AUTOMATIC DETECTION OF NARROW OPEN WATER STREAMS IN AMAZON FORESTS FROM JERS-1 SAR IMAGERY

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Abstract: We extracted narrow open water streams from JERS-1 SAR images of the Amazon rain forest. The extracted range of these streams were almost comparable to a high level extraction of the same streams from near-IR images of JERS-1 VNIR data notwithstanding that these features in SAR images show the strong dependence of the observation angle. Large water bodies are relatively easy to extract from JERS-1 SAR images, as they tend to appear as very dark areas; but streams whose width is nearly equal to or less than the spatial resolution no longer appear as very dark features. By using strong scatterers distributed sparsely along the radar facing sides of the streams, we can successfully estimate approximate ranges of waterways and then extract relatively dark line-like features within these ranges.

Key words: Feature Extraction, Narrow river, Amazon forest, JERS-1 SAR, JERS-1 VNIR, spatial information

INTRODUCTION

Synthetic Aperture Radars (SAR), which, unlike optical sensors, can make observations of the Earth's surface irrespective of sun and cloud cover, play an important role in the environmental monitoring of tropical forests. Backscattering intensity for SAR is determined by a number of parameters, and the direct determination of tree species from SAR data, while possible on a limited scale, is very difficult over a global scale. The most important parameters influencing the growth of vegetation are hours of daylight (temperature), water, soil type, and nutrients. If these parameters can be determined using some combination of other sensor data, it is possible to determine the vegetation type in that region. L-Band SARs, such as the JERS-1 SAR, can be powerful tools for gathering information about water, *e.g.*, the location of open water surfaces such as oceans, lakes, and rivers; and water areas beneath the canopy.

For the present investigation, we extracted very narrow open water streams flowing through the tropical rainforest. Narrow streams compose an extremely small surface area compared to the wide open channels, but their distribution pattern and density are just as important, based on their ability to transport water, soil, and nutrients, in determining a river basin's vegetation type. Large open water surfaces can be extracted from L-Band SAR images such as the ones produced by JERS-1 SAR relatively easily because they appear as areas with a very low backscattering intensity. However, many complications arise when the width of the river narrows to the same size as the resolution size. The rivers can still be detected visually from their shape, but cannot be extracted using the conventional digital techniques of remote sensing that rely solely on backscattering intensity. In this investigation, we extracted such narrow streams using a combination of simple methods that treat spectral and spatial information equally. The same method was applied to an optical sensor image, and the results were compared.

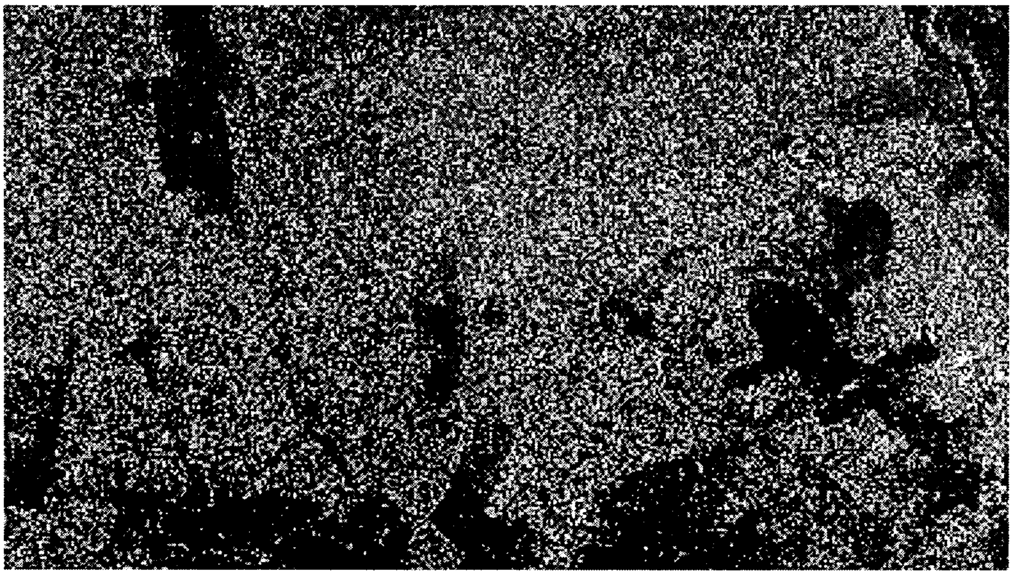


Figure 1. 3-look JERS-1 SAR image of Amazon forest in Rondonia, Brazil observed on August 6, 1994.

