Abstract

There is a lack of information on the seasonal dynamics of floodplain habitats in the Amazon regions of Brazil. This lack of information is due to the large size of the Amazon, persistent cloud cover and difficult access to do field campaigns. Radar data from RADARSAT will provide multitemporal data over these cloudy tropical regions which will result in increased information. As part of the ADRO program, this research investigates the preliminary results of assessing the synergism of multitemporal and multifrequency radar data for the Amazon. This assessment will allow for the understanding of seasonal floodplain dynamics in tropical environments.

RADARSAT and JERS-1 images were acquired throughout 1996 for the Lago Grande test site in Brazil. Three periods of the hydrological cycles were imaged, these being high water, receding flood water and low water stages. The present evaluation is the preliminary results of the two first stages. Images for these stages were calibrated, orthorectified and filtered allowing for the integration of multitemporal and multifrequency data.

These results show that the synergism of multitemporal and multifrequency (C and L-band) data provides the best combination of microwave information to discriminate among the floodplain habitats. C-band data is more sensitive to aquatic plants whereas L-band data is more effective in distinguishing between flooded forest, non-flooded forest, pasture, and aquatic plants. The combination of the two wavelengths increased the spectral separability of different classes, and allowed for monitoring of the seasonal floodplain dynamics.

1. Introduction

The amazon floodplain extends from the Andes to the Atlantic ocean and has an average width of 20 to 100 Km. It is also one of the wettest regions in the world and has an annual water stand fluctuation of 10 m (Junk, 1980). This fluctuation causes water penetration up to 20 Km into the forest on either bank for an average of four to seven months each year. Floodplain settlement, farming, ranching, fisheries and logging have had major effects on the environmental changes.

The Amazon floodplain is formed by different habitats such as: flooded-forest, aquatic-plants, river channels, lakes, levees, islands. The size, shape and water chemistry of the floodplain lakes along the Amazon river vary seasonally and annually depending on the water cycle. The dynamic of the hydrological cycle facilitates the sediment erosion and deposition in some areas, promoting the formation of new beaches and islands.
The flooded-forest is important as a feeding and refuge area for a large variety of fishes. The fishes feeds on fruits and seeds that fall out of the flooded trees. The deforestation of the flooded forest areas for creating pasture for cattle and buffalo ranching has increased and provoked various environmental problems. Floating aquatic plants colonize large deforested areas, decreasing the fruits and seeds available for fishes. The aquatic plants areas are important refuge for fishes and one of the major nutrient contributors to the Amazon waters. However, cattle and buffalo grazing in this vegetation area destroy this habitat (Goulding and Smith, 1996).

The floodplain, however, is not only important on the regional scale, it also plays an important role in the process that affect both local and global climate. The floodplain areas are considered important source and/or sinks of methane to the atmosphere, contributing with approximately 20 to 25% of the total natural emissions to the atmosphere. The methane fluxes of the Amazon basin (floodplain areas, floating aquatic plants, flooded forest and open water) appear to be relatively high when compared with other wetlands emission rates (Bartellet and Harris, 1993). Therefore, it is obvious that a depth understanding of the seasonal dynamic of the different floodplain habitats is important, for both local and global studies.

Melack and Fisher (1989) showed a review with the calculated area (maximum water level) for some floodplain area of the Amazon Basin, but a precise measure does not exist. Estimate and monitoring the Amazon floodplain seasonal cycle, however, is not an easy task. First, because of the huge dimensions of the Amazon and also the difficulty of direct access for conventional data collection. Remote sensing techniques maybe a method to overcome this problems. Since 1973 Landsat data has been used to study deforestation, forest, reservoir, and geological aspects in the Amazon. The cloud cover, however, prevents the use of optical systems for seasonal studies in the Amazon. Radar data, such as provided by Radarsat and Jers-1 satellites may become a key source of information for the seasonal Amazon studies due to its all weather functionality. Previous works have indicated that SAR data is very useful to study flooded areas in the Amazon such as reservoirs (Novo et al., 1993; Costa et al., 1996; Noernberg, 1996; Novo and Costa, 1996) and floodplain (Hess et al., 1995). The first authors reported interesting results of aquatic plants separability using airborne SAR-C band, multipolarization and multi-incidence angle data. Also, the interaction of the vegetation elements with the water surface can produce a double-bounce or a scattering volume effect. Hess et al., (1995), discussed the classification of a test site in the Amazon floodplain using SAR C and L band, multipolarization data. The authors shown very good classification accuracy for classifying distinct habitats of the Amazon floodplain.

