Comparison Between Drainage Network Extracted From Elevation and Surface Models

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***Abstract*—This paper presents a possible procedure to identify critical regions extracting drainage networks from surface model. Qualitative comparison between drainage network extraction from surface and elevation models, both representing the relief, was done. This comparison highlights the differences between drainages extracted from both models and it shows the same critical patterns. For the study area, the radar data was obtained from airborne SAR AES-2 (AeroSensing) with p-band and x-band sensors. Both the elevation model (p-band) and the surface model (x-band) have 2.5m of horizontal resolution. The elevation model represents the actual relief of the land surface, while the surface model is influenced by the coverage of the Earth's surface. This model may show problems in regions with forest, because the canopy of trees forms the relief. Deforestation also causes errors in the drainage representation, leading to spurious drainage formation. To identify where differences occur, a remote sensing image was used. This image was classified to identify forest regions and places with deforestation occurrence. The drainages were superimposed over the classified image to contextualize the critical areas. The remote sensing image was obtained from the Resourcesat-1 satellite, also known as IRS-P6, built by the Indian Space Research Organization, porting the LISS 3 camera operating in three spectral bands (0.52-0.59μm; 0.62-0.68μm; 0.77-0.86μm), yielding 23.5m of horizontal resolution. The *Height Above the Nearest Drainage* (HAND) parameter, a useful terrain descriptor, was used to find the critical areas in the surface model. TerraHidro, a hydrological modeling system, was used to extract the drainage networks.**

Keywords-drainage network; surface model; elevation model.

I. CONCEPTUALIZATION

Drainage network is basic information for studies involving water resources. As a consequence, drainage network extraction must be very precise. Otherwise, the results can lead to wrong decisions. To reach this aim two factors are important: a good drainage extraction method and a good quality Digital Elevation Model (DEM).

If the drainage extraction method is not adequate, unrealistic local features can appear in drainage representation. These features cause wrong representation of the drainage paths, quantitative errors in path length or watershed areas, and other errors. Among the methods to extract adequate drainage network, the Priority First Search (PFS) method was chosen [1] to extract the drainage network with the TerraHidro system.

In relation to data quality, representing the surface of a geographical region, there are two problems to consider: spurious pits and surface versus elevation models.

The spurious pits are created in the generation of the DEM, whether from isolines or image pairs, such as radar images. The interpolation [2], stereoscopic [3], or interferometric [4] processes are responsible to create DEM spurious pits.

The other aspect regards the relief representation data type. There are two data types that represent DEM: one is the elevation model representing the terrain relief, and the other is the surface model, where the altitude is the land cover, for example, the canopy of trees in a forest. As this last type of data model is much more available, it is desirable to identify problems in the generation of drainage networks by using this type of data set.

It is difficult to the user to identify the drainage network positioning errors when he has only the surface model. This work aims to propose a method to determine the most critical error areas. The user can use this information to seek auxiliary data to help him in the manual edition task or, at least, to realize that the results in those regions can be out of acceptable quality range.

This work also shows the differences in drainage network representation when extracted from elevation and surface models to highlight the differences between both drainages and to show that the bigger differences are situated in the most critical areas. To identify the differences, a remote sensing image from Resourcesat-1 [5] was classified and used to understand the problem areas.

Section II describes the relief data models. Section III describes the study region and used data sets. Section IV presents the processing steps adopted. Section V presents the discrepancy analysis of the drainage networks. Section VI proposes a method to determinate the critical areas and makes evaluation of the results obtained. Section VII presents the concluding remarks.

II. RELIEF DATA MODELS

There are two relief data sets to download for free. The first is the Shuttle Radar Topography Mission (SRTM), available at the horizontal resolution of 90 meters [6]. The SRTM data set was generated from images acquired by radar

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technology. The other data is the ASTER Global Digital Elevation Model (ASTER GDEM) [7] with horizontal resolution of 30 meters from optical images.

Both data sets are surface model representations. As they show land cover, the relief is not well represented everywhere. In this way, a clearing created anywhere in the forest will cause problems in the determination of the drainage network. In large areas, tree tops may be a fair and acceptable relief representation. Deforestation, many trees of different sizes, roads and sudden changing in vegetation type, all these introduce errors in the subjacent relief information, introducing artifacts in the data, lending to an inexact drainage extraction.

Another problem is related to the generation of surface models from texture images. In the SRTM case, texture images are converted to surface model by a procedure called interferometry that creates flat areas in large water regions such as rivers and lakes. In the ASTER case, the images are opticals and the procedure for generating the surface model is called stereoscopy. Optical images suffer direct interference of cloud cover, and where it occurs, the surface values are estimated.

