TEXTURE ANALYSIS OF SAR-ERS1 IMAGES FROM SOUTH CAMEROON

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ABSTRACT

Texture characterisation of SAR images from a forested smooth landscape of South Cameroon was performed using mathematical morphology and multifractal analysis processing. The first method involves to apply gradient-oriented filters according to directions perpendicularly to the radar emission - after removing the speckle and smoothing the original image by using a centre connected and a Nagao filter successively. Reconstruction and erosion was then operated to delineate the drainage network structures - reflecting geological and environmental patterns. The second method consists to analyse the inner multifractal structure of an image with a set of regional multifractal spectra - each was computed for a given area. Regional multifractal spectra were obtained using a naïve estimator based upon the statistics of the singularity maps in subscenes - according to different textures. Our preliminary results indicate that the coupling of classical processing with multifractal analysis could be promising to SAR image segmentation.

1. INTRODUCTION

Detailed field studies carried out in the South Cameroon rain forest have allowed to determine relationships between (i) soil formation and processes and (ii) slope morphology and drainage pattern [Bitom et al., 1997]. The texture of SAR-ERS1 images emphasises the typical slope and drainage network patterns on which depends the landscape roughness. Two processing methods have been performed to analyse the texture of SAR images in the dense homogeneous rainforest of the South Cameroon (Fig. 1).

Mathematical morphology consists to extract dark continuous lines corresponding to stream networks performing binary morphologic processing and geodesic transformations - these latter ones keeping structure outlines. We have also used grey-scale morphological transformations - an extension of the morphologic transformation of binary images.

Multifractal method was used to provide a number of descriptor parameters well suited to radar images analysis. These parameters were integrated in an image segmentation algorithm that fully describes the variations of natural textures. This method consists to examine the inner multifractal structure of the image with a set of regional multifractal spectra, each of them being computed for a given area of the original image.

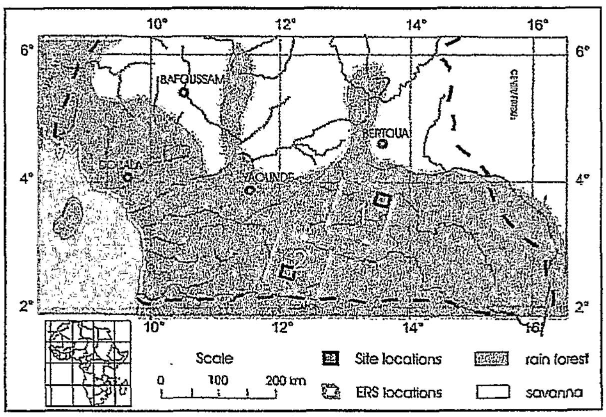

Figure 1. Location of the SAR images and study area.

SAR IMAGE ACQUISITION AND PROCESSING

The two methods have been tested on two subscenes of C band radar images (SAR-ERS1, frequency 5.3 GHz, wavelength 5. cm), with a nominal resolution of 25 m in range and 22 m in azimuth. The two radar images were acquired on August, 1994, (image 1) orbit 15947, frame 3519, (image 2) orbit 16191, frame 3555 with the scene centre located at 04° 19' N - 13° 37' E and 02° 32' N - 12° 29' E respectively (Fig. 1).

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Mathematical morphology was applied to delineate the drainage network of a 1600 * 1400 pixels subscene of image 1, while multifractal analysis was used to describe the texture of a 800 * 700 pixels subscene of image 2.

2. METHODOLOGY

2.1 Mathematical morphology

First of all, the speckle of radar images was removed by applying a connected central filter [Mering & Parrot, 1995] (Fig. 2a). Then the resulting image has been smoothed out by a Nagao filter that fractionates each neighbour 5*5 into 9 sectors [Nagao & Matsuyama, 1979], (Fig. 2b)- the mean and variance of which was calculated to select the neighbour exhibiting the lowest values. The following processings were then applied to both the ""unspeckled"" and the Nagao filtered images.

The channel network structure was delineated using an oriented gradient filtering procedure along three directions NW, W and SW which are suitable to depict the valleys, while the east direction outlines the ridges. The south and north directions only yield a low signal as they are parallel to the radar satellite transmission. Directions NW, W and SW were equally processed after smoothing by a Nagao filter. Then, a low threshold was applied, and it was cleaned up by a geodesic reconstruction [Coster & Chermant, 1989] using a high threshold as a marker.

