K&C Science Report – Phase 2

Application of ALOS/PALSAR in support to Brazilian Forest Monitoring Program

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Abstract— **This paper presents the status of ALOS/PALSAR - Kyoto and Carbon Initiative radar images for the Brazilian Forest Monitoring Program. Using deforestation polygons mapped by INPE's DETER and PRODES projects, ALOS/PALSAR ScanSAR images were analyzed considering the capability to detect deforestation patterns. Assessments on the capabilities and limitations of multi-temporal PALSAR K&C ScanSAR (HH polarization) data for detecting recent deforestation are presented. The multi-temporal data processing included image co-registration and multi-temporal speckle filtering which benefited subsequent segmentation and classification of the imagery. For a deforestation hotspot in the state of Para, Brazil, 83 % of deforested areas classified using ScanSAR images from 2007 and 2008 were also mapped by PRODES. 62 % of DETER warning's were identified, which collectively corresponded to 85 % of the deforested area. Most areas of deforestation > 1 km^2 and degraded forest prior to clear cutting could be detected before the DETER warning, largely because of the ability to penetrate cloud. The study concludes that the PALSAR ScanSAR HH polarization multi-temporal product is a valuable complementary data source that should be used for forest monitoring within PRODES and the DETER system**

Index Terms—**ALOS PALSAR, K&C Initiative, forest monitoring, DETER.**

I. INTRODUCTION

A. Deforestation and SAR data over Brazilian Amazon

Early deforestation stages by slash-and-burn practices were previously identified at L band JERS images as distinct patterns from those of the original forest cover in the Brazilian Amazon [1]. Airborne L Band data also demonstrated to be very sensitive to radiometric differences between recent deforestation and primary forest [2].

Polarimetric radar data acquired in a Mapsar simulation showed also capability to detect recent deforestation over Tapajós National Forest (Pará), in the Brazilian Amazon [3]. Among polarimetric data, HH-HV showed to be the most adequate polarization combination for land cover mapping, for it is possible to discriminate primary forest, secondary forest, bare soil, agriculture and degraded forest [4]. Preliminary investigations using ALOS PALSAR images, using only HH polarization, over Amazonia, showed distinct responses from slash-and-burn practices and also different degradation stages of the forest [5].

Comparisons between optical and radar images suggested that SAR L-band images are an important and complementary information source for land cover change mapping, specially over frequently clouded areas as is most of Amazon region [6].

This paper describes the project developed within the Kyoto & Carbon (K&C) Initiative [7] which is assessing the use of ALOS PALSAR K&C images for the DETER qualification procedure as initial steps to introduce ALOS PALSAR products to the Brazilian Forest Monitoring Program.

B. ALOS Imagery for forest monitoring in Brazil

The Brazilian Institute for Space Research (INPE) conducts the Amazon Deforestation Monitoring Program which comprises of a set of remote sensing based systems to monitor the state of the Amazonian forest cover. The Real-Time Deforestation Detection System [8] identifies and maps recently deforested areas in the Brazilian Amazon forests every fifteen days to support law enforcement for deforestation control. DETER is based on TERRA/MODIS and CBERS-2B/WFI images to exploit their high revisiting capability. With spatial resolution of both sensors limited to 250 meters, DETER maps new deforestation areas of at least 25 ha. In DETER, all deforestation identified in an image and not previously detected by Legal Amazon Deforestation Monitoring Project [9] is considered new deforestation, regardless of chronological time. The PRODES map, containing deforestation from prior years, together with nonforest areas (such as savannah, water surfaces and rocky outcrops) is used to mask out old deforestations. New deforestations are detected and outlined by visual interpretation of the MODIS image.

For every interval of 15 days the best set images is selected in order to attain maximum cloud free data. DETER produces a digital map with all new deforestation observed during this period. These digital maps containing Alert polygons and tables describing them are sent to IBAMA (Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis) within 15 days after the image acquisition period. IBAMA is responsible for law enforcement and deforestation control at the Federal level. A cloud cover map is also provided to inform the area that was effectively monitored. The maps for the two halves of each month are integrated and, together with the cloud cover maps and images for the period, are placed on the Internet (http://www.obt.inpe.br/deter/) for consultation, where they remain available for download.

For every month, associated to DETER data, a technical report assessing DETER information and results is also published on the Internet. Based on cloud free and high spatial resolution images (20 – 30m), a sample of DETER Alert polygons is validated. Multi-temporal and visual analysis classify DETER Alert polygons as light forest degradation, moderate forest degradation, intense forest degradation, clear cut and non-confirmed deforestation. Validation results provide basic information about types of deforestation mapped by DETER and data accuracy, considering also the information about polygons area. From May to August, 2008, an average of 91% of DETER Alert polygons were confirmed as deforestation [10].Data from field observation is also periodically obtained to improve DETER methodology and data evaluation [11]. This validation of DETER Alert polygons using optical remote sensing imagery is strongly limited by the cloud cover over the Amazon region.