This work shows the drainage networks extracted from surface and elevation models for the same region, with radar technology. The aim is to point out important differences between the drainage networks extracted using both models, and to indicate some way to determine the critical regions prone to error occurrence, using only the surface model data.

III. GEOGRAPHICAL REGION AND USED DATA SETS

The study area of this work is located in the Brazilian Amazon region, (Brazil in green), Pará State (yellow), between latitudes s03^{0}11’03” and s03^{0}03’57”, and longitudes w55^{0}06’03” and w54^{0}54’00” (white rectangle), as shown below in Fig. 1.

For the study area, the radar data was obtained from airborne SAR AES-2 (AeroSensing) [8] with two sensors: p-band and x-band. Both the elevation model (p-band) and the surface model (x-band) have 2.5m of horizontal resolution, comprising an area of 14km by 22km. Fig. 2 presents both models.

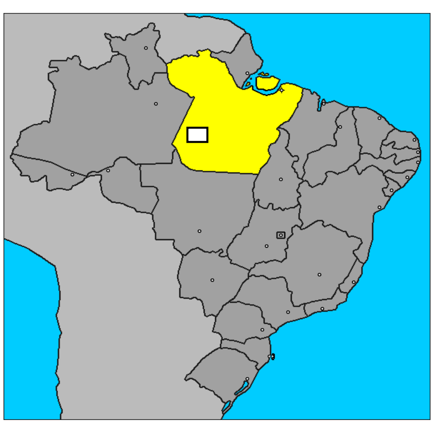

Figure 1. Location of the study area.

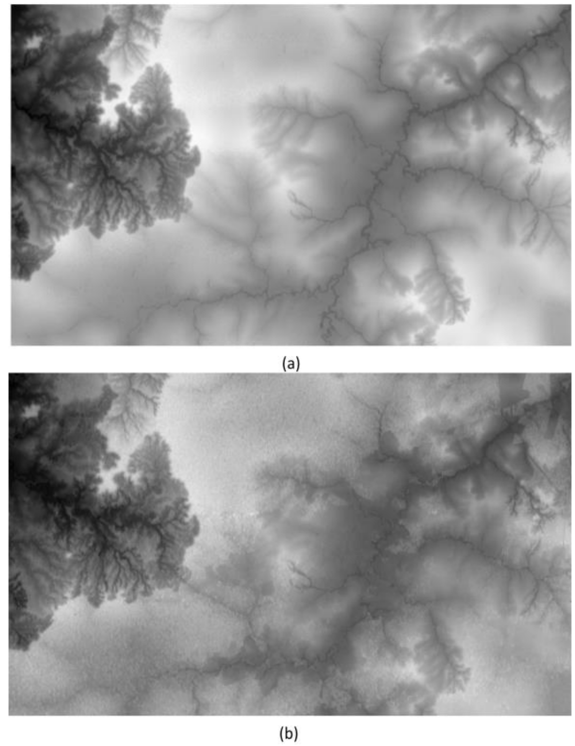

Figure 2. (a) p-band elevation model; (b) x-band surface model.

The other data used was a color image composition from Resourcesat-1, also known as IRS-P6, built by the Indian Space Research Organization, with the LISS 3 camera operating in three spectral bands (0.52-0.59µm; 0.62-0.68µm; 0.77-0.86µm) having 23.5m of horizontal resolution. These images are from 2012. Fig. 3 shows the used color image composition.

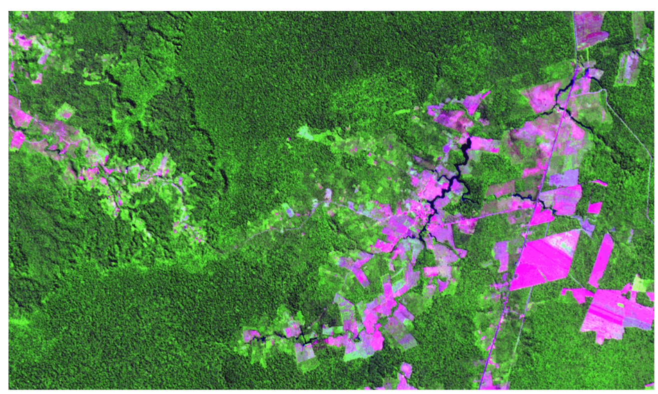

Figure 3. Color image composition: band 1 red, band 2 green and band 3 blue.