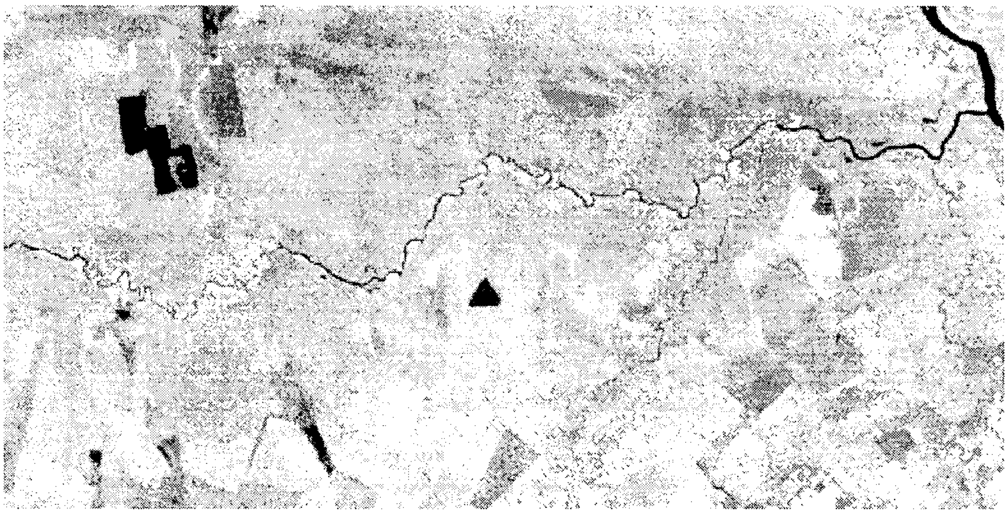


Figure 2. Near IR image from JERS-1 VNIR data of the same region observed on August 13,1994.

DATA

The Rondonia region of Brazil is well-known as a large-scale clear-cut area. In 1994, the JERS-1 made simultaneous observations of this area using SAR and VNIR sensors. In this investigation, we selected a cloud-free optical VNIR image in which thin rivers can be seen flowing through forested areas. This was used to compare extraction results from the SAR image. From a scene located at Path=415, Row=319, we used level 2.1, 3-look SAR data (©MITI/NASDA) observed on August 6, 1994 (Fig. 1) and VNIR data (©MITI/NASDA) observed on August 13, 1994. The VNIR data consists of visible and near-IR data, but for the present investigation, we did not use the visible image, as the image suffered very much from electrical power noise. In the near-IR image (Figure 2), the water appeared as the darkest areas and were relatively easily distinguishable; in addition, there was much less image degradation from electrical power noise.

EXTRACTION FROM NEAR IR IMAGE

A fractal-based linear-feature extraction algorithm, which is effective on TM images (Iisaka, 1998), could not avoid extracting the side-long power noise present in the near IR images. While removal of these extracted stripes was not impossible, they made the use of the algorithm impractical. Algorithms that assume continuity (Sakurai-Amano and Iisaka, 1998) were also not applicable, as the streams in the images were often obscured, albeit over short distances, by the forest canopy, and did not appear as totally continuous lines.

In the present investigation, we extracted narrow streams with small discontinuities using the following algorithm: first, we created a continuous thin region (which we call the "river area mask") by processing the sum of the absolute difference between each pixel and its surrounding pixels. Within this mask, we then extracted dark thin line-like features as narrow rivers. Finally, the extracted areas were combined with the large river areas, to produce a map of all observable open water surfaces as illustrated in Figure 3.

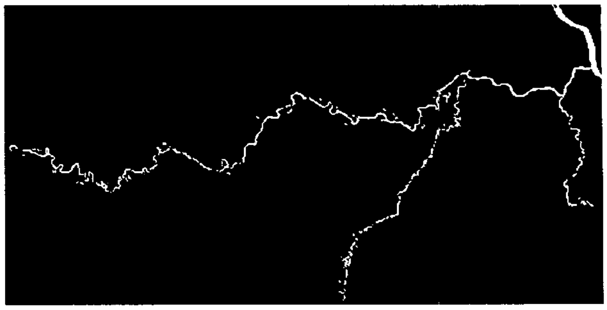


Figure 3. Rivers extracted from JERS-1 VNIR data's near IR image.