We propose the use of ALOS PALSAR K&C ScanSar images as additional data source for deforestation monitoring, as part of DETER system. It is not expected that PALSARr imagery would provide information about different deforestation intensity, as it is usually detected by optical images and multi-temporal approach, but to increase the monitoring frequency avoiding cloud cover limitations for optical images.

II. Description of the Project

A. *Relevance to the K&C drivers*

The use of ALOS imagery operationally at DETER system, as an improvement of the forest monitoring system, is in according to the Conservation thematic driver outlined in the K&C Science Plan [12]. To effectively monitor deforestation, especially over frequent cloud cover areas, ALOS information will be very helpful to define policy and plans of actions, either for carbon emission reduction or for conservation strategies.

B. *Work approach*

The main objective of this project is to understand the temporal variation of deforestation detection, and to develop a feasible methodology in order to include ALOS/PALSAR ScanSar data operational at DETER deforestation detection. More than providing deforestation maps, we are focus on the usefulness and potential of radar L band data at INPE´s Amazon Deforestation Monitoring Program.

This paper describes the results and the progresses for deforestation detection based on multi-temporal PALSAR ScanSar data for a deforestation hot-spot area in the Brazilian Amazon, based on PRODES deforestation mapping, and DETER deforestation Alerts comparisons.

C. *Satellite and ground data*

In the Brazilian Amazon, most of the deforestation in recent years has been taken in Pará and this area was therefore selected to assess the potential of ScanSAR data for detecting deforestation and degradation. In 2008, Pará state was responsible for 38% of DETER Alert polygons (from January to December), and associated with the highest deforestation rate (5606 km^2 y^{-1} from PRODES) in the Legal Amazon [13]. The southwestern of Pará, the region comprising the boundaries of the municipalities of Novo Progresso, Itaituba, and Altamira (Figure 1a), is a notorious hotspot of change that has two distinct patterns of deforestation. Deforested areas that correspond to approximately 1 km^2 in area, and are adjacent to previously deforested areas, closer to the main BR-163 highway, can be attributed to small ranches within the municipality of Novo Progresso. The second pattern are related to deforestation between 2 and 20 km^2 in area, located in the municipalities of Altamira and Itaituba, more distant from the BR-163, and hence more difficult to access. These clearings can be attributed to bigger livestock farmers Figure 1b). Within these area, fieldwork was conducted in September 2008, and in September 2010, whereby DETER deforestation polygons were validated from aerial photographs, available at http://www.obt.inpe.br/fototeca/fototeca.html.

For the analysis presented here, we used the followed ALOS-PALSAR K&C ScanSAR images acquired in descending mode (WB1, K&C format), slant range format and HH polarization for the dates:

a) For the first and second analysis: 28th May, 13th July and 28th August 2007 and also the 13th January, 30th May and 30th August, 2008, from the same path (RSP406)

b)For the third analysis : 4th November 2009, 4th February and 7th August 2010 from the path RSP 407, and also on the 18th January, 20th April and 21th July 2010 from the path RSP406.

Based on the method for routine and automated processing of PALSAR K&C ScanSAR images previously developed (Figure 2), the images were co-registered, filtered, and georeferenced using SRTM - digital elevation model, and resampling to 100 m of spatial resolution. Multi-temporal Anisotropic Non-Linear Diffusion Filter reduced the speckle noise and provided smoother images for deforestation detection [14]. From these, maps of deforestation were generated and compared subsequently to the deforestation mapping from PRODES in 2009, and DETER deforestation warnings from 2007 and 2008.

