# TOPOGRAPHIC MODELING OF MARAJÓ ISLAND

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## INTRODUCTION

This paper aims to describe techniques that can be adapted for processing SRTM data in order to enhance topographic features of the Marajó Island, and which can be extended to analyze the morphology of other areas with similar low topography. This study area is characterized by an abundance of morphological features attributed to a complex history of channel abandonment as a response to tectonic activity, whose adequate reconstruction might be the key to substantially improve our understanding on the evolution of the low Amazon drainage system through time.

## MATERIAL AND METHODS

This work was based on the analysis of SRTM-90m InSar data. The data used here corresponds to the version 1 data, downloaded by August 2003 from The National Map Seamless Data Distribution System, provided by the United States Geolgical Survey. SRTM-90m data were pre-processed to improve its information potential and to allow for morphometric analyses. The applied modifications were pixel thinning (from 3" to 1") after removal of the data failures, with a slight smoothing directed to a reduction of artifacts (unrealistic presentation due to pixel size and abrupt variations between height-contrasting objects and canopy) and distribution of the spatial randomness.
After this pre-processing of the elevation data, a suite of algorithms programmed with GIS (Geographical Information System) functions was applied to produce digital images of slope angle (steepness), aspect, plan curvature, profile curvature and thalweg-divide delineation. Slope angle images were calculated through the vector sum of slope orthogonal components, as quantified through moving windows in "x" and "+" orientation systems, taking the maximum height in each windowed direction and the maximum resultants between the orientations. The method to map profile curvature is based on local 3x3 pixel windows designed to perform geometrically the second order derivative through the slope profile. Curvature calculations required the DEM spatial resolution as one of the inputs, so as to calculate a comparable absolute value, with the slope change rate per horizontal distance as unit, in degrees per meter ($^o$/m). Plan curvature was mapped through a similar application of moving windows, on the slope direction image instead, providing the slope direction change rate per horizontal distance ($^o$/m). Slope direction maps were directly obtained through the aspect function of the used GIS. Interpretation of elevation itself was made possible by the use of the software Global Mapper. Given the very low topography, the study area had to be visualized accordingly using customized shade schemes and palettes to efficiently highlight the morphologic features of interest to this paper. When examining different locations, color schemes had to be rearranged in order to present strong hue transitions along the height span of the observed features, requiring often adjustments from a local to another. This was applied only for the recognition of features, since local adjustments would affect internal consistence when observing the whole image.

## RESULTS AND DISCUSSION

A hypsometric presentation of the Marajó Island shows a clear bi-modal distribution of heights, reflecting two main topographic regions (Figure 1). Hence, although the overall mean height for the entire island is 12.55 m, the western side is of higher relief, recording heights averaging 20 m, with a maximum height of 36 m. In contrast, the relief in the eastern half of the island, which is flooded through several months every year, commonly ranges from 2 m to 6 m, occasionally reaching a maximum of 30 m. Beside elevation differences, the western side of the island showed higher topographic features than those observed in its eastern side, as can be seen in section A-A' of Figure 1. A remarkable observation was a circular feature of flat and low elevation in the southeast portion of the island (transect B-B', Figure 2), between Afuá and Arari rivers. The bimodal relief distribution in the Marajó Island corresponds to sedimentary deposits of different ages, with the terrains to the west being related to older Plio-Pleistocene deposits, while the lower topographic terrains to the east encompasses mostly Holocenic deposits. Observations of refined elevation model, coupled with occasional verifications on morphometric maps, allowed a better (cleaner) characterization of a complex drainage network through identification of paleochannel systems, mostly in the western side of the Marajó Island. In the eastern side of the island, a smaller number of these features were detected in the topography. Additionally, field observations confirmed an exaggeration effect due to canopy affecting SRTM data, as forests cover the paleochannels while the surrounding terrain is covered by grasses and low vegetation. Indeed, paleochannel SRTM heights record tens of meters, but the terrain itself was observed to present only 2-3m elevation relative to its surroundings, being covered with high (tens of meters) dense forest canopy.