EXTRACTION FROM SAR IMAGE

In SAR, emitted microwaves reflect forward and away from the sensor off smooth water surfaces, thus rendering them as dark regions in the image. As the width of the river narrows, other effects are also observed. When the river runs approximately parallel to the view angle, the emitted microwave is still reflected forward by the smooth water surface; the pixel usually appears darker than the surrounding area, but it is also dependent on what other objects are inside the resolution cell. When the river runs approximately perpendicular to the view angle, the microwave reflected off of the water surface gets scattered back to the antenna by the forest on the opposite shore, so it no longer appears as a dark feature, and is often indistinguishable from the backscatter coming from ordinary forest. However, there are cases in which the microwave reflects off the river surface and is backscattered intensely off of the tree trunk on the opposite shore. These strong backscattering signals lining up along the radar-facing shoreline can be used to locate the river.

Preprocessing:

1) In order to enhance the effect of bright points along the shore and the dark water surface, images were composed so that the dark regions consisted of values produced by the Enhanced SFP filter, and all other regions consisted of values produced by the SFP filter

(Sakurai-Amano and Iisaka, 1999).

2) The size of one pixel in the 3-look JERS-1 SAR (12.5m x 12.5m) is smaller than he resolution cell (18m x 18m), so the image was decimated by ½ vertically and horizontally

Extraction of wide rivers: consider the darkest regions as pure bodies of water

1) Binarize near the lowest peak (pixel value of 500) in the histogram, remove pixel-sized blobs and holes under 10 pixels in area, and keep linear features (axis ratio<0.2 or >5) of more than 100 pixels in size.

2) Binarize at the pixel value of 600 and process the image as in 1).

3) Define pure bodies of water as regions in 2) which include 1).

Construction of river mask: We take advantage of the bright points lining up along the river banks, creating a mask by assuming that there are rivers near them.

1) Using the pixel-swapping method (Iisaka, 1998), emphasize bright isolated points by calculating the sum of the absolute difference between the central pixel and surrounding pixels for each pixel in the image.

2) Smooth the image with a low-pass filter.

3) Threshold along the high end of the histogram (=3000) in 1), and remove small blobs.

4) Threshold at a slightly lower value (=2400).

5) Within 4), remove objects that contain 3).

6) Remove isolated objects.

Extraction of dark line-like features:

1) Binarize at pixel values of 500, 600, 700, 800, and 900 .

2) Remove very small blobs and holes, and clean up the image.

3) Extract line-like features from each binarized image using the pixel swapping method.

4) Sum up line-like features over all threshold values . High values correspond to pixels with high local line-likeness.

5) Remove pixels with low value (=1) as noise.

6) Extract linear features that include high line-likeness pixels as narrow rivers.

Extraction of rivers:

1) Of the thin dark features extracted above, extract only those that are within the river mask area.

2) Combine with pure water bodies, and classify as rivers .