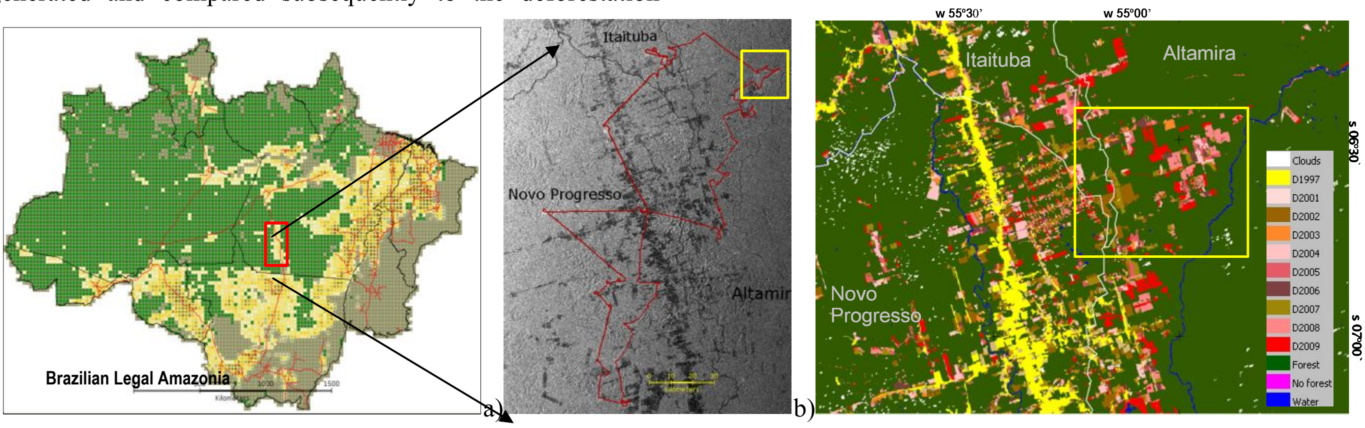

Figure 1. Study site comprising the municipalities of Altamira, Novo Progresso and Itaituba (Pará), Brazil: (a) Fieldwork track over ALOS ScanSAR image (WB1-HH–083008) and (b) PRODES deforestation map 2009.

Every clear-cut polygon was visually interpreted over the PALSAR image, seeking to identify differences in the radar response as lighter digital values, with linear boundaries, or backscattering patterns different from the forest background and the darker pattern of older deforested areas.

DETER Alert polygons from May to August 2008 field checked (September, 2008) were superposed to the PALSAR K&C image from Augut. All of the analyzed DETER polygons referred to clear-cut deforestation, comprising areas that will be likely converted to pasture, located at municipalities of Itaituba, Novo Progresso and Altamira (PA) (Figure 1b).

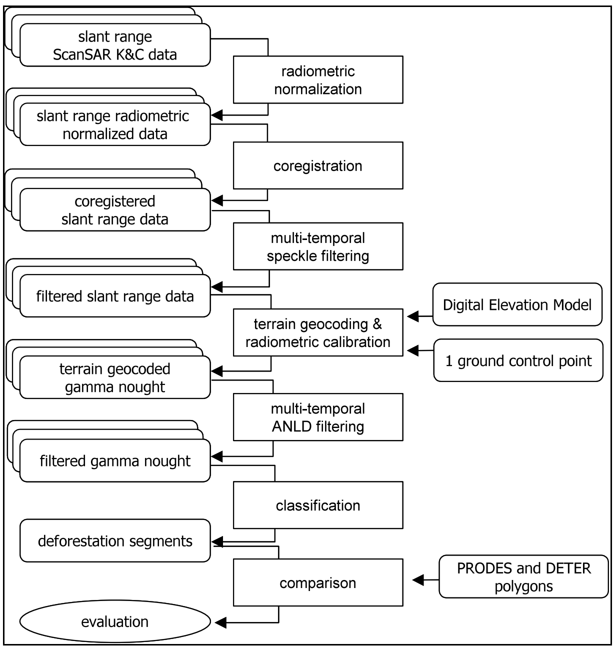

Figure 2. Processing steps for deforestation classification based on PALSAR ScanSAR imagery

A second analysis was performed observing only DETER Alert Polygons for September 2008, over ALOS PALSAR ScanSAR image from October (10-15-2008), with the same methodological procedure. This analysis simulated the use of ALOS PALSAR in an operational basis.Finally, a third analysis compared ALOS PALSAR multi-temporal images of 2009-2010 with PRODES 2009.

III. Results and Summary

ALOS PALSAR K&C ScanSAR classification x DETER Alerts

Most of deforestation segments identified from ScanSAR were equivalent to clear-cut class of PRODES in the correspondent year of mapping (Table 1); a few segments referred to old deforested areas, and several segments were only mapped by PRODES in the consecutive year. Considering the average for the six individual PALSAR ScanSAR analyzed images, the general agreement between ScanSAR deforestation segments and PRODES deforestation mapping was of 62%. Analyzing each PALSAR ScanSAR image separately, a large number of segments (an average of 38%) corresponded to Forest class at PRODES mapping. This was attributed to relieve roughness that confuses the identification of deforested areas, but also can be associated to forest degradation process that is not mapped at PRODES. Considering those segments identified as DETER warnings from 2007 and 2008, the percentage of deforestation segments detected by ScanSAR that corresponds to deforestation mapping reaches 69%. As pointed out by Almeida-Filho et al. [15], although most of the recent deforestation appears brighter than mature forests, the identification of these areas using only the HH band depends on the stage of the clearing process. The average of ScanSAR segments area identified as forest (1.01 km^2) and deforestation (1.45 km^2) was statistically different (P value equals to 0.0006), suggesting that an area threshold could be applied to generate a better efficiency in the deforestation detection based on PALSAR ScanSAR segments.