The drainage networks were extracted from both radar data and the color image composition was used to verify the differences between the two extracted drainages.

IV. PROCESSING STEPS

Drainage was extracted using TerraHidro, a distributed hydrological system for water resource applications [9]. TerraHidro uses a modified PFS method to extract good quality drainage networks [10]. This method eliminates all pits and finds water flow in flat areas. These are the two main problems extracting drainage networks. Fig. 4 presents the drainage extraction for elevation and for surface models.

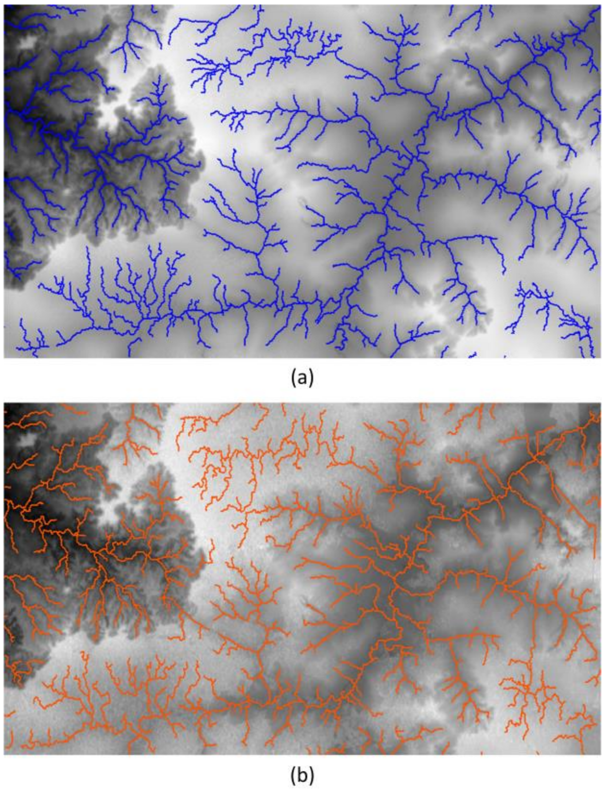

Figure 4. (a) drainage network for elevation model; (b) drainage network for surface model.

Characteristics of land cover can help to identify the differences between both drainages. The images were classified to discriminate areas of water, forest and deforestation. This process was executed in the SPRING system [11] using an automatic classification method, by means of unsupervised classification, using the Isoseg algorithm. Unsupervised classification is a method that works on segmented areas. It examines a large number of unclassified pixels and divides them into a number of classes, based on natural groupings present in the segmented image. The classification process can be described briefly as follows: first, a percentage acceptance threshold is chosen. This threshold is used to calculate the maximum Mahalanobis distance [12] a region created by the segmentation process can be separated from the center of a class and still be considered as belonging to that class. It also determines the number of class clusters detected by the algorithm. Iteratively, the classifier removes all regions with a Mahalanobis distance to any class greater than the acceptance threshold. The user controls the level of details through the acceptance threshold: fewer classes for higher threshold levels or more classes for lower threshold levels. After testing several values, the threshold value of 95% was accepted, which appropriately defined the classes without creating redundancy. Fig. 5 shows the classified image.

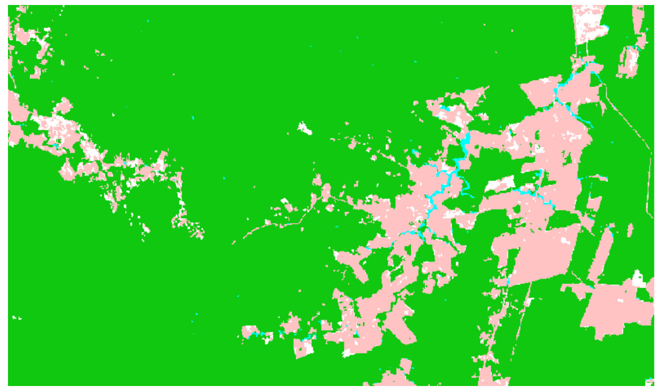

Figure 5. Classified image with forest in green, water in blue, and deforestation in pink.

As the color image composition has 23.5m of horizontal resolution, the drainages must be extracted in the same resolution. TerraHidro uses an upscaling methodology that converts a high resolution drainage network into a low resolution one [13] [14]. In this work, a factor of 9 was used to convert the original grid resolution from 2.5m to 22.5m. As the factor must be an integer, this value yields the best approximation. Fig. 6 shows the drainage networks of the elevation and surface models on top of the classified image.

