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ALOS PALSAR to Complement an Operational Amazonian Deforestation Monitoring Systems

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Abstract. Deforestation monitoring for the Brazilian Amazon has been carried on by INPE since 1988, under the PRODES program, and recently, the DETER, both have been used by IBAMA for operational purposes and law enforcement. However, optical sensors are limited by the presence of clouds. The ALOS was launched in 2006, and its data became available to IBAMA thought the JAXA's ALOS Kyoto and Carbon Initiative project. The study site is an area of forest facing a growing pressure of deforestation. The first approach was developed with ScanSAR strip mode image was geo-rectified and DN image values were converted to the normalized radar cross section (σ^o), in dB, with a calibration factor of -83 dB. In the second approach we have also used five Fine Bean Single Mode Strips Slant Range data for visual interpretation and 738 were identified and it represents 15% of *posteriori* deforestation detections of DETER. The mean σ value for recent deforested area was -5.315dB and the mean so value for preserved native forest was – 7.569dB. From five fine bean strips The executed methodology, using a threshold to classify new deforested areas, has a good potential to be the base of a semiautomatic detection system for operational purposes, using ScanSAR images. The third approach was developed using a temporal RGB composition to identify possible changes in the detained areas object of a fine. This system has potential to produce data that could complement the information already available from well established optical sensor satellites monitoring systems of Brazil.

Key-words: Deforestation monitoring, SAR, Radar, ALOS PALSAR, Amazon, Monitoramento do desmatamento, Amazônia.

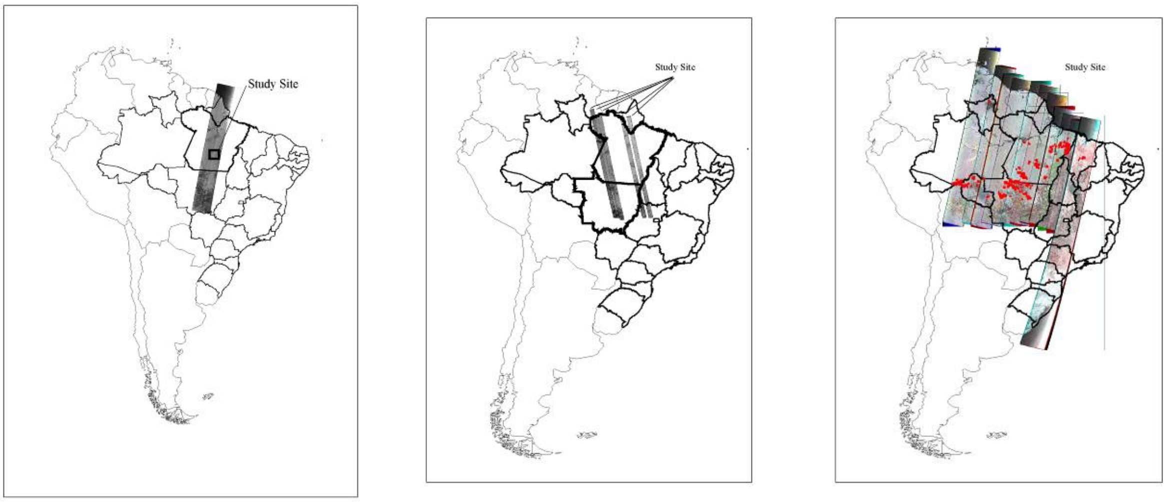
1. Introduction

Deforestation monitoring for the Brazilian Amazon has been carried on annually by INPE (National Institute for Space Research) since 1988, under the PRODES (Brazilian Amazonian Forest Monitoring by Satellite) program. More recently, the DETER (Real Time Deforestation Detection System) program was launched to give a faster response (twice a month). PRODES uses Landsat TM and Brazilian-Chinese CBERS data, while DETER is fed by the MODIS sensors on board NASA's Aqua and Terra satellites. The data from both programs have been used by IBAMA (Brazilian Institute of Environment and Renewable Natural Resources) and the Brazilian Federal Police to detect deforestation areas for operational purposes and law enforcement. However, the use of orbital optical sensors to detect deforestation in the tropical rainforest on the Amazon region is limited by the presence of clouds. Some areas remain covered for more than a year. This problem affects critically affects the time spend by the authorities mentioned above to react against the ongoing deforestation processes.