Regarding to the relieve effect, based on the digital elevation model from SRTM data (90m), the study site is relatively flat, with 48% of the area having slope values under 5% (average slope of 7.55%, with variance of 50%, and maximum of 69%). PALSAR ScanSAR segments identified as recent deforestation but corresponded to Forest class at PRODES mapping, presented slope values of approximately 20%, and preferential east-facing slope (aspect values of about 87^o). For the K&C PALSAR ScanSAR imagery, with incidence angle of 27^o, the roughness of these small hills were observed as brighter values, misleading the recent deforestation detection.

Table 1. Recent deforestation segments identified at PALSAR ScanSAR images from May 2007 to August 2008, compared to PRODES 2009 deforestation mapping

PRODES09*	PALSAR ScanSAR Segments					
	070528	070713	070828	080113	080530	080830
D1997	0	1	0	0	1	1
D2000	0	1	0	0	0	0
D2003	0	0	0	0	1	0
D2004	1	0	0	0	0	0
D2005	1	0	0	0	0	0
D2006	0	0	0	0	0	1
D2007	21	36	33	5	0	2
D2008	5	7	7	2	14	39
D2009	2	2	2	0	1	16
FOREST	13	34	18	8	11	30
TOTAL	**43**	**81**	**60**	**15**	**28**	**89**
% Deforest	69.77	58.02	70.00	46.67	60.71	66.29
% Forest	30.23	41.98	30.00	53.33	39.29	33.71

(*) PRODES classes are associated to the year when first the clear-cut area was mapped.

The rainy season in the study area takes places from November to June [16], when deforestation activity is generally less intense, and at the same time, the deforestation backscatter became less distinctive in the radar scene. The primary physical property that affects the microwave measurement is directly dependent on the amount of water present in the soil: increasing the moisture level in the surface, generally improve the backscattering coefficients, independent of the land cover. High values of moisture (field capacity higher than 100%) do not allow the discrimination between bare soil, pasture and field crops [17]. These factors explain the minor performance for January 2008.

Even tough, the total number of PALSAR ScanSAR segments was comparable to DETER warning for each month, there are differences in the detection time between ScanSAR imagery and DETER warnings (Table 2 and Table 3). Considering monthly DETER warnings as reference for the temporal ability of ScanSAR to detect recent deforestation, single ScanSAR images showed to be more conservative in detecting recent deforestation than DETER deforestation warnings for the same month (Table 2 and Table 3). At DETER, any change in the forest cover identifiable at MODIS imagery in a month period, not mapped by PRODES in the previous year, is considered an Alert. Eventually, some Alert was already issued, and at the same time, the cloud cover can preclude forest conversion for a couple of months. This can explain the differences between ScanSAR segments and DETER deforestation warnings polygons. Taking May 2007 as example (Table 2), only seven PALSAR ScanSAR segments were corresponding to May DETER warnings (15 deforestation warnings polygons), the others segments were detected by DETER in June and July. As previously described, after the clear-cut, the radar backscattering of deforested areas can evolve to darker signatures, closer to forest response, indistinct in a single PALSAR ScanSAR image.

Table 2. Recent deforestation segments identified at PALSAR ScanSAR images from May 2007 to August 2008, compared to monthly DETER 2007 deforestation warnings.

		PALSAR ScanSAR Segments						
	DETER07	070528	070713	070828	080113	080530	080830	Total
May	15	7	6	2	0	0	0	15
June	40	7	8	6	5	1	2	29
July	27	2	12	8	2	0	1	25
August	13	0	1	2	0	0	0	3
September	12	0	0	0	0	0	0	0
October	5	0	0	1	0	0	0	1
TOTAL	112	16	27	19	7	1	3	**73**

Table 3. Recent deforestation segments identified at PALSAR ScanSAR images from May 2007 to August 2008, compared to monthly DETER 2008 deforestation warnings.