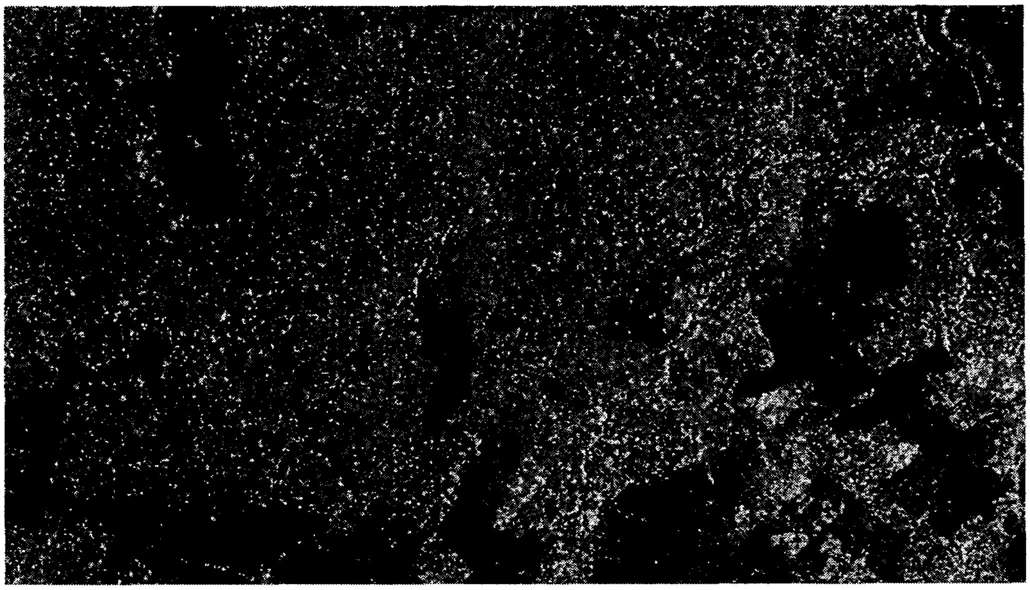
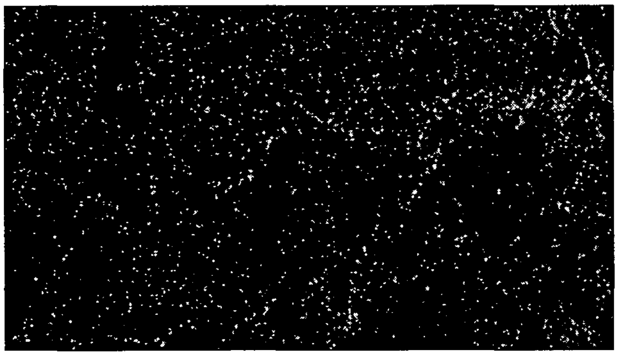


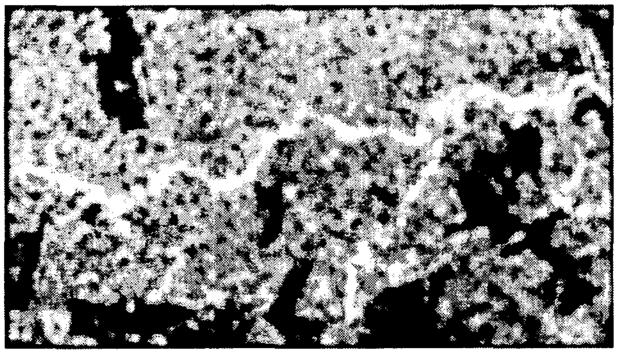
figure 4. The Filtered image of JERS-1 SAR. (see text for detail)

RESULTS AND DISCUSSION

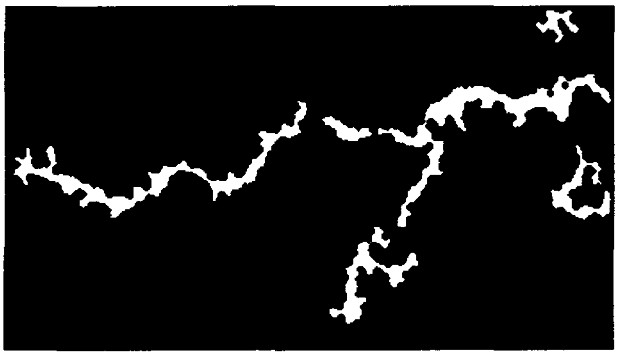
Figure 4 shows the input filtered image obtained by combining the results of the SFP filter and the Enhanced SFP filter. Figure 5 shows a few results from the creation of river area mask.



(a) Sum of absolute difference of each pixel and the surrounding pixels.



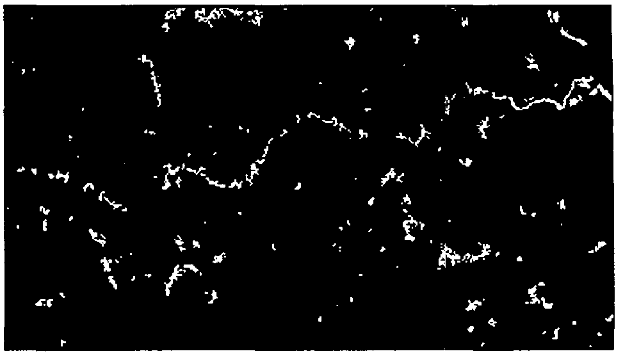
(b) After applying low-pass filter.