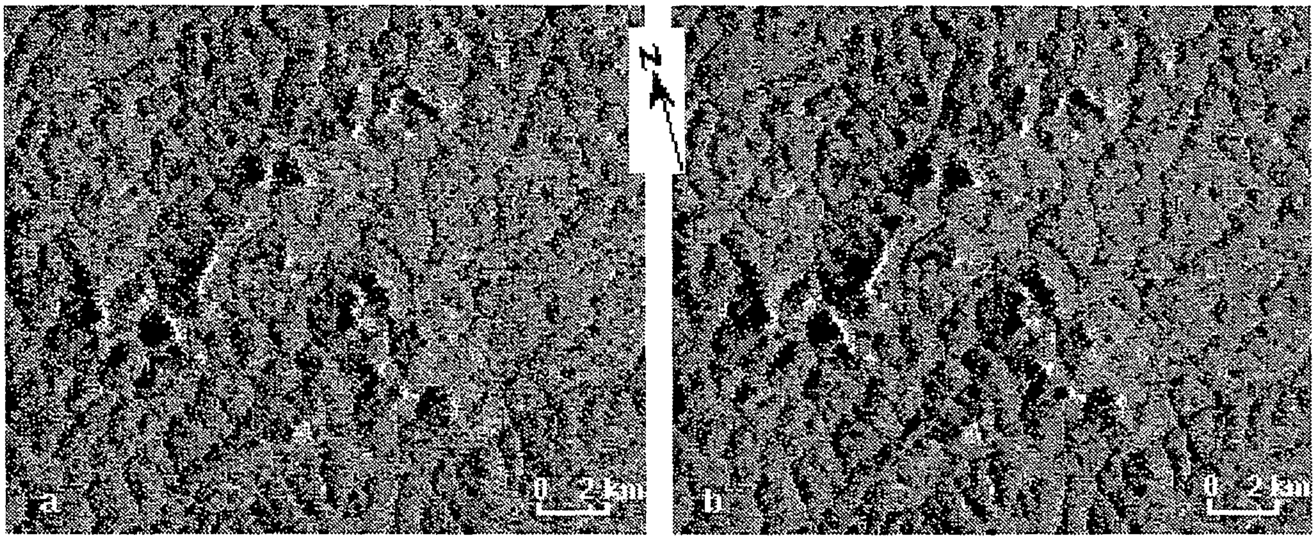

Figure 2. Processing of a subscene of the original image 1 (a) "unspeckled" image , (b) "unspeckled" image smoothed by a Nagao filter.

The three cleaned up directions are then merged. Although the network is pretty well delineated, small entities still remain. To remove these entities a closing of size 1 was applied [Serra, 1982] using an octagonal shape, and then cleaned up again by a geodesic reconstruction with an erosion of size 1. The real width of the channels is then restored by the intersection of the resulting image with the merged image.

2.2 Multifractal analysis

A multifractal formalism was used to calculate the singularity map and the spectra from the original intensity map (Fig. 3). The singularity map is a map of the local Pointwise Hölder exponent obtained by regression analysis based on surfaces of 2190m x 2190 m. The global image singularity spectrum have been computed by the Moment Method (or Legendre Method). As the Legendre Method application is limited by the size of the images, due to the speckle, another $f(\alpha)$-estimator have been used to obtain local singularity spectrum on 100 x 100 pixels sub-images (see [Sailhac & Seyler, 1997] for further details on the calculation method).

3. RESULTS

3.1 Mathematical morphology

The result obtained from Nagao smoothed images is fairly better than that of the simply "unspeckled" image. The resulting image was further processed by testing the opening residuals to enhance the directions, in particular the very thin elements. The residuals or "top hat" forms are processed either by a morphologic opening or by reconstruction if we apply a connected opening [Grimaud, 1991]. In both case the residuals have been cleaned up by a a geodesic reconstruction using a low threshold as a marker. The resulting directions have