		PALSAR ScanSAR Segments						
	DETER08	070528	070713	070828	080113	080530	080830	Total
May	9	1	0	0	0	8	17	26
June	22	0	2	0	1	9	13	25
July	18	0	0	0	0	1	6	7
August	29	0	0	1	0	0	11	12
September	1	0	0	0	0	1	0	1
October	68	1	1	2	0	0	8	12
November	6	1	0	0	0	0	0	1
TOTAL	153	3	3	3	1	19	55	**84**

Considering the multi-temporal color composition for image segmentation and classification for 2008 image composition 2008-08-30 (R), 2008-05-30 (G), 2008-01-13 (B), PALSAR ScanSAR recent deforestation segments presented an agreement of 83% with PRODES deforestation mapping (Figure 3, Table 4). Half of PALSAR ScanSAR segments mapped by PRODES as Forest was consistent to DETER warnings, increasing to 92% of correct deforestation detection by PALSAR. Also, 25 polygons identified as PALSAR ScanSAR 2008 recent deforestation segments can be related to forest degradation, since they were mapped as D2009 by PRODES.

Table 4. Recent deforestation segments identified at PALSAR ScanSAR composition 2008-08-30 (R), 2008-05-30 (G), 2008-01-13 (B), compared to PRODES 2009 deforestation mapping.

PRODES09*	PALSAR ScanSAR Segments 2008
D1997	2
D2000	0
D2003	0
D2004	1
D2005	0
D2006	3
D2007	5
D2008	34
D2009	25
FOREST	14
TOTAL	**84**
% Deforest	**83.33**

% Forest		16.67

(*) PRODES classes are associated to the year when first the clear-cut area was mapped.

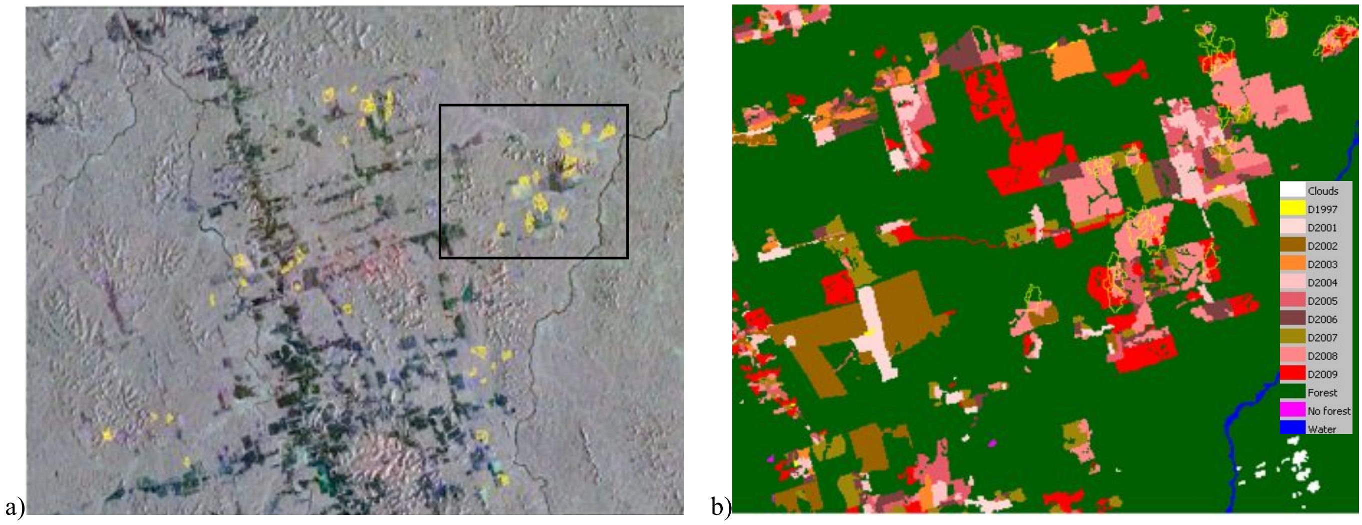

Figure 3. Recent deforestation segments over (a)ALOS PALSAR ScanSAR composition 2008-08-30 (R), 2008-05-30 (G), 2008-01-13 (B), and (b) PRODES 2009 mapping for a detail area of the study site.

Comparing to DETER warnings, the multi-temporal PALSAR ScanSAR recent deforestation classification identified fewer polygons than DETER (Table 5). Analyzing DETER warnings that were not detected by PALSAR ScanSAR procedure for the same time period (May to August), it was observed that 38% of DETER warnings were not detected by PALSAR ScanSAR classification (Table 6). However, in terms of deforestation area, 84% of deforestation was identified with PALSAR ScanSAR classification. Deforestation segments with area smaller than 1 km^2 were not detected with the proposed procedure, what is in agreement with the average area of segments corresponded to Forest class at PRODES mapping (false positive) described earlier.