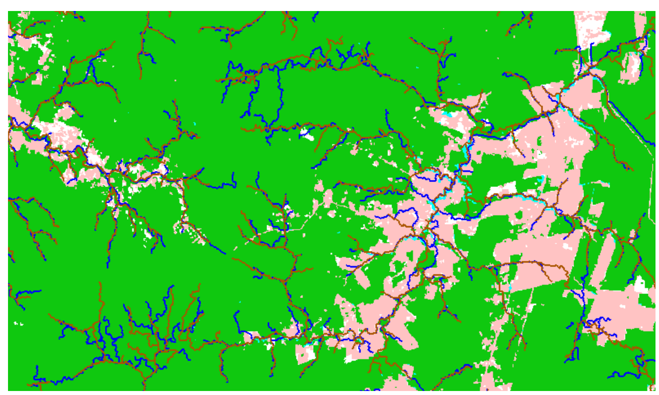

Figure 6. Drainage network for elevation model in orange and drainage network for surface model in blue.

The analysis of the differences between the drainage networks will be qualitative, verifying each drainage portion regarding to the context of the elevation and surface models.

V. DRAINAGE DISCREPANCY ANALYSYS

The drainage analysis is based on understanding how the drainage changes by using the surface model in place of the elevation model. Two elementary errors occur when using the surface model regarding to the drainage network in

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deforestation areas and when the relief is represented by canopy of trees. Fig. 7 presents the drainage networks, by using the surface model (blue) and by using the elevation model (white), with the background derived from the classified image, representing in purple the deforestation and forest areas in green.

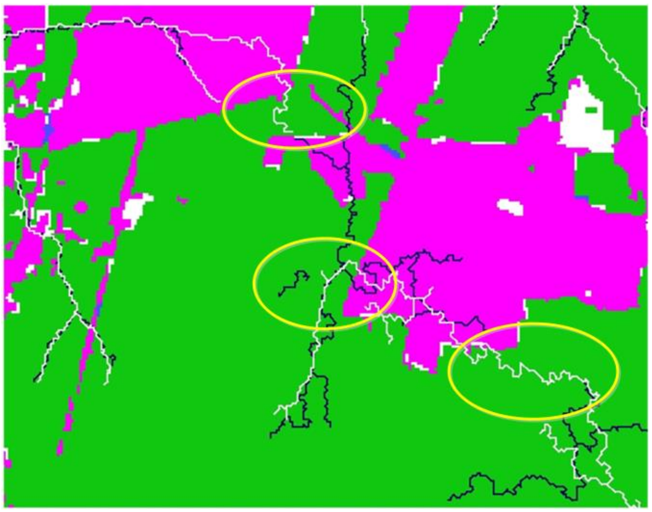

Figure 7. Drainage network for the elevation model in white and drainage network for the surface model in dark blue.

The deforestation creates regions of low elevation with respect to its neighborhood, which is formed by forest. As the elevation is given by the forest (canopy of trees), a path of drainage probably will be erroneously created in the deforested region. Fig. 8 shows the differences between the drainages extracted from elevation and surface models. The yellow ellipses highlight some examples showing significant differences between both drainage networks.

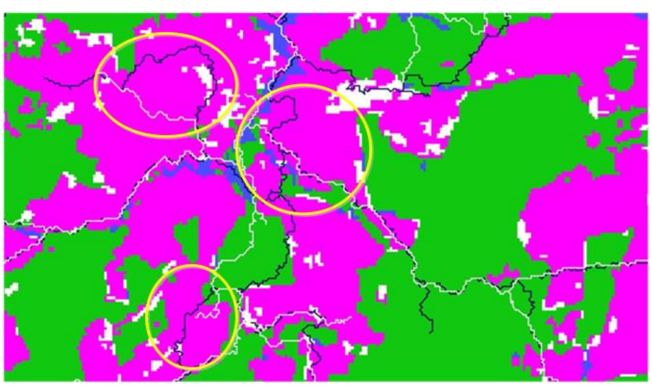

Figure 8. Consequences of using the surface model to extract the drainage network in deforestation areas.

The other problem regards the canopy of trees representing relief. This can causes errors when there are lack of uniformity between the relief formed by the canopy of the trees and the actual terrain topography. Fig. 9 presents some examples of this type of problem.

