



INPE – National Institute for Space Research
São José dos Campos – SP – Brazil – May 16-20, 2016

USING TWO-DIMENSIONAL CONTINUOUS WAVELET TRANSFORM TO DETECT DIFFERENCES AMONG PRIMARY FOREST, WATER BODIES, CLOUDS AND CLOUD SHADOWS ON REMOTE SENSING IMAGES OF AN AMAZON RAIN FOREST REGION: FIRST RESULTS

Cledenilson Mendonça de Souza¹, Margarete O. Domingues², Marcos Adami³, Leonardo Deane de Abreu Sá³

¹Universidade Federal do Amazonas (UFAM / ICSEZ), Parintins - AM, cledenilsonms@gmail.com

²Brazilian Institute for Space Research Laboratório Associado de Computação e Matemática Aplicada (LAC/CTE/INPE), São José dos Campos, SP, margarete.domingues@inpe.br

³Centro Regional da Amazônia (CRA-INPE), Belém, PA., marcos.adami@inpe.br, leonardo.deane@pq.cnpq.br

Abstract: One issue in practical uses of remote sensing imagery is to map clouds and cloud shadows. Often the clouds can be confused with snow, sand or straw cover. Moreover, the shadows of the clouds can be confused with water bodies. In this way, we are using Two-Dimensional Continuous Wavelet Transform (CWT2D) in order to identify differences between primary forest, water bodies (lakes and rivers) from clouds their shadows. The site is located at the Uatuma Reserve (USDR) in Central Amazonia. We use CWT2D to detect per scale differences among patterns of the surface texture. The results show the existence of statistically significant differences among the distinct classes of areas mentioned above.

keywords: Time series analysis, infrared imagery, Amazon forest, cloud and cloud shadow and water body detection, two dimensional wavelet transform

1. INTRODUCTION

The main land use and land cover of the earth surface are: agricultural crops, urban areas, forests, pasture land, wetlands, among other areas that generate different landscape settings with different textures whose analysis has received increasing attention.

The texture is usually associated with structural patterns of the target and most often consists of repetitive patterns

whose disposition can be periodic or random [5].

A question of scientific interest is to investigate the inter-relationships between the variability of the spectral response of the targets observed by remote sensing imagery and the variability in surface. The solution of this issue has great potential for application in the investigation of environmental issues in the Amazon.

In order to understand the effects of this dynamic of use and cover of the earth upon the hydrological and biogeochemical cycles is necessary to perform the mapping of deforestation as well as of the use and cover which have been chosen for these areas.

In this sense, the Brazilian Institute for Space Research (INPE) develops six forest monitoring systems to the Brazilian Amazon, the Detection of Selective Logging (DE-TEX), Project Mapping Forest Degradation in the Brazilian Amazon (DEGRAD) the Amazon Deforestation Monitoring Project (Prodes), Near Real Time Deforestation Detection project (DETER), Monitoring of Vegetation Fires (Queimadas) [1] and the Project Qualification Deforestation in the legal Amazon (TerraClass), except DETER and Queimadas Projects, all other use Landsat-like images. However, given the weather conditions of this region for persistent cloud cover that remains even in the dry season, which occurs from June to November in most part of the basin.

Even the images with higher temporal resolution, obtained by satellites such as MODIS, used in DETER and Queimadas projects in many of these areas there is little chance of obtaining cloud free images. For these projects accurately assess the changes occurring in the land occupation, they need to have estimates of net floor area for the mapping of what was demanded, which requires removing the areas covered by clouds and their shadows projected on the images. It seems to be a simple and intuitive procedure to distinguish between clouds and the ground. Nevertheless, the clouds can be confused with snow, sand or straw cover. Furthermore, the shadows of the clouds can be confused with water bodies.

2. PURPOSE

The Two-Dimensional Continuous Wavelet Transform (CWT2D) [3], is used in order to project images per scale and from them to perform statistical procedures for successfully identify differences of areas covered by primary forest from those presenting water bodies (lakes and rivers) as well as regions covered by clouds and shadows of these clouds which are observed on the images.