Table 5. Recent deforestation segments identified at PALSAR ScanSAR composition 2008-08-30 (R), 2008-05-30 (G), 2008-01-13 (B), compared to monthly DETER 2008 deforestation warnings.

	DETER08	PALSAR ScanSAR Segments 2008
May	9	4
June	22	13
July	18	14
August	29	25
September	1	2
October	68	5
November	6	0
TOTAL	153	63

Table 6. DETER 2008 deforestation warnings (May to August) compared to PALSAR ScanSAR recent deforestation segments.

DETER Warnings 2008 (May-Aug)					
DETER Warnings	Number of polygons		Area (km^2)		
	Total	%	Total	%	Average
Scansar Segments	48	61.53	153.74	84.03	3.20
NO Scansar Segments	30	38.46	29.20	15.96	0.97
Study Area	78		182.95		2.34

In addition, during the identification of recent deforestation in the PALSAR ScanSAR multi-data colour composition, there were differences in backscattering values for some regions clearly associated to local soil moisture variation from local precipitation, and flooded areas along rivers, similar to recent deforestation backscattering values. The intense local variability in precipitation and the absence of sufficient meteorological stations to cover the Amazon make difficult to propose an automated solution to discriminate these moisture variation features from recent deforestation areas. However, a semi-automated procedure, as proposed at this work for segment classification minimizes the local precipitation effect.

ALOS PALSAR K&C ScanSAR time series x PRODES

For the study site, PRODES 2009 deforestation map was used as reference to monitor the evolution of deforestation backscattering pattern along ALOS PALSAR ScanSAR images from January 2009 up to August 2010.

We evaluated the mean backscatter (average of the digital numbers after the methodology described earlier) of PRODES deforestation polygons larger than 25 ha (compatible to the detection limit of DETER), and some forest samples. From an ordinary rank of deforestation and forest polygons response (Figure 4) most of deforestation areas were similar to forest for every ScanSAR image (DN average from 140 to 180). However, some deforestation polygons were darker than forest (DN < 130), and brighter then forest (DN > 180).

We observed the deforestation evolution over this PALSAR time-series, computing the mean digital number of PRODES2009 polygons, no rmalized by the response of homogeneous forest samples. PRODES2009 polygons with backscatter values higher than forest in the first date (09/11/04) are presented in Figure 5. PRODES2009 polygons with backscatter similar to forest in the first date (09/11/04) are presented in Figure 6. And finally, PRODES2009 polygons with backscatter values lower than forest in the last date (10/08/07) are presented in Figure 7.

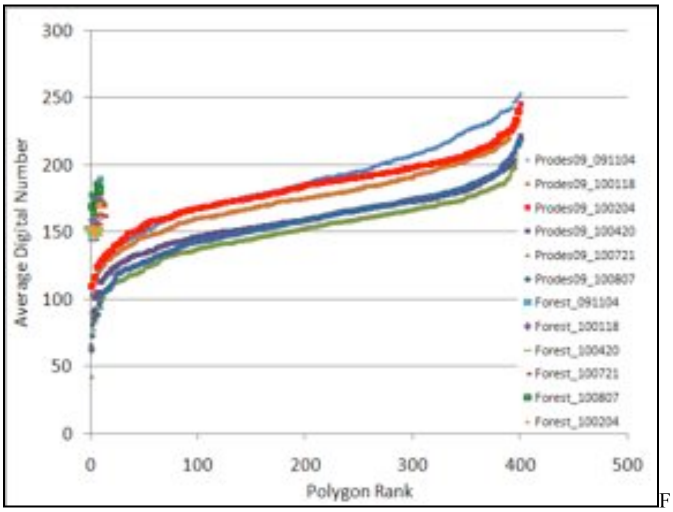

Figure 4. Ranking of PRODES2009 polygons according to PALSAR ScanSAR backscatter value (Digital Numbers) related to images acquired in 09/11/04, 10/01/18, 10/04/20, 10/07/21 and 10/08/07.

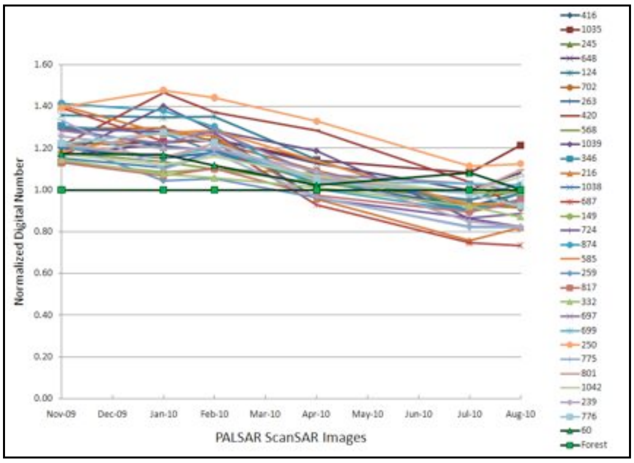

Figure 5. PALSAR ScanSAR backscatter value (Digital Numbers) related to images acquired in 09/11/04, 10/01/18, 10/04/20, 10/07/21 and 10/08/07 for the 30 brightest PRODES2009 polygons, normalized by forest signal.

