# WFI/CBERS imagery simulation for understanding water pathways from Amazon River to the floodplain

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## ABSTRACT

This paper describes an experiment performed to simulate WFI/Camera spatial features using a TM-Landsat digital mosaic re-sampled to 258 m x 258 m, 100 m x 100 m resolution. The re-sampled mosaic and selected sub-scenes from the original TM data were submitted to digital processing in order to map different water types found in the Amazon River floodplain. The mosaics were classified and classification results for selected reaches were compared. The results support that in spite of the degraded spatial resolution WFI images offer a good deal of useful information on water types.

## INTRODUCTION

The fundamental problem in understanding the spatial and temporal distribution of water types in large floodplains is its non-uniformity in space and time. In a river basin such as the Amazon River, this problem is even bigger. Amazonian rivers and lakes vary seasonally in water quality and sediment load as a function of the geochemistry and hydrology of their catchment basins (Junk and Furch, 1985). The discharges of Amazon River tributaries are variable and out of phase with the main stem (Richey et al., 1986). Moreover, in rivers such as Rio Negro (a Black Water river) and Madeira (a White Water river) the discharge can vary for about a factor of 10 from the low to the high water season. This large annual amplitude in the Amazon River and its tributaries results in a variable pattern of periodic flooding of Amazonian lowlands. The nature and origin of the water in the floodplain is also dependent on other sources such as direct precipitation and water from local tributaries. The proportion of those different water types, however, is not known because of the variable transfer of water, sediment and materials from rivers to floodplains and from floodplains to rivers. In spite of the huge research efforts for collecting ground information (Fisher and Parsley, 1986, Richey et al., 1986), there is still a need for better understanding of those exchanges.

Remote sensing data have been used to study the river dynamics and the biological diversity of the lowland forests (Salo et al., 1986) , suspended sediments in surface water (Mertes et al., 1993), and the zones influenced by river water (Mertes et al., 1995) in the Amazon River basin. The various water types have distinctive spectral reflectance making it possible to distinguish among them and even to quantify their optically active components (Kirk, 1994). The synoptic view provided by satellite images make them an useful tool for monitoring the influx and dispersion of river water into the floodplain lakes. In spite of the potential of optical remote sensing data for monitoring water quality variables, cloud cover limits the effective use of the technology (Clark, 1983). It took a 10-year period to assemble 29 almost cloud-free TM-Landsat images to build the Amazon River floodplain mosaic (Shimabukuro et al., 1998). The majority of cloud-free images, however, were restricted to the high-water season, preventing the assessment of seasonal changes in the distribution of water types in the floodplain. Limnological and hydrological studies require a much more frequent imaging than the rate provided by present land research satellites such as Landsat and SPOT.

On October 14, 1999 the China-Brazil Earth Resources Satellite (CBERS) was successfully launched carrying on board a wide field of view imager (WFI). WFI (table 1) is a CCD pushbroom camera operating in two bands with the potential of acquiring low resolution but wide swath (890 km) images in about every five days. The satellite orbital pattern provided by CBERS allows for a complete coverage of the Amazonia in less than a week and increases the possibility of acquiring data without major natural changes in water type distribution. The high imaging frequency also increases the probability of acquiring cloud-free images. This high frequency of data acquisition makes this camera potentially useful for studying the spatial distribution of water in the Amazon River basin floodplains.

The main disadvantage of the WFI/CBERS camera as compared to other remote sensing systems currently in use for water quality assessment is the reduced number of wavelengths (2 bands) and the spatial resolution (258 m by 258 m at nadir). The reduced number of wavebands theoretically is not a major problem if the interest is to map the three major water types found in the Amazon region. The literature shows that those water types differ significantly in the total suspended solids. White water have extremely high total suspended solids whereas black water have extremely low and clear water have intermediate values (Junk and Furch, 1985; Richey et al., 1986). Several authors reported high correlation between red and near-infrared reflectance and total suspended solids at concentrations larger than 10 mg/l (Lathrop and Lillesand, 1989, Novo et al., 1991).

The spatial resolution, therefore, seems to be the most restrictive feature of the WFI/CBERS camera and must be investigated before WFI data can be recognized as a new tool for monitoring water types in the Amazon basin floodplain.

| Center Wavelength | 654 nm | 834 nm |
|---|---|---|
| Bandwidth at 0.5 peak transmittance | 62 nm | 126 nm |
| Band width | 630 to.690 nm | 770 to 890 nm |
| Swath coverage | 890 km | 890 km |
| Radiometric Range | Min = 0.01 $W/m^2$.sr<br>Max=9.5 $W/m^2$.sr | Min = 0.02 $W/m^2$.sr<br>Max = 15.1 $W/m^2$.sr |
| Radiometric Levels | 256 levels | 256 levels |
| Spatial Resolution | 258 m x 258 m | 258 m x 258 m |
| Frequency of acquisition | 5 days | 5 days |

Table 1 – WFI/CBERS camera features (Source: http://www.inpe.br/programas/cbers/portugues/index.html)

The present study was proposed to assess the potential of the WFI camera to gather information about the spatial distribution of water types in the Amazon River Floodplain. In this study, 29 TM-Landsat images assembled into a digital mosaic (Shimabukuro et al., 1998) were used to simulate the spatial and spectral features provided by the WFI camera.


