USE OF INFORMATION DERIVED FROM RADAR REMOTE SENSING (RADARSAT-1 INTERFEROMETRY AND SRTM MOSAIC) FOR MAPPING NEOTECTONIC ACTIVITIES IN THE REGION OF MANAUS CITY (AMAZONAS STATE)

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ABSTRACT

The prime objective of the present research is to understand and contextualize, from a tectonic and structural standpoint, the results obtained by an interferometric study recently carried out in the Manaus area, Amazonas State, Brazil in which a stack of archived RADARSAT-1 data has been processed. The research question has been approached through the analysis of the drainage network extracted with the aid of SRTM (Shuttle Radar Topography Mission) data, as well as through the comparison with images from different optical sensors and with geologic and geomorphologic information available in the literature.

1. INTRODUCTION

Synthetic Aperture Radar (SAR) systems have been lately used for the remote detection of recent crustal movement, possibly associated with neotectonic events. These systems are advantageous because they are able to cover vast regions using an extremely high accuracy, which represents an advance for terrain monitoring. Manaus is the biggest city of Amazonas state and represents an important site for oil and gas exploration and transportation surrounded by delicate ecosystems, making it highly sensitive to the presence of oil industry. In this context, an understanding of the temporal dynamics and spatial distribution of neotectonic events is fundamental for the definition of proper environmental management practices. PETROBRAS is, therefore, in search of cutting edge remote sensing technology based on radar at exploration boundaries through Amazonas Basin was begun in the late 1980s, and 90. These studies combine different data from space and also geophysical and surface’s geochemistry information to detect indicative oil features onshore [1]. In addition, reference [2] indentified new tectonic features as grabens over Manaus region. Complementing the previous knowledge, the present research considers the hypothesis of recent crustal movement associated to neotectonic activities at Amazonas basin, using RADARSAT-1 interferometry. The first orbital interferometry project conducted in Brazil was developed by PETROBRAS Research & Development Center (CENPES), in collaboration with MacDonald Detwiller and Associates (MDA) and Threetek in 2007 for pipeline risk detection. The great results encouraged the methodology application over Manaus region where Cenozoic tectonics was verified. The preliminary results of Solimões Project indicates an area of crustal movement located adjacent to a circular drainage feature [3] inside Manaus city urban area. It’s expected that the final analysis and results from Solimões Project will include an improved understanding of the geological activities and crustal motion in the Amazon Basin as complementary study for Beavis [4] that describes an annual cycle of vertical displacement with an amplitude of 50-75 mm measured by a GPS station near the centre of the basin. This is considered a large crustal oscillation and indicates the lithosphere is subsiding and rebounding in response to changes in the weight of the Amazon River system flow. The Amazon River annually cycles through a vertical height range of 10-15 m. The oscillation patterns appear related to regional flooding patterns, and dominated by changes in water loading developed within about 200 km of the Manaus GPS station. This flexing of the lithosphere is thought to propagate downstream in conjunction with the Amazon’s annual flood wave.

2. STUDY AREA

The site of investigation is situated in Amazonas sedimentary basin and comprehend Manaus city and vicinities, totaling 4.000 km² approximately (Fig.1).
3. GEOMORPHOLOGICAL SETTINGS

The study area comprehends terrain elevation ranging between 50 and 100 m through relief rises and watersheds oriented in NW-SE and NE-SW directions. Geomorphologic relief and drainage features as scarps, valleys, watersheds, anomaly patterns, captures, confluence zones, drainage basin asymmetry and drainage lineaments was previous mapped using topographic maps in scale 1:100.000, remote sensing data and digital elevation models validated in the field by Silva [5]. In the present research the drainage lineaments was compared to existent geological and field work information and further spatially analysed to generate structural understanding above the study area. Linear/curvilinear features developed due to the tectonic stress and strain are defined as lineaments. Comparison of stream and lineament orientations helps in assessing lineament control, exercised on the drainage architecture.

4. RADARSAT-1 INTERFEROMETRY

Interferometric synthetic aperture radar (InSAR) is a proven technique that uses two or more satellite images to measure subtle movements of ground features. The basis of the technique is the measurement of change in radar phase between consecutive SAR images that are acquired in identical position and attitude but at different times. If any movement or changes to ground features has occurred between the time that consecutive images were acquired, differences in radar phase can be observed. These changes in phase are converted to sub-centimeter motion measurements. With it’s 24-day repeat cycle, RADARSAT-1 collects an image over the same location every 24 days.