Recent deforestation exhibits a brighter L-band HH backscattering coefficient compared to mature or older secondary forest (Figure 5). This pattern is associated with the felling of the taller trees, the trunks of which are left lying on the ground, and these produce a strong double bounce scattering response. The moisture content of the vegetation may also contribute to the relative magnitude of the response. However, as the trunks are removed and the deforested areas become progressively drier, the L-band HH backscatter similarly decreases until the deforested areas support a backscatter equivalent to the forest areas and can no longer be discriminated (Figure 6). This change in the backscattering pattern occurs over a period of approximately 5 months, with the rate depending upon the ground moisture variation as a function of season and also rates of regrowth if this is allowed to occur. Subsequently, and often within a year, many of these areas are converted to pasture or agriculture and the L-band HH backscatter reduces further such that they again become distinguishable from forest (Figure 7).

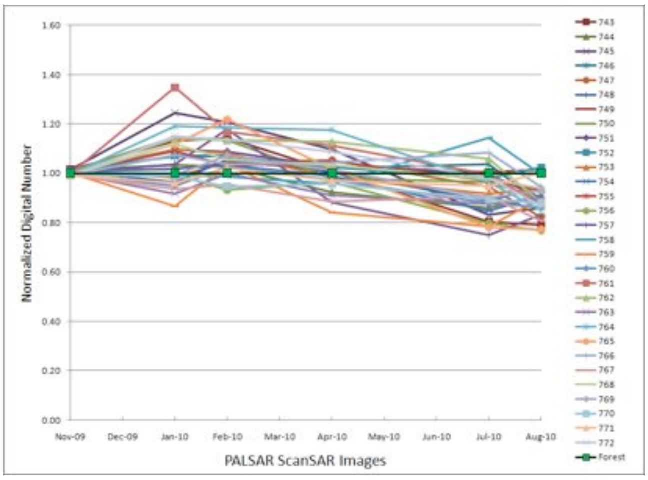

Figure 6. PALSAR ScanSAR backscatter value (Digital Numbers) related to images acquired in 09/11/04, 10/01/18, 10/04/20, 10/07/21 and 10/08/07 for the 30 PRODES2009 indistinct from forest in 09/11/04, normalized by forest signal.

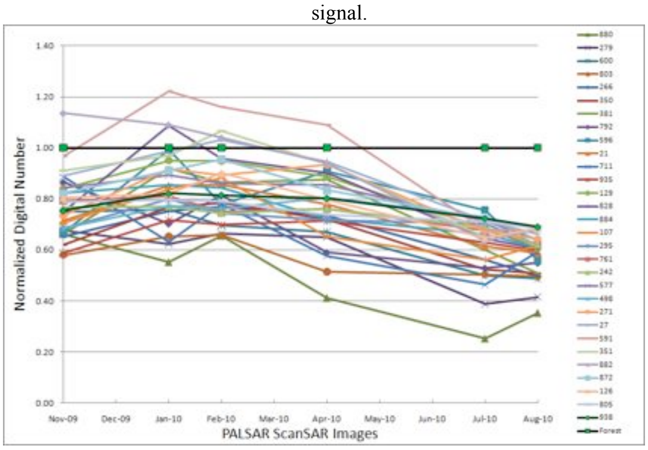

Figure 7. PALSAR ScanSAR backscatter value (Digital Numbers) related to images acquired in 09/11/04, 10/01/18, 10/04/20, 10/07/21 and 10/08/07 for the 30 darkest PRODES2009 polygons in 10/08/07, normalized by forest signal.

ALOS PALSAR K&C ScanSAR – Fieldwork

Following the BR-163 road from the municipalities of Santarém to Novo Progresso (Pará) the fieldwork was held on September 13th to 24th, 2010. Different land cover were registered as well as deforestation areas identified at PRODES2009 and DETER. The correspondent photographic records are available at INPE´s photo-library (http://www.obt.inpe.br/fototeca/fototeca.html, reference: 2010-Cenários/Santarém). Most of the new deforested areas selected from ALOS PALSAR ScanSAR multi-temporal color composition classification could not be observed because they were inaccessible by roads.