Past research has pointed out that data from SAR satellite sensors can be used to detect land cover changes in tropical forests. The Advanced Land Observing Satellite was launched in 2006, and from August 2007 its data became available to IBAMA through the JAXA's ALOS Kyoto and Carbon Initiative project (K&C). The ScanSAR-ALOS is one of the products available under the K&C. With L band and HH polarization, it is suitable for vegetation analysis.

2. **Study Site**

The study area related to the first approach is defined by a rectangle (180km by 200km) centrally located in the state of Pará, Brazil, centroid with coordinates of 52º 47’ 44” W and 6º 34’ 03” S (**Figure 1**). The second approach was conduct in some parts of Pará and Mato Grosso States (**Figure 1**). The third approach was conduct on all the Amazon region. These corresponds to areas of forest that has been facing a growing pressure of deforestation, with a good amount of recent deforested areas detected by DETER. The area was selected to be used as pilot area to test new methodologies on real-time deforestation monitoring.



(a) (b) ©

Figure 1. (a) Study site location in the Pará State, (b) five fine bean strips in the Pará and Mato Grosso Satates, (c) all the detained areas in the Brazilian Amazon Region.

Seasat was launched on 1978, and was the first Earth-orbiting satellite that had the spaceborne synthetic aperture radar (SAR), L-band, on board. The use of L-band orbital SAR images for vegetation analysis starts with SeaSat data, developing to the SIR-A,B and C data, followed by JERS-1 and recently with ALOS PALSAR data.

The L-band SAR images have been related with the canopies and have been related with biomass estimation and structure modeling. Luckman & al. (1998) developed a semiempirical model for the retrieval of above-ground biomass density on the tropical forests. Several papers were developed on this matter to understand this relationship. Neeffa & al. (2003) developed a model for the tropical forest stand structure using SAR data.

Sgrenzaroli & al. (2004) have shown that on the published remote sensing literature, there are several Amazon forest-mapping experiments actually deal with single SAR satellite images (i.e. JERS or European Remote Sensing – ERS), with focus on local-scale mapping. In this category, approaches based on visual inspection or automatic classification, were investigated.

Saatchi & al. (1997) have studied the radar characteristics of the training sites on the State of Rondônia for land cover-type classes identification using L-band SIR-C data.

More recently, Almeida-Filho & al. (2005) evaluated the potential use of orbital L-Band SAR images of JERS-1, to test a multitemporal monitoring methodology. They found that for the initial deforestation process the proposed methodology is not able to unequivocally detect areas in initial phase of deforestation, and the unambiguous detection of deforested areas is only possible if the entire clearing process has already been concluded. They also mentioned that for an operational program to monitor deforestation, based on SAR data, it is very important to have a properly geo-referenced multi-temporal database to integrate different sources of data.

The use of orbital optical sensors to detect deforestation in the tropical rainforest is usually delayed due to presence of clouds. The age of a certain deforested area is defined by the period that starts when original forest was last observed and ends when deforestation was first observed with satellite images. Recent deforested areas are considered priority for law enforcement agents because they can indicate the ongoing deforestation processes. DETER's data provides deforestation polygons with an age that can vary from 15 days up to more than a year long (**Figure 2**). By the beginning of the dry season most of the deforested areas detected by DETER are old (more than 90 days) due to a long period without clear images. ALOS-ScanSAR can be used to identify recent deforested areas and to reduce the interval between two observations.