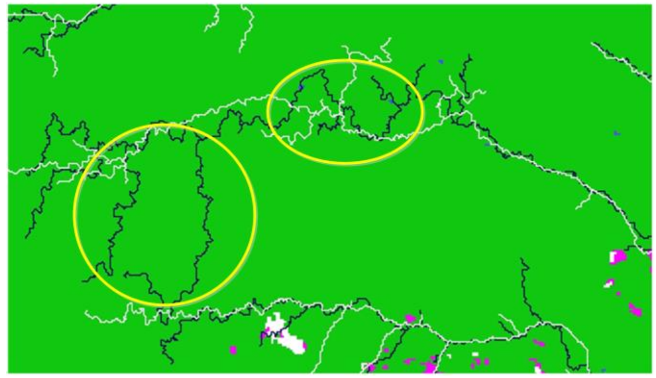

Figure 9. Consequences of using the surface model to extract the drainage network in forest areas.

The yellow ellipses highlight the locations with error occurrence.

VI. Determination and Evaluation of Critical Areas

It was observed that the surface model data, in many cases, varies abruptly in the critical areas, something that is not so common to observe in the elevation model data. As the HAND (Height Above to the Nearest Drainage) [15] terrain descriptor is sensible to drainage changes in regions of sudden terrain variations, it was used as a tentative way to determine critical drainages areas.

HAND calculates, for every cell of the relief regular grid, the altimetry difference between this cell and the nearest cell pertaining to the drainage network, following the local drain directions.

Fig. 10 and Fig. 11 show the resulting DEMs depicting the HAND terrain descriptor for the x- and p-band, respectively, calculated using the TerraHidro System. The x-band drainage is shown in green, and the p-band drainage, in yellow. Critical areas, where the HAND descriptor shows sudden variations in value, are shown inside red ellipses.

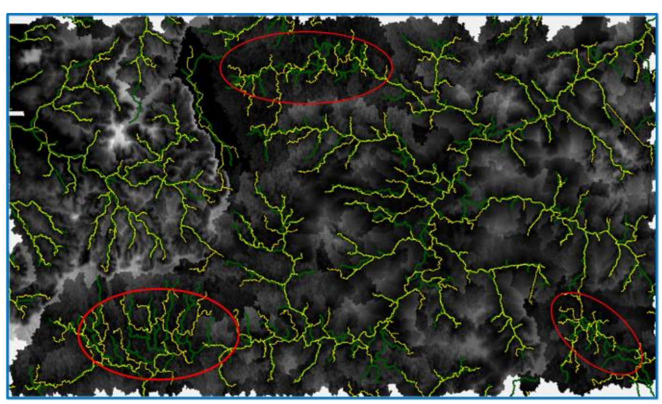

Figure 10. Descriptor HAND for the x-band.

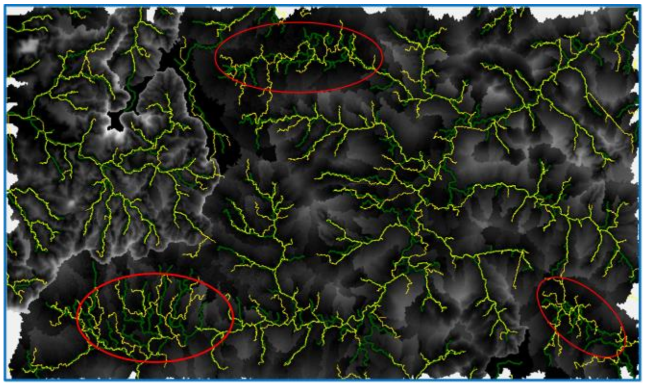

Figure 11. Descriptor HAND for the p-band.

The use of the HAND descriptor can help to spot areas where the drainage network is less precise and may contain errors. It can be useful if an x-band radar data DEM is the only data available.

VII. CONCLUSION

This article presented the drainage networks differences when they are extracted from the surface model and from the elevation model. Real data was used for both models and two situations causing problems, deforestation and forest areas, were shown.

Drainage networks extracted from surface models have errors that can significantly impair the quality of the results. Not always, however, it can be easily identified. Use of classified images, identification of deforestation and forest regions, are strategies to make better drainage extraction.

This work also presents a procedure to determine critical areas for extracting drainage network from x-band radar images. A limitation of this procedure is that it shows only the most critical areas. Other critical areas are not found by the suggested procedure.

This procedure can be useful when there is only an x-band DEM available, with no additional information. It signals potential critical areas, being necessary to have more data or information about these areas to correct the extracted drainages. In the worst case, when there are no other data, the drainage network extracted in these areas is not to be trusted.

This issue is important because large databases of reliefs, such as SRTM and ASTER, were created from surface models and are worldwide used.

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