3. METHODS

The experimental site is located in the Uatumã Sustainable Development Reserve (USDR) in Central Amazonia, approximately 150 km northeast of the city of Manaus, Amazonas State ($S02^{\circ}08'38.8''W58^{\circ}59'59.5''$). The research area in the Reserve is within the terra firme forest area on a plateau of 130 m altitude (above mean sea level) [2]. We used two Landsat 5/TM scenes obtained in wet season (2011/01/12) belonging to path/row 230/61 and 230/62. Those data were atmospheric corrected using LEDAPS system and provided by Global Land Survey (GLS) datasets. The GLS datasets are a collection of orthorectified, providing near complete coverage of the global land area [4]. We selected the band 4 ($0.76-0.90\mu m$) due the spectral response of the water, clouds and shadow. In that band the spectral response of the clouds are highs and water and shadow spectral response are low. These spectral characteristics can facilitate the distinction between targets. Figure 1 shows in a) an overview of the lake, and b) an approximate view of the lake.

To obtain the results, the Two-dimensional Continuous Wavelet Transform (CWT2D) is applied to the data. Its equation can be written as

$$W(a, \theta, \vec{x}_0) = a^{-1} \int_{\mathbb{R}^2} d^2 \vec{x} \quad s(\vec{x}) \quad \overline{\psi(a^{-1} r_{-\theta}(\vec{x} - \vec{x}_0))}, \quad (1)$$

$$= a \int_{\mathbb{R}^2} d^2 \vec{\xi} \quad \exp(i \vec{x}_0 \vec{\xi}) \quad s(\vec{\xi}) \quad \overline{\hat{\psi}(a r_{-\theta}(\vec{\xi}))}, \quad (2)$$

where $W = W(a, \theta, \vec{x}_0)$ represents the wavelet coefficients, s is a two-dimensional signal (picture), a is the scale parameter and the vectors $\vec{x}$ and $\vec{x}_0$ corresponds to the position and translational images respectively. The wavelets used in this study are the traditional Morlet and Mexican hat ones.

To compute the partial variance, we select in the original image the space positions corresponding to the lake, cloud

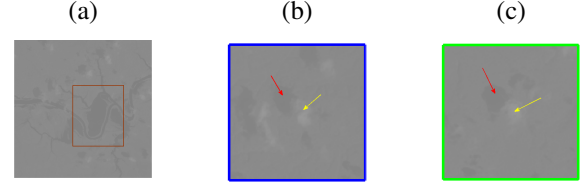


Figure 1 – Infrared band ($0.76 - 0.90\mu m$) of Landsat 5 image of the lake in the UATAMÃ region. (a) Zoom in the lake region; (b) Zoom to region A with clouds and its shadows; (c) Zoom to region b with clouds and its shadows. The yellow arrow indicates the cloud, and the red arrow indicates cloud shadow regions, around these marks the space series are take out.

and cloud shadows surfaces. After that, we extract, in the CWT2D result corresponding to fixed values of θ and scale, the real part of the wavelet coefficient at the same space positions. Then, we compute the variance of these wavelet coefficients. This process is repeated to all scales a and rotation parameter θ . In this paper, we use the free software YAWTB to compute the CWT2D in Gnu/Octave ¹

4. RESULTS AND DISCUSSIONS

On this study we analysed different rotation parameter θ and we verify that $\theta = 45^{\circ}$ represented the best identification of the lake, cloud, and cloud shadow region by a visual identification of the regions on the scalogram considering all the scales. Therefore, all analysis presented here are related to a rotation parameter $\theta = 45^{\circ}$. On Fig. 2 we present the scalograms for study image focus on scale variations. We observe that mexican hat wavelet identify much better the contours, as expected.

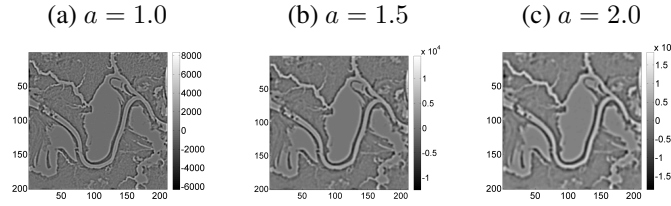
In Figure 3 shows the results of applying CWT2D of Morlet to the images of Figs. 1 just for the regions of the surface of the lake, cloud, cloud shade and forest. In each chart, the angle θ is oriented in the specific direction of 45° . All points of each line are the result of calculating the variance of the real part of the wavelet coefficients in a specific range.