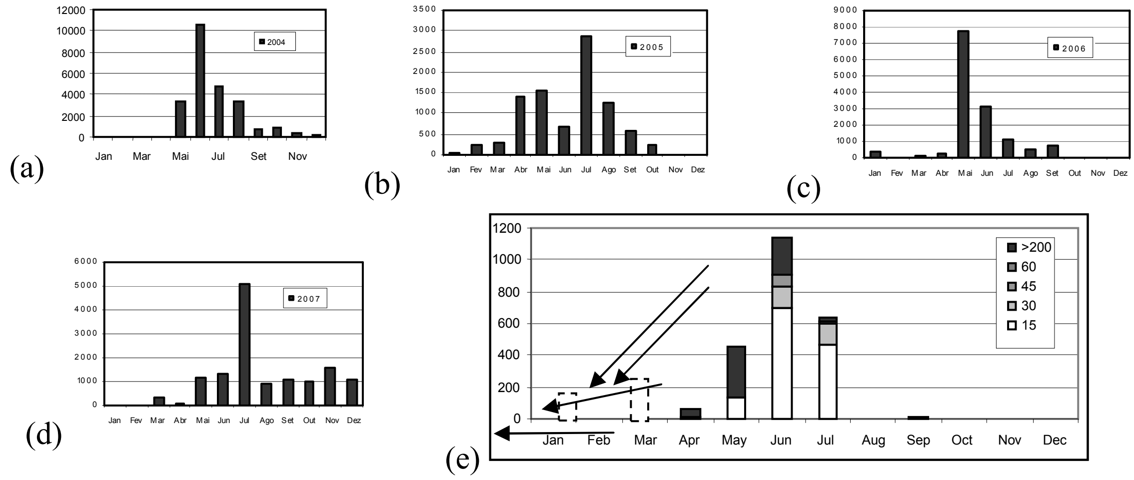


Figure 2. Monthly distribution of DETER deforestation detection in area (km2). (a) 2004, (b) 2005, (c) 2006, (d) 2007, and (e) 2007 with the proportion of the each age per month in the beginning of the dry season. Dashed columns means hypothetic scenario of PALSAR complementary data, showing some deforestation that may be not able to detect during the rainy season.

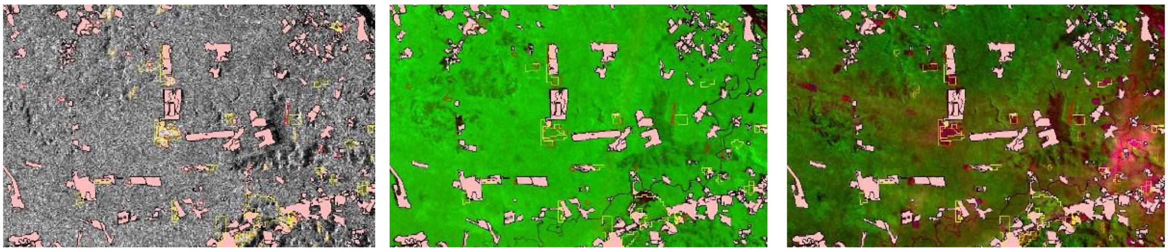
3. **Methods**

On the first approach the strip of 2730km of length by 380km of swath, on wide bean mode 1 of ScanSAR images, with 100 per 100 meters resolution and HH polarization, of august 23rd, 2007. In order to validate the ALOS detection Landsat-TM images path 226 row 64 and 65 of September 2sd, 2007 and path 225 row 64 and 65 of September 27th, 2007. CBERS images path 164 row 106 and 107 of September 11th, 2006 were used to verify the forest condition one year before the ALOS image acquisition. Images were registered using orthorectified images from Geocover Landsat Facilities project (GLCF orthorectified data).

This study was conducted to test operational capability of ScanSAR images as complementary resource to the optical sensors already used in Brazil. First, an analysis was carried out in order to understand how deforested areas would show up on PALSAR sensor imagery. Than the ScanSAR strip mode image was geo-rectified and subset. DN image values were converted to the normalized radar cross section (□o), in dB, with a calibration factor of -83 dB.

