of study. We suggested future studies to find a standard for measuring quality in the delineation of drainage based on different parameters. Evaluation of the interpolation effect considering only RMS is not sufficient to determine the quality of the generated model.

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