## METHODS

A full description of the methodology used to build the mosaic is found in Shimabukuro et al. (1998). The first step in this simulation was to resample band 3 (red) and 4 (near infrared) of the TM-Landsat digital mosaic to 100 m by 100 m and to 258 m to 258 m spatial resolution mosaics. The resampling was performed using a nearest neighbor algorithm to reduce radiometric degradation of the original 30 m by 30 m resolution TM data (Richards, 1995). The rational for producing a 100 m by 100 m mosaic is the possibility of resampling WFI images to that resolution using data fusion procedures and image restoration techniques (Richards, 1995).

In spite of the radiometric rectification developed by Shimabukuro et al. (1998), several mosaic scenes of band TM 3 were heavily affected by cloud cover. To overcome this problem, band TM 4 was used to generate a water body mask. This mask was then used to exclude the land (mostly covered by clouds and cloud shadows in band 3). The masked bands (TM 3 and TM 4) were then added and linearly scaled to 256 digital counts to produce a single band sensitive to changes in particle concentration (Novo et al., 1991). At both resolutions, the minimum and maximum number of classes was set as 5 and 10, respectively. The resulting spectral classes were examined and combined according to the range of digital levels of known water body types such as Rio Negro (Black Water Type), Tapajós (Clear Water Type), and Solimöes (White Water Type).

The proportion of water types was determined at selected Amazon River reaches. Changes in the proportion of the various water types were then graphically compared to examine the effect of spatial resolution on the water type mapping.


## RESULTS

Figure 1 represents the color composite of simulated WFI red and near infrared bands as follows: Red Band (Red and Blue), Infrared Band (Green). In spite of the coarse resolution, the simulated WFI composite allows the identification of two major water types in this reach. White Water, seen as magenta, is responsible for the strong reflected radiance in

both red and near infrared region. Black Water, seen as black, is responsible for strong absorption of red and infrared radiation due to the small concentration of suspended particles and high concentration of dissolved organic matter (Kirk, 1993; Mobley, 1994). In the floodplain lake, one can see a patch of white water indicating the advection of river water into the lake as reported by Fisher and Parsley (1979).

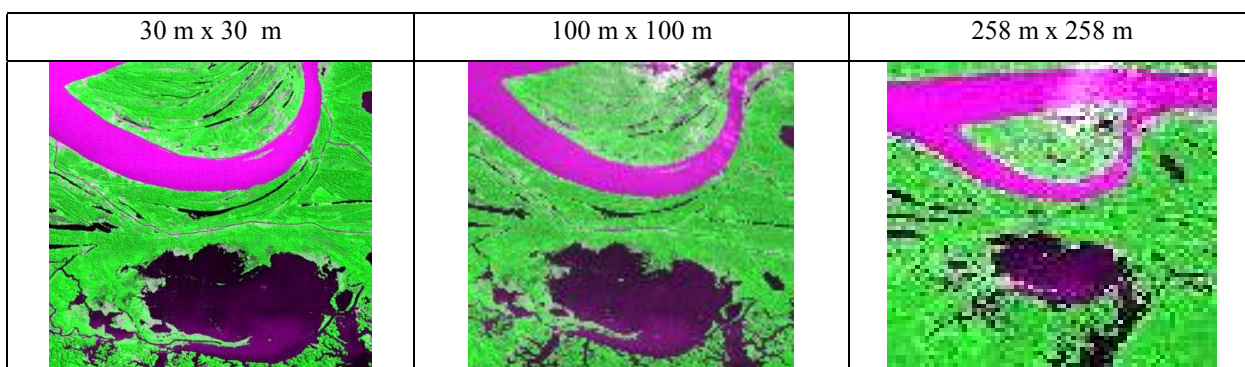| 30 m x 30 m | 100 m x 100 m | 258 m x 258 m |
| --- | --- | --- |



Figure 1 – Effect of the spatial resolution on the identification of water types.