The ancillary deforestation areas previously detected by PRODES were masked to eliminate old deforestation areas. An analysis was done using all DETER data sets of the year

2007. The mean sigma value was extracted for all sets of DETER deforestation detections along the year 2007 and also for the rain forest. A Lee-sigma speckle reduction filter was applied to the ScanSAR image. This image was then classified using the mean sigma value of the recent deforested areas as threshold to identify other deforested areas not detected by DETER.



(a) (b) (c)

Figure 3. The yellow lines are the DETER detection polygons, the red lines are de ALOS detection polygons while the pink areas correspond the PRODES polygons. (a) ALOS ScanSAR image used with the defined threshold value and the to identify the possible recent deforestation, (b) CBERS Image from 2006 before to characterize the situation before ALOS image acquisition, (c) Landsat image after ALOS image acquisition.

An illuminated topographic image based on the position of the PALSAR sensor was generated from the SRTM data. The simulated image was used to exclude the classified areas that could present relief related response on the ScanSAR image.

In the second approach the visual interpretation was conducted using the knowledge obtained on the first approach were some of the highlighted areas (e.i. square deforestation shape) were identified over Fine bean images overlaid by PRODES 2007 + DETER from August to December of 2007 (**Figura 4**).

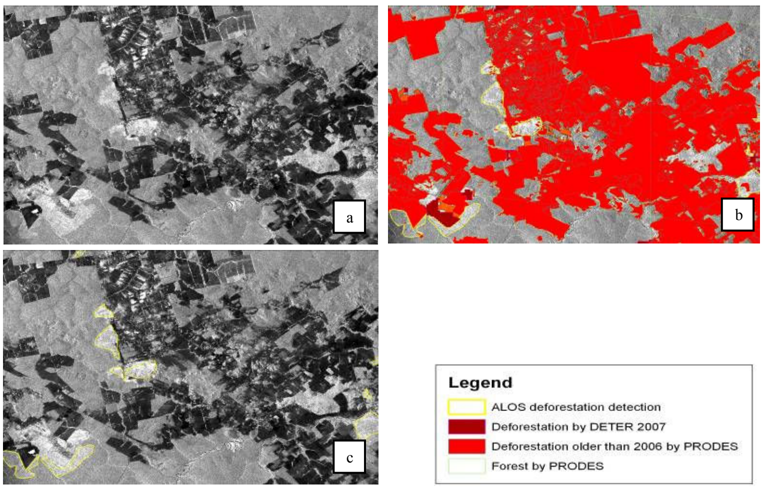


Figure 4. (a) ALOS PALSAR Fine Bean Slant Range 50m resolution of December 2007, (b) ALOS PALSAR Fine overlaid by PRODES 2007 and accumulated DETER until December 2007, (c) ALOS PALSAR Fine overlaid by the drawn polygons detected using PALSAR image.

On the third approach ScanSAR images were used to build-up temporal color composites, this methodology were used together with visual interpretation inside of the detained areas were a fine were applied by the enforced law agents of IBAMA. Figure 5 are showing one example of temporal color composite applied in one of the eleven strips that cover all the detained areas.