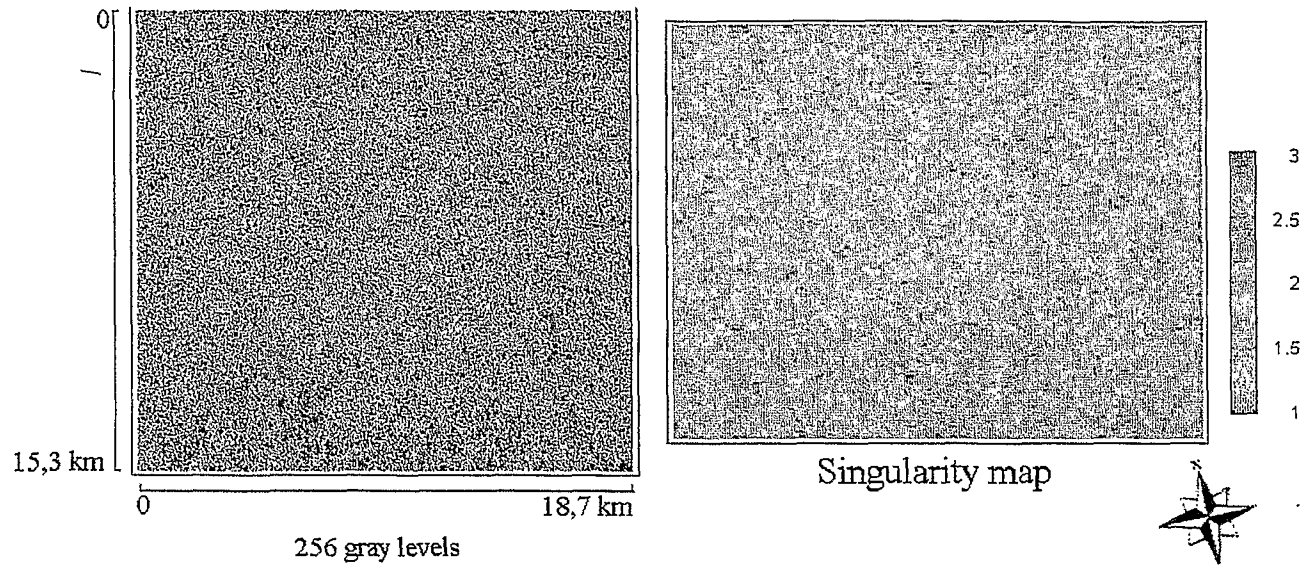

Figure 3. Maps of (a) intensity and (b) singularity of image 2 subscene.

been then merged and processed as above.

The difference between the four processes was quantified by a transformation allowing to compare two binary images - here, the results obtained on two extracts of the studied subscene are compared (Fig. 4). Comparison of two equally looking binary sets A and B implies to makes the symmetric difference between A and B as: $A \Delta B = A \cup B - A \cap B$ [Callot et al., 1994]. The resulting set C is a binary image composed of all pixels discriminating A and B. Then the intersection of this image with A and B permits to quantify the respective contribution of A and B (Fig. 4). Figure 5 shows the structure of drainage network delineated by the above processing.

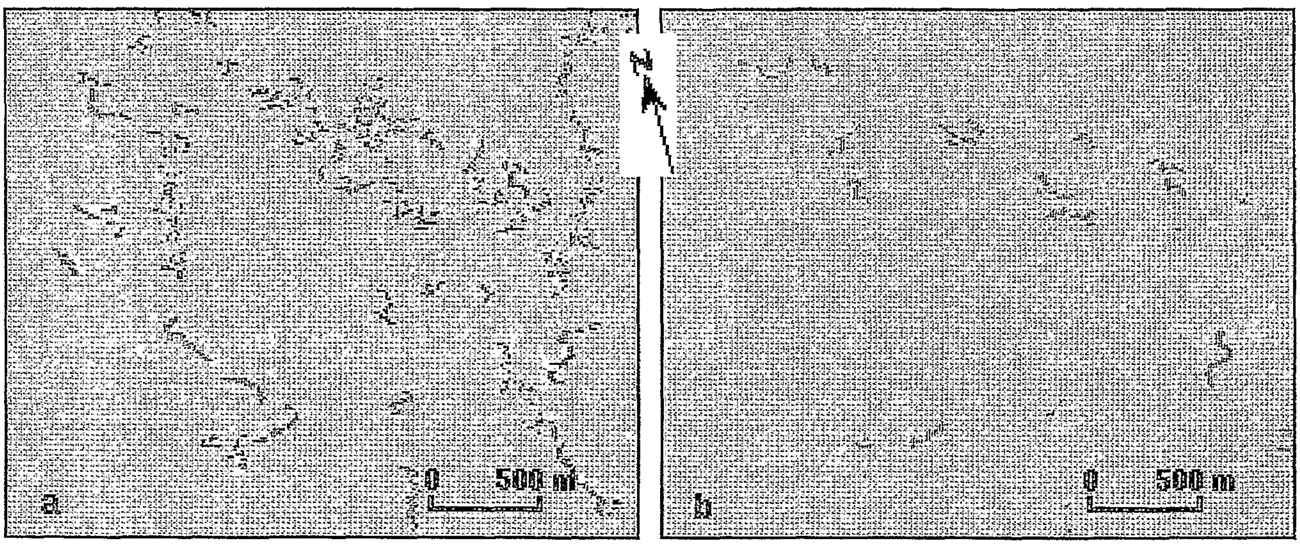

Figure 4. Comparison of results got from two extracts of image 1 subscene between (a) "unspeckled" image (blue) and smoothed image (red), (b) smoothed image (red) and the morphologic 'top-hat' on smoothed image directions (green).

3.2 Multifractal analysis

The singularity map is another representation of the texture perceived on the intensity image (Fig. 3). Unlike other image textures we have analysed, that does not show any orientated structures. A Fourier transform performed on this image also featured this lack of any linear structure, likely due to the half circular shape of the hills that prevail here. The values of the map are increasing with the heterogeneity of the topography, low values about 2 for the large flat area occupied by swamps, and high values ranging from 2.5 to 2.8 for the forested hills whose the slope forms induce systematic changes of orientation with regard to the radar emission angle.