It is interesting to observe that the reduced spatial resolution prevents the detection of the smaller channels (paranas) flowing between the Amazon River and the floodplain lakes, but does not prevent the detection of river water in the lake. The results also suggest that the 100 m x 100 m resolution data preserve most of the information found in the 30 m x 30 m resolution image. Therefore, improving the spatial resolution up to 100 m by applying image restoration algorithms can improve the application of WFI/CBERS camera for floodplain water type monitoring.

Figure 2 shows the classification of water types derived from the simulated WFI image. Reaches selected for comparison with the 100 m by 100 m resolution image are specified on the figure.
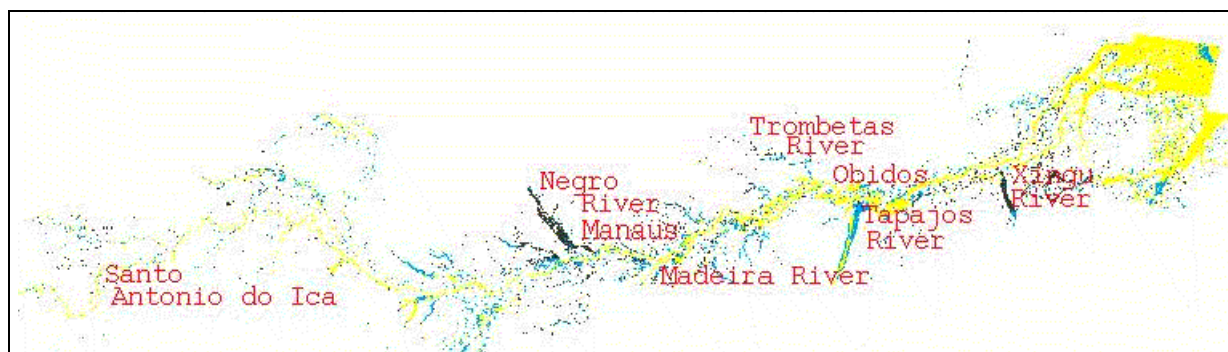


Figure 2 – Water Type Classification (Yellow – White Water; Cyan – Clear Water; Dark Grey – Black Water)

Figure 3 presents the classification results for 100 m and 258 m resolution images at Santo Antônio do Icá, in the upper Amazon River basin. In this reach, both the main stem and tributaries are narrower. The average width of the main channel near this reach was reported as 2000 m (Mertes, 1985). The secondary channel width is quite variable ranging from tenths of meters to hundreds of meters. Some of them can not even be detected at 30 meters resolution because of they run beneath a dense forest cover. The classification results at this reach are not affected by scaling up the resolution from 100 m to 258 m.

Figure 4 presents the classification results at a reach at Madeira River. It is clear that at the reach some information is lost when scaling to 258 m resolution. This reach has a very complex geomorphology with a mixture of narrow channels, scroll bars, levees organized at fine spatial scale. Some white water channels resolved at 100 m resolution are lost at 258 m resolution. Figure 5 shows the classification results for the reach at Trombetas River.

The effect of the resolution on the discrimination and mapping of water types can be better assessed by looking at Table 2. Three trends are observed in Table 2: 1) Reaches where the spatial resolution does not affect the amount of pixels classified as water (Santo Antônio do Içá, Manaus, and Madeira); 2) Reaches where the increase in spatial resolution from 100 m to 258 m results in an overestimation of the amount of pixels classified as water; 3) Reaches where the

increase in spatial resolution from 100 m to 258  m results in an underestimation of the amount of pixels classified as water.
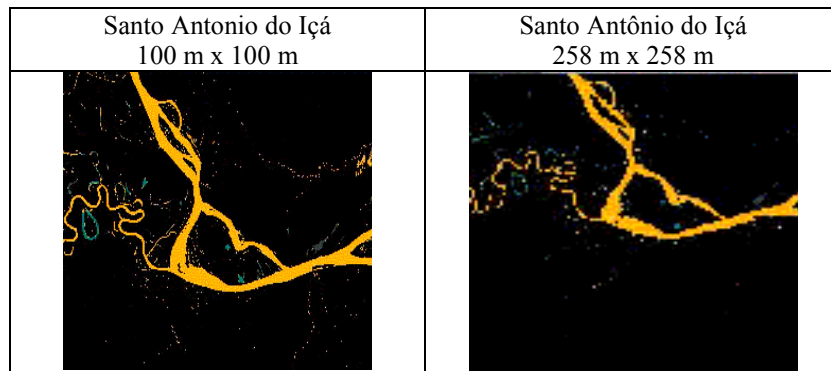
| Santo Antonio do Içá<br>100 m x 100 m | Santo Antônio do Içá<br>258 m x 258 m |
| --- | --- |
| | |

Figure 3 - Water types classification (yellow – white water; dark blue – clear water – black – forest and floodplain forest).