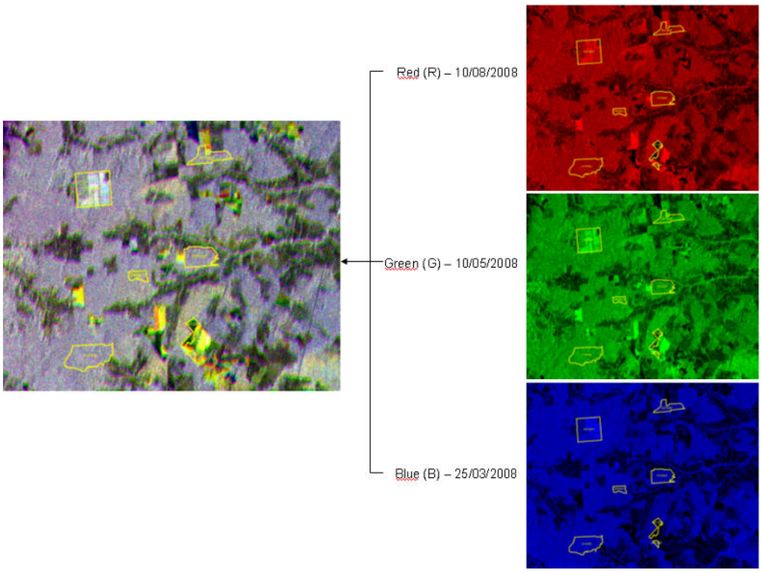
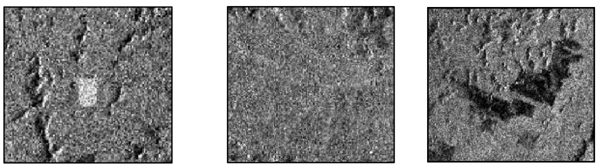


Figure 5. Temporal RGB composition using tree ScanSAR Strip images of tree different dates were DN of images show changes with different colors.

4. Results

On the first approach, DETER polygons were used to extract average values inside these areas, was possible to recognize that most of older deforestations in the same year were low values compared with the very recent detections. The **figure 6** shows the average sigma values obtained for old deforestations (may be crops or pasture) compared with one year old deforested areas detected by DETER system using Terra-MODIS images and the signal obtained for primary forest.

Class	Area	Min	Max	Mean	Std
DETER Recent (1)	2279	-12,330	4,204	-4,992	1,893
Forest PRODES (2)	132020769	-15,520	0,178	-7,254	1,818
Deforest PRODES (3)	162780000	-20,374	0,899	-11,020	2,505



(1) **(2)** **(3)**

Figure 6. Comparison between very recent deforestation from DETER of the year 2007, Deforestation detected with PRODES system from 1997 to 2006 in average and the remnant primary forest identified by PRODES database.

The results showed that areas corresponding to old deforestation are related to low dB values, while recently deforested areas are related to high dB values. The mean σ^{o} value for recent deforested areas was -5.315dB and the mean σo value for preserved native forests was - 7.569dB.

Based on the threshold value classified ALOS image, 1476 polygons were generated. Using the arbitrary criteria that more than 10 degrees slope can be affected with an increased brightness, 1239 polygons on slope areas were eliminated. From the resultant 237 polygons, 133 were confirmed to be over the relief but were not eliminated because they were geographically displaced, one was a false detection, and 99 were confirmed deforestations. From the 99 deforested polygons, 19 were coincident with PRODES from the year 1997 to 2006 and 55 polygons with PRODES 2007 (finished on august 2007), 4 were on areas of non forest (neither considered by PRODES nor DETER) and 17 are new detections of ALOS, not detected by any other optical system.

On the second approach five strips of Fine Bean Single Mode, polarization HH with 50m resolution on the month December 2007 and January 2008 were used to detect possible recent deforestation by visual interpretation based on the knowledge acquired on the approach number one. Overlaid the PALSAR images with PRODES 2007 and year before and accumulated DETER from August to December 2007, 738 polygons were generated (**Table 1**). These polygons were compared with the posterior detection made by DETER from January to September of 2008, were 1346 polygons were identified on the same area monitored by ALOS. From the total DETER polygons 207 (15.38%) were intersected with ALOS PALSAR polygons, 878 (65.23%) were polygons that their areas were monitored month(s) before in the year 2008 and were not detected (possible these polygons occurred after ALOS PALSAR detection), and 261 (19.39%) had their areas covered by clouds until their detection by DETER (we are not able to define when it occurs in relation to ALOS PALSAR detections).

Table 1. Comparison between ALOS PALSAR detections and *posteriori* DETER detections.