The present evaluation is the preliminary results of the ADRO project. Flood monitoring and Floodplain Management. This report shows some comments of how Radarsat and Jers-1 data would be important to understand and mapping the Amazon floodplain seasonal dynamics.

2. Study site and data set.

The study area is part of sedimentary basin formed during the tertiary, and the rivers/floodplain system was established during the Pleistocene epoch. The area (Fig. 1) is located in Monte Alegre lake (2°10'S/54°20'W) in the northeast of the Brazilian Amazon. The Lake has approximately 70 Km of length, depending on the flooded stage of the Amazon and Tapajós rivers. The lake is connected to the Amazon river through narrow channels and to the Maicuri river. The high water level of the lake happens with the maximum water level from Tapajós, Maicuri and Amazon rivers (April and May), promoting an yearly water level variation around 5-7 meters. These three rivers have different aspects in terms of water color and chemistry composition. The Amazon river is a “white water” river with high concentration of suspended clay. The Tapajós river is as “clear water” river with low concentration of suspended solids. The Maicuri is a “black water” river with high concentration of humic acids (Sálatti et al., 1983).
The region is geomorphologically characterized by a seasonal flooded plain, a permanent flooded area and higher land area with intensive anthropic use as pasture and small agriculture fields (Fig. 2) and a forest area. The seasonal flooded area is intensively used for cattle and buffalo grazing. The flooded area also includes a wide variety of aquatic plants and inundated trees (Fig.3). Among the aquatic vegetation (Fig. 4) we can exemplify *Paspalum repens* (premenbeca), *Oryza* spp. (arroz selvagem), *Montrichardia arborescens* (aninga) (Fig. 5). The average high of the aquatic plants (blade-like leaves) in the area is 1 meter and the wet biomass 4591 gm\(^2\) (Novo et al., 1997). The average high of aninga forest (aningal) is 5 m. The inundated forest is colonized by several different species of trees such as *Astrycaryum jauari* (jauari) and *Pseudobombax munguba* (munguba). The last one loses the leaves in the high water season (May). The forest region (northwest of the data) is not a typical Amazon rainforest. It is characterized by a not so dense trees population (savanna) and a soil covered by grimeina or baresoil.
In the Lago Grande area, as in many areas of Amazon with rural populations, forestland is gradually being converted into pasture for herbivores, particularly cattle and buffalo. This deforestation has a number of adverse consequences, mostly notable increased siltation and nutrient enrichment of the lake water. Additionally, the fruits of some tree species are an important source of nutrition for certain valuable fishes. Deforestation of the flooded forest, which removes important fruit- and nut-bearing trees, is an addition cause for concern.

Table 1 summarizes the date acquisition of the satellite data. A better description of the data set can be find in Costa et al., 1997. The water level data (Fig. 6) was obtained from the Brazilian navy gauge in the Tapajós river near to Santarém. The higher and lower water levels are reported as being on May and November, respectively.

<table>
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<th>IgJM</th>
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3. Discussion and conclusion