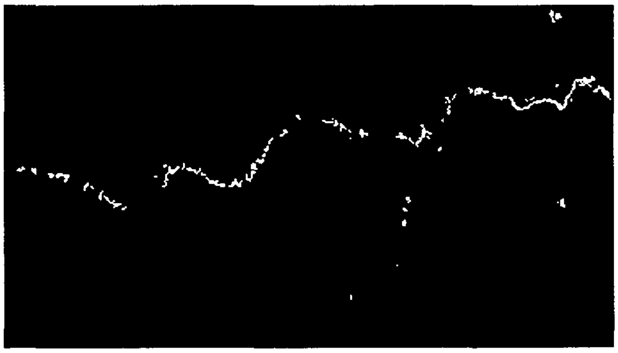
(c) Extracted approximate river area.

Figure 5. Creating a river mask.

Figure 6 shows a few images of extraction of dark line-like features. Figure 7 shows the final result by combining dark line-like features with wider river portion.



(a) distinct line-like features



(b) after applying the river mask.

Figure 6. Extracting dark line-like features.

A comparison of the extraction results from the near-IR image (see Figure 3) and the SAR image (see Figure 7) shows a very good match of the flow range of streams despite the fact that in the JERS-1 SAR image, streams running perpendicular to the observation angle are not observed as dark objects in the first place, and their existence is only suggested by the sparsely distributed bright reflections from the radar facing shoreline. Man-made objects such as roads and clear-cut areas, which also appear dark, caused some confusion at the nearly vertical branch in the lower center of Figure 7. Confusions, such as this, that are caused by man-made objects can be corrected by the use of other information such as optical images or maps. We intend on further applying this method to remote tropical forest areas; however, we have not been able to find any cloud-free images of such areas. All cloud-free images were found to be near human civilization and over clear-cut areas.

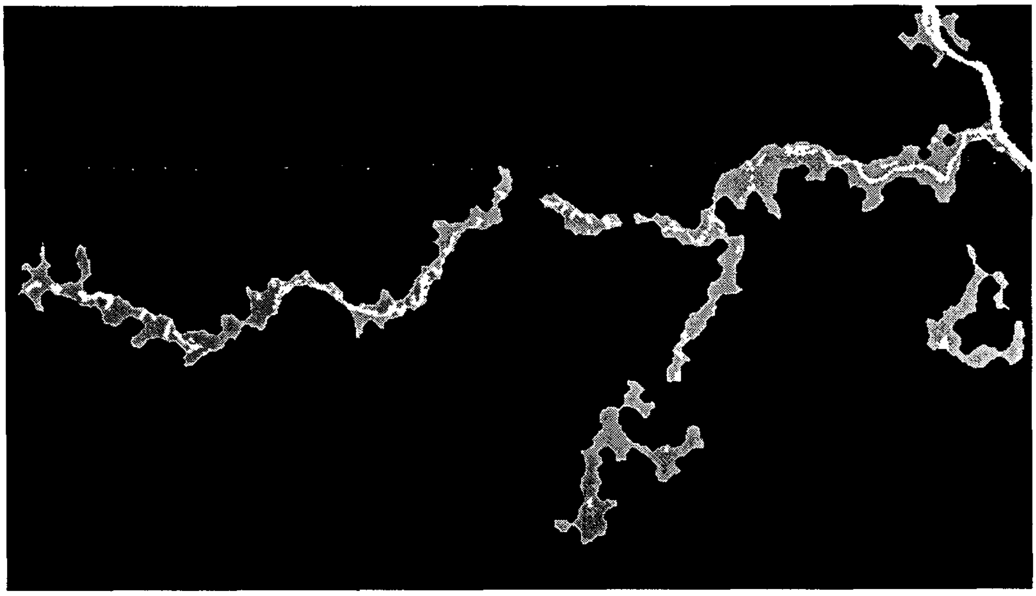


Figure 7. Final result from the JERS-1 SAR image.
Grey area: approximate river area. White area: open water area.

CONCLUSION

We were able to extract barely visible narrow open water streams from a JERS-1 SAR image. The entire flow range estimated using bright targets distributed along the radar facing shore was almost comparable to a high-level detection of the same rivers from a near-IR image. The portion of streams along the radar observation direction were extracted using line-like features darker than surrounding forest within an estimated river flow range. We consider this method as a very effective tool to assist investigating the tropical rainforest ecosystem, which is often covered by clouds and inaccessible by optical sensors.

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