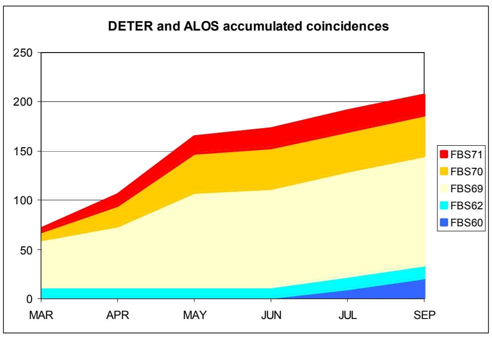
	DETER	ALOS	Intersect	MAR	ABR	MAY	JUN	JUL	SEP
FBS60	139	215	21	1	0	0	0	9	11
FBS62	137	100	13	11	0	0	0	1	1
FBS69	409	290	111	48	14	34	4	7	4
FBS70	437	77	41	8	12	19	2	0	0
FBS71	224	56	21	3	9	6	2	1	0
Total	**1346**	**738**	**207**						

Without clouds month(s) before DETER detection in 2008

	JAN	FEB	MAR	APR	MAY	JUL	**TOTAL**
FBS60	2	23	3	0	44	16	**88**
FBS62	50	53	0	2	5	0	**110**
FBS69	0	113	19	15	1	54	**202**
FBS70	0	257	3	47	0	15	**322**
FBS71	0	117	0	37	0	2	**156**
							878

Covered by clouds until their detection by DETER

	JAN	FEB	MAR	APR	MAY	JUL	**TOTAL**
FBS60	0	0	26	0	0	4	**30**
FBS62	0	12	0	0	0	2	**14**
FBS69	0	0	54	5	1	36	**96**
FBS70	0	0	38	28	0	8	**74**
FBS71	0	0	24	23	0	0	**47**
							261



Seeking for changes we could find an area that were checked by optical images in other to generate an indicative of changes that may represent an break down in a detained areas after received a fine by the IBAMA´s enforced law agent. The **Figure 7** is presenting an example of changing detection. This methodology still need much field activities to determine the level of changes ALOS PALSAR are identifying and how it can be used by the enforced law agents to return in the detained areas.

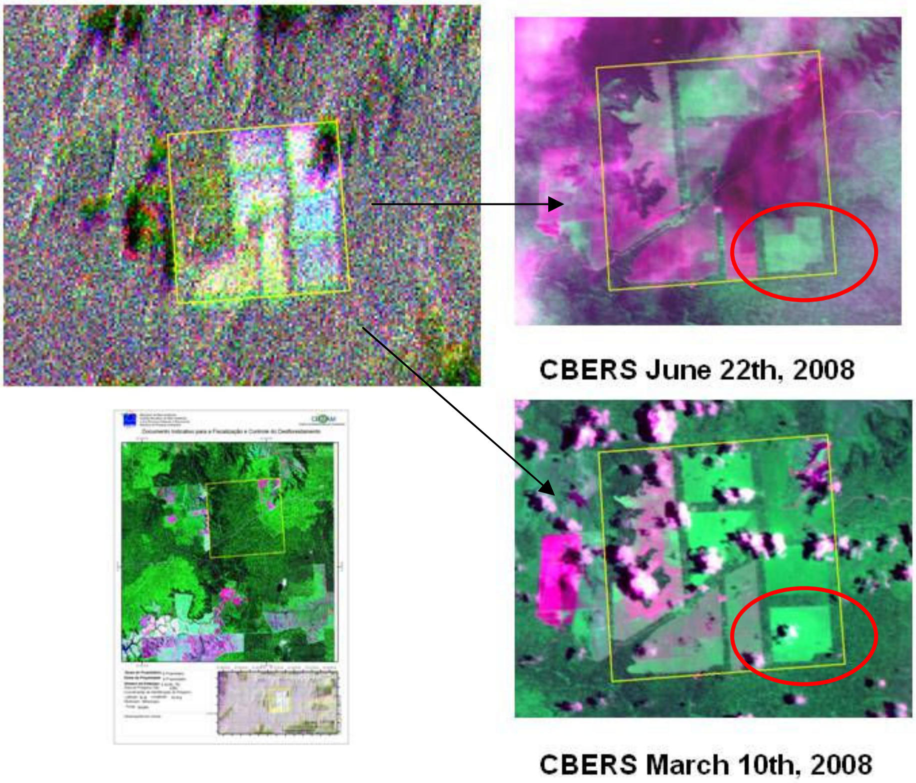


Figure 7. Up left ALOS ScanSAR temporal composites, on the right CBERS images used to confirm the changes detected by ALOS and a Indicative of temporal changes in detained areas.