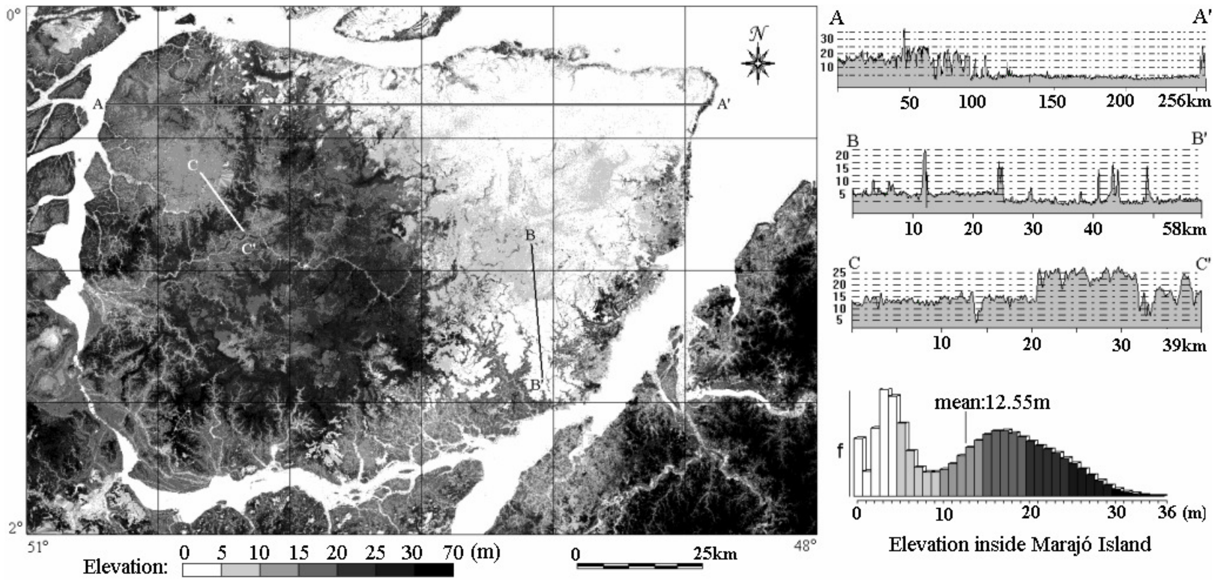


Figure 1 – SRTM data of Marajó Island. Profile A-A' shows the topographic gradient existing between the western and eastern side of the island, which higher values to the west; B-B' cuts through an area with circular nature having an overall slightly lower topography to the south; and C-C' illustrates a higher belt in the northwest side of the island, probably related to a paleochannel.

In the western part of the island, the paleochannels were easily detected in the SRTM data because they consist of elongated, highly sinuous, and usually branched features presenting positive relief (convex transversal sections) that differs from the relatively lower topography of the surrounding terrains (see section C-C´ in Figure 1). Additionally, hydrologically meaningful drainage networks of modern channels often intercept paleochannels, producing a number of disconnected segments. The SRTM observations of the paleochannels showed that more than one drainage system were successively replaced or covered by another, and suggested that their height relative to the surrounding terrain might help to distinguish the different paleodrainage networks.

In an attempt to isolate the individual heights of the paleochannels from bulk elevation, a "floor" elevation model (bald Earth) was constructed by interpolating points selected through morphometry and subtracting its height from the actual DEM. Since there is not a reliable elevations data source in appropriate scales in Brazil, like the National Elevation Model – NED (Gesch et al., 2002) DEM used by Kellndorfer et al. (2004) for this task, bald Earth DEM has to be extracted from the same SRTM data, by indirect means. In a vertically wide relief, low areas are expected to present concave curvature, low steepness, convergent flow lines or to match thalweg conditions. However, the low relief amplitude caused much of the morphometric variations to result from roughness of surface data, due to terrain or canopy roughness or even data noise, rather than hydrological and geomorphological constraints. The distribution of local morphometry resulted in a crispy pattern, producing fragmented concavities and thalwegs everywhere, not only in lowlands. Thus, the various morphometric criteria applied to automatically select floor pixels failed, with much of them being erroneously selected on positive relief features. Although the terrain particularities disabled numerical approach efforts for parametric description of the paleochannels, the procedure caused an interesting enhancement of these features, bringing new features where they could not be perceived before and enhancing the promptly visible ones (Figure 2).