5. CONCLUSION

It was possible to investigate the existence of patterns of variability of vegetation, lake surface, cloud and areas with cloud shadows and its possible detectability on areas of interest from scalogram analysis based on the Two-dimensional Continuous Wavelet Transform (CWT2D) coefficients. Furthermore, we investigated the existence of possible patterns of variability of vegetation texture for different rotation angles of the Morlet's CWT2D for a specific range from the use of a satellite image. These results suggest the possibility of discrimination of different surfaces. The results are encour-

¹Yet Another Wavelet Toolbox (YAWTB Toolbox) Version 0.1.1, GNU General Public License, 02111-1307, USA, 2002. <http://www.mathworks.com/matlabcentral/linkexchange/links/1187-yawtbs-homepage>.

Mexican hat wavelet:



Morlet wavelet:

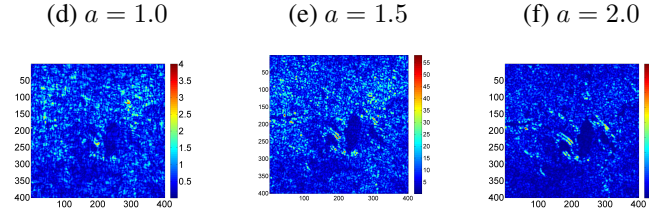


Figure 2 – CWT2D using mexican hat (gray-scale) and Morlet wavelet (colour-scale). Scalograms for the lake region considering different scales a and the rotation parameter $\theta = 45^\circ$. Colormaps varies according to the scales.

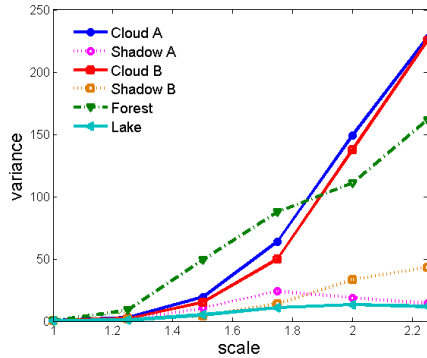


Figure 3 – Variance per scale compute from the real part of the wavelet coefficients.

aging for the development of future specific pattern detection studies of failures in vegetation cover and cloud cover detection. More targeted studies are also needed in this context.

ACKNOWLEDGMENTS

The authors would like to thank INPE and INPA/LBA project for providing the image dataset, Fundação de Amparo à Pesquisa do Estado do Amazonas-FAPEAM for the PhD scholarship of CMS, and the Brazilian agencies CNPq(projects 03.728/2010 – 8, 483226/2011 – 4, 306828/2010 – 3, 306038/2015 – 3) CAPES and FAPESP (project 2015/25624 – 2)for the financial support, and Eng. V. Menconi and Dr. E. Arai for their helpful computational assistance.

References

- [1] Achard, F., Eva, H.D., Stibig, H.-J., Mayaux, P., Gallego, J., Richards, T., and Malingreau, J.-P. Determination of Deforestation Rates of the World's Humid Tropical Forests. *Science*, 297, 999-1002, 2002.
- [2] Andreae, M. O. et al. The Amazon Tall Tower Observatory (ATTO): overview of pilot measurements on ecosystem ecology, meteorology, trace gases, and aerosols. *Atmospheric Chemistry and Physics (Online)*, v. 15, p. 10723-10776, 2015.
- [3] J. P. Antoine, R. Murenzi, P. Vanderghyest, and T. S. Ali. Two-dimension wavelets and their relatives. Cambridge University, Cambridge, 2004.
- [4] G. Gutman, C. Huang, G. Chander, P. Noojipady, and J. G. Masek. Assessment of the Nasa-USgs global landsurvey (GLS) datasets. *Remote Sensing of Environment*, 134:249–265, 2013.
- [5] Malhi, Y. and R. M. Román-Cuesta, R. M. Analysis of lacunarity and scales of spatial homogeneity in IKONOS images of Amazonian tropical forest canopies, *Remote Sensing of Environment*, 112, 2074-2087, 2008.