5. Discussion

The mean σ^{o} value for recent deforested areas, for preserved native forests and old deforested areas are similar to those found by other authors are shown on the **Table 2**.

Table 2 – Comparison between the sigma values obtained from different studies: (1) present study, (2) Sgrenzaroli & al., 2004, (3) Saatchi & al., 1997 and (4) Luckman & al., 1998.

Covarage Type	1	2	3	4
Primary Forest	-7,254	-7.71dB	-9.71	-8.3 to 7.1
Recent deforestation	-4,992	----	-5.75	----
Old deforestation (may be crop or pasture)	-11,020	-1.11dB	- 14.45	-11.9 to -10.7

Almeida-Filho & al. (2005) notice the importance of high quality georegistration on the several databases in order to implement an operational monitoring system. In this study the georegistration was a very limiting factor and was solved by using the recent implementation of the geocoded methodology.

6. Conclusions

The executed methodology, using a threshold to classify new deforested areas, has a good potential to be the base of a semiautomatic detection system for operational purposes, using ScanSAR images. This system has potential to produce data that could complement the information already available from optical sensor satellites (CBERS-CCD, Landsat-TM and Terra-MODIS images). The resulted monitoring system, combining optical and SAR data, would decrease the average age of the deforested areas. As a result, the response time related to law enforcement activities to combat illegal logging would decrease.

Two points need to be stressed here. One is the new detections of ALOS images which were not detected by any other optical systems. These detections are probably related to very recent deforestations that may have occurred some days before ALOS image acquisition. The second point is the number of ALOS detection coincident with PRODES 2007, these detections can be used to the enforcement law agents, because these polygons where not detected by DETER until the end of the year when the mask were changed to the PRODES 2007 database.

The DETER detections were always correct and the area not covered by clouds before DETER detections means that there was no deforestation on this areas. This presumption presumes that detection recognized after are new very recent deforestations.

In the third approach the no changes can not be necessarily defined us compliment determined in the detained areas, us well us, some cases of changes need to be studied to determine the level of change can be related to re-growth process.

7. Acknowledgements

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8. References

Almeida-Filho, R.; Rosenqvist, A.; Shimabukuro Y.E.; Santos J. R.; 2005. Evaluation and Perspectives of Using Multitemporal L-Band SAR Data to Monitor Deforestation in the Brazilian Amazônia. **IEEE Geoscience and Remote Sensing Letters**, 2(4):409-412.

Neeffa,T.; Dutra, L.V.; Santos J.R.; Freitas, C.C.; Araujo, L.S.; 2003. Tropical forest stand table modelling from SAR data. **Forest Ecology and Management, 186:159–170**.

Saatchi, S.S.; Soares, J.V.; Alves, D.S., 1997. Mapping Amazon Deforestation and Land Use in Amazon Rainforest by Using SIR-C Imagery. **Remote Sensing of Environment**. 59:191-202.

Sgrenzaroli, M.; Baraldi, A.; De Grandi, G.D.; Eva, H.; Achard F.; 2004. A Novel Approach to the Classification of Regional-Scale Radar Mosaics for Tropical Vegetation Mapping. **IEEE Transections on Geoscience and Remote Sensing**, 42(11):2654-2669

Siqueira, P.; Chapman, B:.; McGarragh, G.; 2003. The coregistration, calibration, and interpretation of multiseason JERS-1 SAR data over South America. **Remote Sensing of Environment** 87:389–403.