# Identification of the Tropical Forest in Brazilian Amazon based on the DEM difference from P and X bands interferometric data

José Claudio Mura, Leonardo Sant'Anna Bins, Fabio Furlan Gama,
Corina da Costa Freitas, João Roberto dos Santos, Luciano Vieira Dutra

Instituto Nacional de Pesquisas Espaciais
12.227-010 São José dos Campos, Brazil
Phone +55 12 345 6517 Fax: +55 12 345 6468 E-mail: mura@dpi.inpe.br

**Abstract - In this paper the difference between digital elevation models, derived from P and X bands interferometric data, is used as a main information to identify land cover classes. The radar data used in this work were collected on September of 2000 over Tapajós National Forest, which is a region of Brazilian Amazon, Pará State. The SAR images were acquired from an airborne polarimetric system, AeS-1, that could provide P and X bands interferometric data. During the radar mission ground survey was carried out, and the georeferenced information about the forest typology were acquired, and used as a support for the thematic identification and calibration of the remoted sensing data. The X-band DEM was generated using one-pass interferometric data and the P-band DEM was generated using two-pass interferometric data. The grid of the DEMs has a spatial resolution of 2.5 meters. Images from P and X bands and coherence maps were also used in order to improve the classification. Supervised and unsupervised classifications techniques are used and their results are shown.**

## I - INTRODUCTION

SAR interferometry potentiality for land cover mapping application has been demonstrated in addition to its main application as a tool for Digital Elevation Model (DEM) construction. In particular, coherence map is a valuable feature to discriminate land cover classes in tropical environments. [1], [2], [3]. We will focus here a method for mapping rain forest height (and volume) using the difference between the DEMs generated by X and P band interferometry, and the use of this product to discriminate land cover classes. DEM model from INSAR X band is relative to the top of the forest canopy. INSAR P band can provide an approximated DEM of the forest floor, although the interferometric phase difference of P band data suffers the influence of the crown, trunk and bush layers. The difference between both DEMs will give us an approximated forest volume.

In the experiment described in this paper, SAR imagery were acquired from an airborne polarimetric system, AeS-1 [5] that can provide P and X bands interferometric data The mission was carried out in September, 2000 over Tapajós National Forest (FLONA), which is a region of Brazilian Amazon, Pará State. This experiment was a joint effort between Aerosensing Radarsysteme, GmbH, the Brazilian Army and the National Institute for Space Research (INPE). During the radar mission, a ground survey was also carried out to provide georeferenced information about the forest typology. The X-band DEM was generated using one-pass interferometry and the P-band DEM was built using HH polarization two-pass interferometry, with a spatial resolution of 2.5 metes and height resolution of 0.5 meter. The total height RMS error was 3.0 meters and 1.0 meter for P and X bands respectively, where the accuracy of the DEMs were measured using 8 corner reflectors inside the study area The heights of these corners reflectors were measured with an accuracy better than 2 cm by using differential GPS.

Although the main concern of the mentioned product would be assessing the accuracy of volume mapping, which is not done at this moment, the difference between the digital elevation models are used to map land cover classes, by means of supervised and unsupervised classifications techniques. X band backscatter image and coherence map from P band, HH polarization, were also used in order to improve the classification. The results obtained from these different data and techniques are shown.

## II - LAND COVER IDENTIFICATION

The test site for the experiment is located in the Tapajós National Forest with an area of 5.5 $Km^2$. In this test site were indentified, during the ground survey, the following class of land cover: dense tropical rainforest, regeneration, dirt pasture, agricultural fields and pasture.

The DEM difference, shown in Figure 1, was, in a first analysis, segmented (unsupervised classified into regions) by a segmentation method [6], based on region growing technique.