The Japanese radar satellite JERS-1 acquire data at L-band, HH polarization, in mid-morning with an incidence angle of 35°. The Radarsat images (C-band, HH polarization) were acquired during a descending pass. Since the time of overpass corresponds closely to sunrise at this equatorial location, we expect the air to be saturated and the ground surface to be quite moist. However, this is a superficial effect, and the radar backscatter will still respond primarily to the bulk moisture content of the vegetation and soil. L-band penetrates in the low grass-like vegetation (pasture and aquatic plants), and a large fraction of the radiation reflects off the soil or water surface away from the receiver. The result is a low backscattering signal from pasture and aquatic plants. The radiation is multiply scattered in the forest canopy, with a significant fraction being reflected back to the receiver, resulting in a good contrast between pasture and forest. In the Lago Grande area, the wet season begins in April, and it is expected that the conditions would be drier for the images acquired in June and August than for the May images. Both Jers-1 images show clearly the pasture areas. However, the May image has lower contrast between the forestland and the pastureland. For Radarsat images the contrast between forest and pasture is lower than for Jers-1. This is to be expected, because the shorter C-band wavelength will experience more backscatter from soil irregularities and low vegetation than the L-band, resulting in a low contrast between forest and pasture areas. Again, the pastureland was better distinguished from the forest in the image acquired in the drier period (August). Most of the differences between the two May images, taken only three days apart, are a result of the difference incidence angle. Many of the pastures are undetected on the S1 image, but slightly visible on the S6 image, due to the lower backscattering of the pasture areas. With all other variables held constant, a slightly rough surface, like the pastures at C-band, will appear smoother, and thus backscatter less energy, as the incidence angle increases (Ulaby, et al., 1986). The other difference between the Radarsat images acquired on May is the higher backscattering of S1 mode (20-27° of incidence angle) of flooded areas when compared with the S6 mode (41-46° of incidence angle) images. However, the aquatic plant backscattering is a bit higher when compared with that of the flooded-forest backscattering, allowing the discrimination between these two targets. The higher aquatic-plant backscattering is a result of the steeper incidence angle and C-band penetration into the vegetation stand, resulting in a double-bounce effect. Jers-1 steep incidence angle and L-band acquisition
promotes a high flooded forest and low aquatic plant backscattering. Previous papers have already indicated that standing water beneath a canopy strongly reinforces backscatter at L-band with HH polarization (Richards et al., 1982; Hess et al., 1990). The low aquatic plants backscattering is due to the interaction of the L-band wavelength with this vegetation, which means that the aquatic plant roughness is the very low at this wavelength.

Color composites of multitemporal Radarsat and Jers-1 images are shown in Fig. 7 and 8. Figure 7 is a Radarsat multitemporal composite; the data acquired at 27.05.96 is shown as red, 30.05.96 as green, and 07.06.96 as blue. The water level (Table 1) decreased about 1 meter for the image acquired on August. The same water level difference was observed on the tree trunks water marks in flooded forest. This water level variation is probably not enough to show strong differences among the images, except for the aquatic plants communities displacement. The yellow color in the composite represents presence of aquatic plants only in May (higher water). It means that during the failing water the aquatic plants were displaced to the Amazon river or died in the local. The permanent vegetated flooded areas during May and August show a white color, due to the strong double-bounce return caused by the interaction of vegetation and standing water beneath the vegetation (flooded-forest and aquatic plants). Pastures are not so easy to distinguish in the composite.

The Radarsat and Jers-1 composite (Fig. 8) shows a much better result due to the complementary of wavelengths and incidence angles information. The red channel is a Radarsat S6 data 07.08.96, green is Jers-1 16.05.96, and blue is Jers-1 29.06.96. The white or pale blue areas represent flooded-forest, which means a high backscattering return at the three bands, mainly the Jers-1. The aninga (aquatic plant) forest (Fig. 4) is misinterpreted as flooded forest because of its canopy structure. The reddish color is a result of the high Radarsat and low Jers-1 sign of aquatic plants. The pure green color represents floating aquatic plants present in May (Jers-1) but not in June and August. The pasture areas are easily identified due to the better separability of pasture and forest with L-band.

It appears from this preliminary investigation, that both L-band and C-band Satellite SAR data can be used to detect and map the seasonal variation of the Amazon floodplain. The L-band wavelength provides greater contrast among the habitats. However, Radarsat C-band is a complementary data that offers wider swath images and a programmable data acquisition, which may be an advantage in some cases. When the SAR data are to be used, the greatest contrast between forest and pasture can be achieved with images obtained during the driest expected conditions. When C-band are to be used, the greatest contrast between flooded forest and aquatic plants can be provided by steep incidence angle. However, it seems necessary more investigation to understand the wide variety of acquisition modes provided by Radarsat.
Fig. 7. Radarsat color composite: 27.05.96 (red); 30.05.96 (green); 07.06.96 (blue).
Fig. 8. Color composite: Radarsat S6.07.08.96 (red); Jers-1,16.08.96 (green); Jers-1,16.05.96 (blue).

RADARSAT for Amazonia: papers presented at GER'97 Conference
References


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