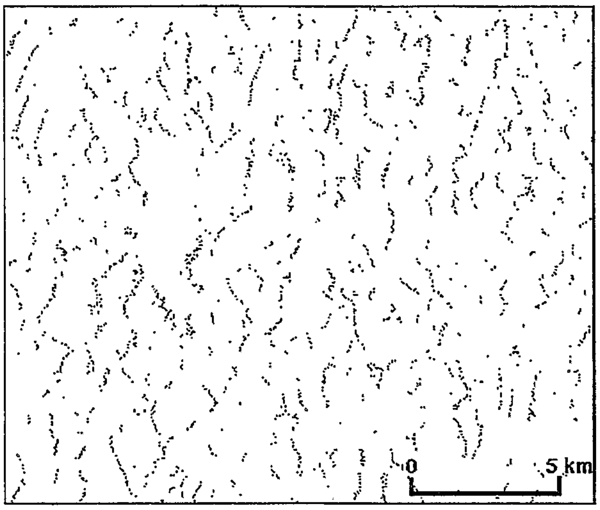

Figure 5. Channel network delineation of image 1 subscene applying mathematical morphology

The comparison of various multifractal spectrum indicates that the spreading of the spectrum to the left is related to the anisotropy of the image (Fig. 6). This part of the spectra thus characterises at best the different textural features prevailing in the studied area.

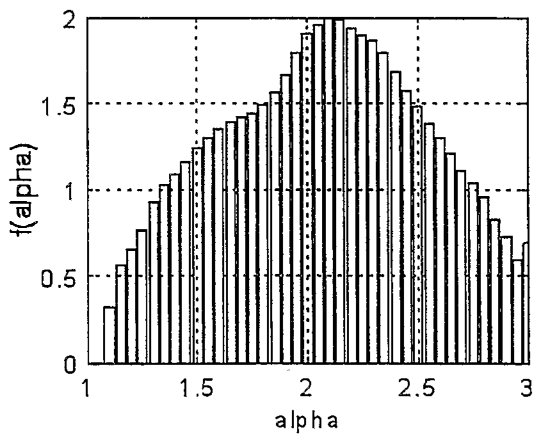

Figure 6. Global singularity spectrum of image 2 subscene.

4. CONCLUSIONS

Mathematical morphology was relatively efficient to delineate drainage network structures, in particular, those oriented perpendicularly to the radar satellite emission - characterised by better incised valleys. This processing will be applied to the whole SAR images - that will allow, we believe, to draw a mosaic of different network structures which will be compared to the other environmental patterns of the forested landscape of South Cameroon. Multifractal analysis was able to discriminate between representative natural textures- the method used to textural characterisation seems promising to ERS1 images segmentation based on the landscape patterns recognition. It may also be of great importance for the measure and the modelling of the landscape evolution and its involved processes. This method will be also tested out to analyse the scaling properties of network structures.

5. REFERENCES

Bitom D, Volkoff B, Beauvais A, & Seyler F 1997, Influence d'une remontée du niveau hydrostatique sur l'évolution des couvertures pédologiques et des modelés en zone intertropicale humide. (submitted to C. R. Acad. Sci., Paris)

Calot Y., Mering C. & Simonin A., 1994, Image analysis and cartography Sand hill massifs on resolution images : application to the Great Western ERG, *International Journal of Remote Sensing*, **15** (18), 3799-3822.

Coster M. & Chermant J.C., 1989, *Précis d'analyse d'images*, (Paris : CNRS).

Grimaud M., 1991, La géodésie numérique en Morphologie Mathématique. Thèse Docteur-Ingénieur, Ecole des Mines de Paris, Fontainebleau.

Mering C. & Parrot J.F.., 1995, Filtering of radar images for geological structural mapping, *SPIE*, 2315, 743-754.

Nagao M & Matsuyama T 1979, Edge preserving smoothing, Computer Graphic and Image Processing, Vol. 9, 391-407.

Sailhac P & Seyler F 1997, Texture characterisation of ERS1 images by regional multifractal analysis: A tool applied to the study of South Cameroon Rain Forest landscape and bio-geo-hydrological processes, to be published in: Fractals in Engineering, June 25-27, 1997, Arcachon, France.

Serra J., 1982, *Image Analysis and mathematical Morphology*, (London : Academic Press).

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Cover image

Multitemporal view of Florence and its surroundings, obtained from three images acquired by ERS-1 and ERS-2 during 1996: Red: *ERS-1 (7 January)* — Green: *ERS-1 (30 June)* — Blue: *ERS-2 (14 October).*

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