For second analysis a hybrid product was synthesized using the inverse IHS transformation where the geocoded X band was considered as the Intensity channel, the DEM difference the Hue channel, and the coherence map (Figure 3) from the P band as Saturation. The result is shown in the Figure 2. This hybrid image was classified by the classical maximum likelihood technique, with the same classes mentioned. Also, the same segmentation method used in the first analysis was applied now to this product.

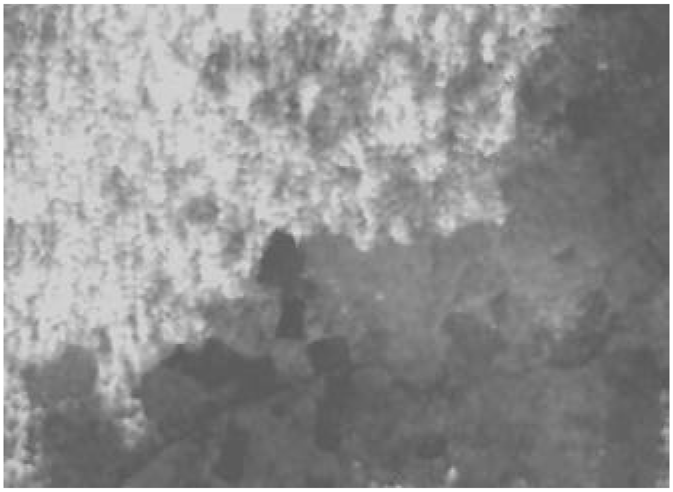

Figure 1 – DEM difference from X and P bands

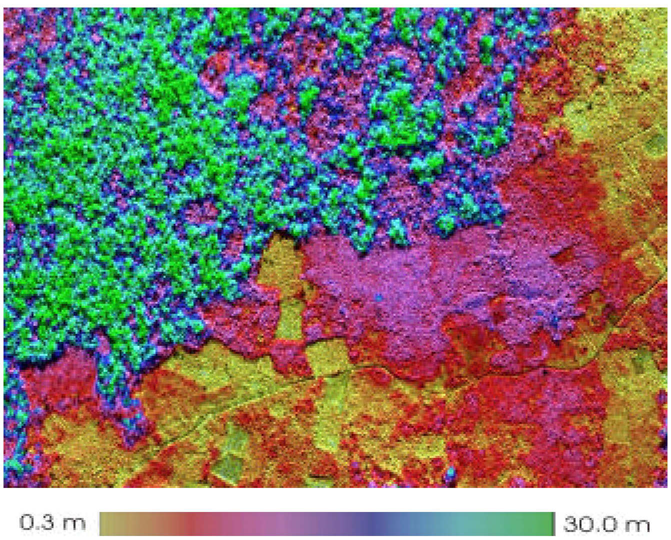


Figure 2 – IHS composition from the DEM difference (hue) and the geocoded X band image (intensity)

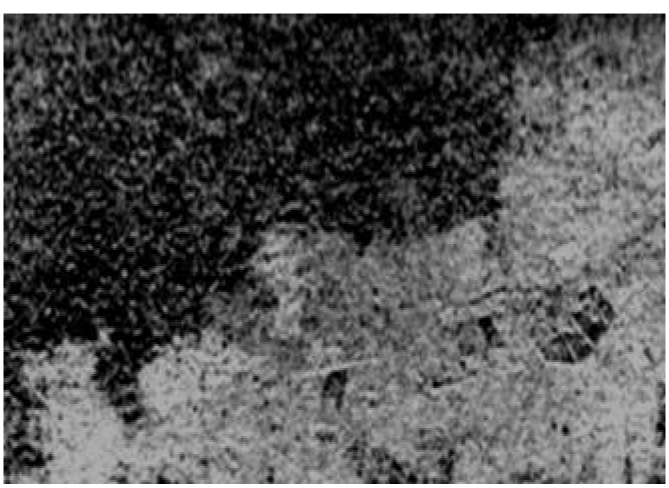

Figure 3 – Geocoded coherence map from P (HH) band

## III - RESULTS

The result of the first analysis is shown in the Figure 4, where regions are classified by minimum distance to the average height of each object. The dark green color represent the dense tropical rainforest, the green color represent the regeneration areas, the brown color represent the dirt pasture, the orange color represent the agricultural areas and the yellow color represent the pasture land .