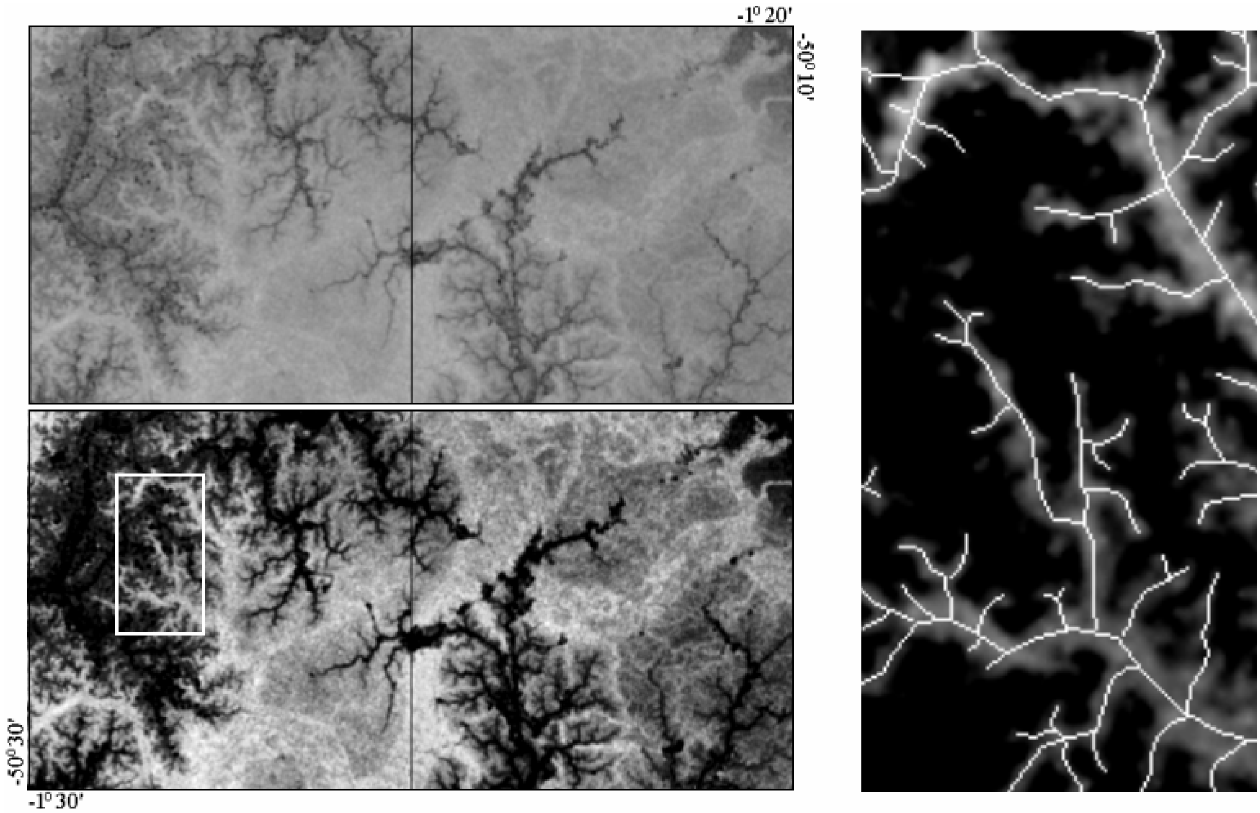


Figure 2 –Enhancement of paleochannels: SRTM full DEM (top left) and height relative to the island “floor” (bottom left); digitizing of paleochannel networks (right).

In Figure 2, the top image presents the full refined SRTM elevation, where modern channels can be observed as the dark network and paleochannels as the brighter networks of varying widths. Removing the island floor, a higher contrast between paleochannels and the remaining terrain is achieved, enhancing the large courses as well as lower order networks of paleochannels. While the vertical aspects of the mapped paleo-watersheds are liable to reflect modern pedo-botanical effects rather than the ancient geomorphometry, the horizontal characteristics of their drainage networks can be partially recovered. The remaining question in this matter is the level of completeness of the recovered network relative to its original, but, at some extent, the general drainage geomorphology can be retrieved, such as density measures, shape, caption area, channel hierarchy and sinuosity, for example.

## CONCLUDING REMARKS

In the SRTM elevation model, Marajó relief presented very low elevation, with a maximum of 36m, and relative relief rarely exceeding 10m. In the eastern side of the island, the observation of terrain features were related to structural changes in the overlying vegetation. In the western side, all covered with dense ombrophyla canopies, the height contrasts around these features were smaller. The observations revealed Marajó Island to present numerous paleochannels displaced in distinct and overlapping drainage systems, which differ in width, curvature and direction. Much of the classical procedures in digital elevation modeling were useless in this relief, where canopy effects prevailed over terrain expression. An attempt to digitally estimate the height of paleochannels relative to their surroundings resulted in their enhancement, allowing the perception of ancient drainage networks.

## AKNOWLEDGEMENTS

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