InSAR technique has a high potential for the measurement of land subsidence and other surface changes in urban areas as described by many authors in Los Angeles, Shangai, Napoli, Mexico city and others.

4.1 Atmospheric Affects

The primary impediment to a wider application of InSAR technology was the traditional limitation to arid regions of the world. The moisture in the air column will affect the speed at which the SAR signal travels. The longer travel times through moist columns corresponds with longer distance and therefore, movement away in Line Of Sight (LOS). This affect is evident as false ramps or fringes in the interferogram. In temperate regions the rate of change of the moisture content is gradual (> 17kms) and can be removed with a high-pass filter. In tropical regions the depth of the atmosphere and rapid changes in moisture content produces highly variable results. Significant effort has been given to developing, refining and validating methods that would allow the successful application of InSAR even in the most difficult of environments.

In Fig.2, the atmospheric affect over a temperate city, Los Angeles and a tropical city, Manaus is presented. The area covered is the same in both interferograms. The long gradual change noted in the Los Angeles interferogram is easily removed because in most cases motion of interest occurs on a much finer scale. The rapid changes noted in the Manaus interferogram is at a scale commonly found in observed motion.

5. MATERIALS AND METHODOLOGY

Besides the RADARSAT-1 interferograms and SRTM and SWBD (Shuttle Water Body Data) data, it was also processed opticals Landsat and IKONOS imagery. Landsat processing was used on drainage lineaments interpretation and integrated to existent geologic and geomorphologic data and survey information. The high resolution 1 meter data from IKONOS sensor shows the detailed land use coverage information from ACM.

For the SRTM data processing as well as for optical data combinations the PCI Geomatica and Global Mapper software have been used. The drainage lineaments analysis was done at Spring software [6].
The GIS analysis of interferograms results with geological and geomorphologic maps and surveying data was currently done using ESRI products.

5.1 – RADARSAT-1 Interferograms

A stack of 28 abeam mode archived RADARSAT-1, Fine 2 Far data was collected up to November 11, 2007 and has been used to do the preliminary InSAR study over the study site. The 30 archived RADARSAT-1 Fine 2F, scenes were processed to assess naturally persistent sample points and evaluate the atmospheric affects over the study region. The data was processed utilizing three InSAR techniques: Common Master, Leap Frog and Network Inversion.

5.2 – SRTM digital elevation model and drainage network analysis (Af index)

From SRTM data were extracted the 9 drainage sub-basins that surround the Study Area. For each one was calculated the Asymmetric Factor geomorphic index [7] which identifies, neotectonic activity in areas underlain by weakly consolidated surficial material particularly in poorly exposed quaternary alluvial areas. Asymmetry factor (AF) is a qualitative index which helps in evaluating basin asymmetry. In a stable setting environment, AF is 50. It is sensitive to tilting perpendicular to the main channel of the basin. AF values more/less than 50 suggests a tilt.

<table>
<thead>
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<th>Drainage Basin</th>
<th>Ar (km²)</th>
<th>At (km²)</th>
<th>Af</th>
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<th>Tilt Direction</th>
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</table>

Table 1 – Af index calculation.

6. RESULTS

After calculating the tectonic effect magnitude (B for big tecnization process, M for medium and P for poor) for each Amazonas river sub-basins, the topologic relationship between them were analysed and the watersheds were classified as unstable, moderated unstable, little unstable, moderated stable and stable ones as represented by the respective colors lines: red, dark yellow, yellow, green and blue as represented at Fig.4.

Figure 3 - Example interferograms from RADARSAT-1 stack where ACM is shown [3].

Figure 4 – Watersheds Stability classification.
Figure 5 – The continuous black line is indicating the AMC. The black dotted lines represents the topographic picks of relief. There two green points indicating field geologic information. The red line represents the unstable watershed and yellow ones are the E-W geologic trend above the areas.

As a result, it has been noticed that the Area of Crustal Movement (ACM) detected by the interferometric study is located above the tectonic unstable watershed that separates the Igarapé São Raimundo and Rio Tarumã-Açu sub-basins. Both areas are characterized by the pronounced occurrence of tilting. In addition, the ACM is situated in the vicinities of a circular drainage anomaly with 4 km of diameter, which strongly suggests a geologic origin for the interferometric feature.

7. CONCLUDING REMARKS

The severe atmospheric effect over the study area precludes any definitive results at this time. The continuing data (RSAT-2) acquisition and processing should improving this study.

With the development of new (SAR) sensors, with high spatial resolution, multiple polarization capabilities, and short visit time, monitoring of urban areas by means of SAR images has grown into a valuable and indispensable tool.

8. REFERENCES