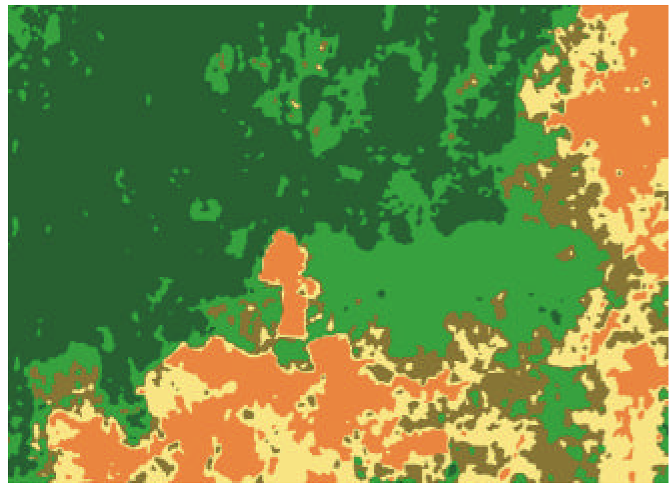

Figure 4 – Classified image using the segmentation method

Figure 5 presents the classification map produced by a k-means clustering procedure, which was run over the region attributes produced by the region growing segmentation of the hybrid product.

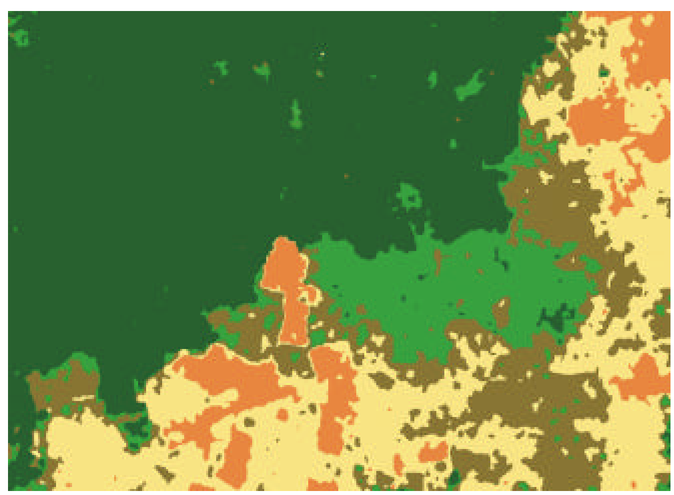

Figure 5 – Classified image obtained by classifying regions of a segmentation output.

A per point classification map based on the standard maximum likelihood (MaxLik) approach [6], applied to the hybrid product, is shown in Figure 6.

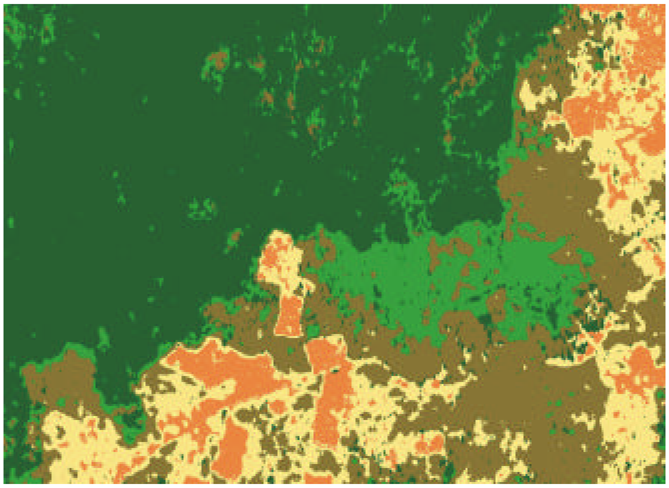

Figure 6 – Classified image using the Maximum Likelihood method.