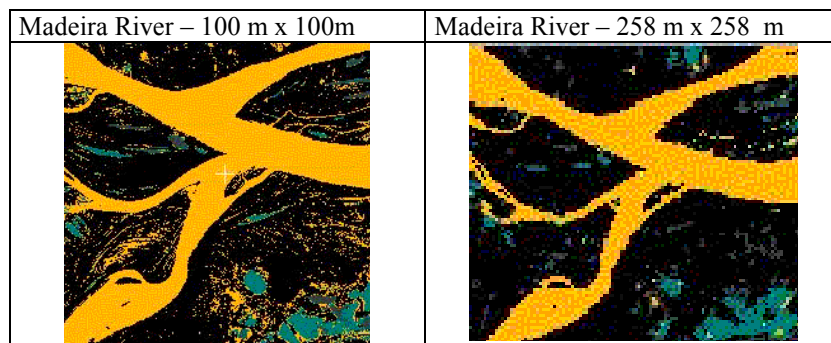| Madeira River – 100 m x 100m | Madeira River – 258 m x 258  m |
| --- | --- |
| | |

Figure 4 - Water type classification (yellow – white water, dark blue – clear water; dark gray – black water; black – forest and floodplain forest).

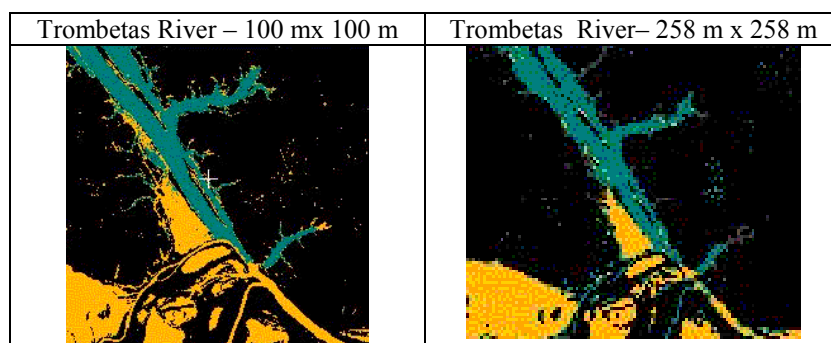| Trombetas River – 100 mx 100 m | Trombetas  River– 258 m x 258 m |
| --- | --- |
| | |

Figure 5 – Water type classification (yellow – white water, dark blue – clear water ; dark gray – black water; black – forest and floodplain forest)

Table 2 – Proportion of Pixels classified in the different water type classes.

| Selected River Sections | Background (%) | | Black Water (%) | | Clear Water (%) | | White Water (%) | |
|---|---|---|---|---|---|---|---|---|
| | 100 m | 258 m | 100 m | 258 m | 100 m | 258 m | 100 m | 258 m |
| Santo Antônio do Icá | 86.88 | 85.47 | - | - | 0.42 | 0.35 | 12.70 | 14.18 |
| Mamiá | 66.64 | 54.21 | - | 4.79 | 11.67 | 12.00 | 21.69 | 29.00 |
| Manaus | 44.10 | 43.43 | 13.99 | 15.59 | 2.38 | 7.64 | 39.53 | 33.34 |
| Madeira | 51.58 | 50.39 | 6.79 | 6.20 | 2.77 | 4.66 | 39.45 | 38.16 |
| Trombetas | 67.42 | 47.93 | - | 10.53 | 9.17 | 14.63 | 23.41 | 26.91 |
| Tapajós | 28.68 | 32.13 | 2.25 | 4.80 | 35.23 | 30.45 | 33.84 | 32.60 |
| Xingu | 43.51 | 47.7 | 15.91 | 17.50 | 15.33 | 17.50 | 25.24 | 21.85 |

Reaches dominated by larger rivers of white water were not deeply affected by changes in resolution. Those are the cases of Santo Antônio do Iça, where classification results differ at about 15 %. At the Manaus reach, the change in resolution affected the discrimination between clear water and white water pixels. White water pixels were classified as clear water probably as an artifact from the adopted resampling scheme.

Results in Table 2 show that in most of the reaches the White Water pixels are coherently classified at both spatial resolutions. They differ in less than 10% except for Mamiá reach where there is a 25% difference between the resolutions.

Based on the preliminary results one can support the use of WFI/CBERS images for mapping water types at the Amazon River basin. The accuracy of the results must be better assessed because they will vary according to the complexity of the reaches under study.

CONCLUSIONS

The experiment allows to conclude that the 258 m spatial resolution of the WFI/CBERS data is not a strong limitation to map the water pathways from the river to the floodplain. Although the resolution affects the discrimination between the three water types at certain reaches, they do not affect the mapping of White Water, allowing the detection of water path from the white water rivers to the floodplain.

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