The proportion of area occupied by each class in the test site is shown in the Table 1.

Table 1 – Proportion of the classified areas.

| Land cover | Test results | | |
|---|---|---|---|
| | First analysis | Second analysis | |
| | | K-Means | MaxLik |
| | % | % | % |
| Dense Tropical Forest | 35.72 | 45.30 | 42.62 |
| Secondary Forest | 34.12 | 12.07 | 13.10 |
| Overgrown pasture | 12.58 | 15.80 | 23.15 |
| Pasture | 18.38 | 19.68 | 14.21 |
| Agricultural areas | 17.21 | 7.03 | 6.77 |

## IV - CONCLUSIONS

Using only the DEM difference, case of the first analysis, a deeper analysis of the map shown in the Figure 4 allows observing some confusion between the classes of dense forest and regeneration. This is caused because there are some parts of the dense forest where the height of the trees are quite similar to the secondary forest.

Adding the coherence information and the X band backscatter image, case of the second analysis, the separation of the dense forest and the secondary forest is observed to improve (Figure 5), because the lower coherence in the dense forest area when compared with the coherence of regeneration, which is more compact. The other classes defined in this test site are also better defined due to the information of the X band image.

The performance of the two methods used in the second analysis, in terms of the classified area as shown in the Table 1, are similar for the forest and agricultural areas. There was a significant difference between dirt pasture class and pasture.

Comparing the classified images, shown in the Figure 4, 5 and 6, regarding to the Figure 2, and the knowledge of the ground truth, the classified image shown in the Figure 5 is the best land cover classification for this test site.

Despite of the simplicity of the analysis done in this work, the DEM difference has been shown to be very useful for forest identification and to discriminate forest areas from clear-cuts, mainly when used together with coherence maps and geocoded X band amplitude image, that are regular products in a process of interferometric topographic mapping, using X and P bands.

Another potential application of DEM difference is the estimate of the forest biomass. The acquired P band polarimetric data can also be used to improve the identification of the forest types, which will be subject of the future work in this test site.


## ACKNOWLEDGEMENT

The authors would are grateful to Marcus Schwäbich, Christoph Hofmann and Christian Wimmer from Aerosensing Radarsysteme GmbH for theirs valuable contributions to this work.

This work was partially supported by Brazilian-German Government Agreement for Scientific and Technological Cooperation (6/09/1969), CNPq (Proc. No. 30092792-4) and FAPEMIG-00054/00.


## REFERENCES


[1] U. Wegmuller, C. Werner, 'SAR Interferometric Signatures of Forest', IEEE Transactions on Geoscience and Remote Sensing, vol. 33, n. 5, pp. 1153-1161, Sept.1995.

[2] N. Floury; T. Le Toan, J. Souyris; K. Singh; N. Stussi; C. C Hsu; J. A Kong, 'Interferometry for Forest Studies', FRINGE 96, ESA, 1996.

[3] L. M. H. Ulander; J. O Hagberg; J. Askne, 'ERS-1SAR Interferometry over Forested Terrain', in Proceedings of 2º ERS-1 Symposium, Hamburg, Oct. 1993.

[4] H. Israelsson; J. Askne; R. Sylvander, 'Potential of SARfor forest bolo volume estimation', Int. J. RemoteSensing, vol. 15, n. 14, pp. 2809-2826, 1994.

[5] J. Moreira, "Design of an Airborne Interferometric SAR for High Precision DEM Generation", in Proceedings of XVIII ISPRS Congress, Vol. XXI, Part B2, Comission II (Wien), pp. 256-260, 1996.

[6] SPRING GIS System, INPE/DPI: http://www.dpi.inpe.br/spring/