Some of features identified in the field were selected to illustrate the patterns from PALSAR ScanSAR multi-temporal color composition. Areas with agricultural activities are clearly identified because of the land cover dynamic from the crop seasonality (Figure 8).

Figure 8. PALSAR ScanSAR colour composition 10/01/08 (B), 10/04/20 (G), 10/07/21(R) and ground information. Extensive areas of grain production in Belterra municipality.

Generally, areas of pasture are more stable than agriculture ones, and in the multi-temporal colour composition will present dark patterns of gray scale for extensive areas (Figure 9). Recent deforestation areas are usually identified because of its brighter backscattering, and in the multi-temporal colour composition are related to light reddish patterns (Figure 10).

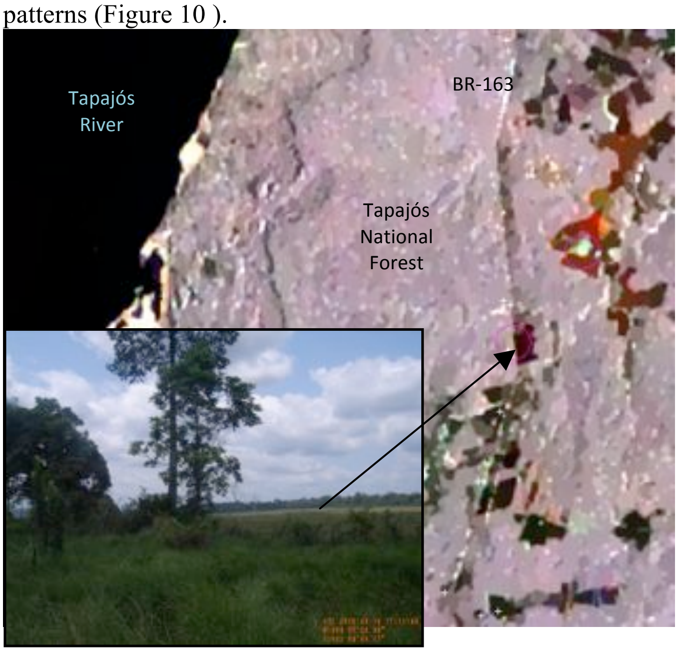

Figure 9. PALSAR ScanSAR colour composition 09/11/04 (B), 10/02/04 (G), 10/08/07(R) and ground information. Extensive areas of grain production in next to BR-163 highway.

Finally, a detail about the influence of hilly surface is presented in Figure 11, where the relief is not flat and in some cases, it can present rocky outcrops, resulting in double bounce and saturate pattern in multi-temporal color compositions.

Figure 10. PALSAR ScanSAR colour composition 10/01/08 (B), 10/04/20 (G), 10/07/21(R) and ground information. New deforestation area identified at Itaituba municipality.

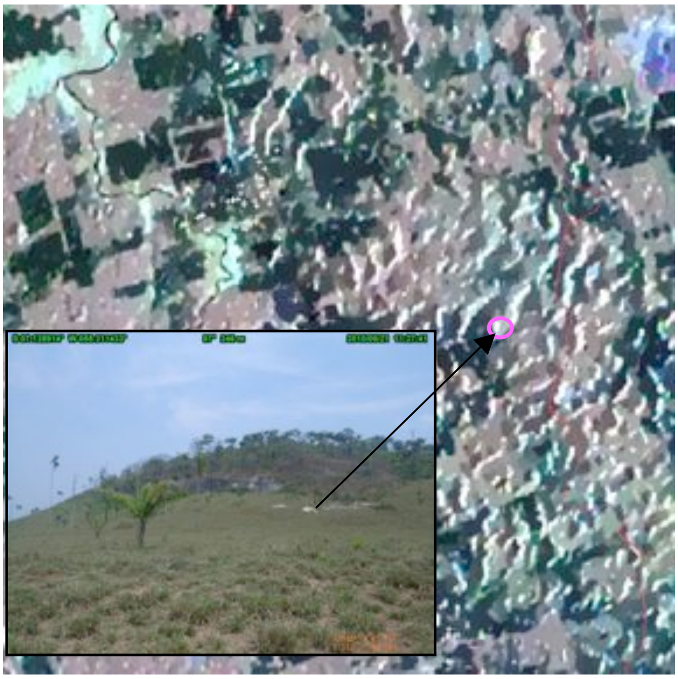

Figure 11. PALSAR ScanSAR colour composition 10/01/08 (B), 10/04/20 (G), 10/07/21(R) and ground information. Effect of relief at Novo Progresso municipality.

IV. Final Remarks

The ALOS K&C Initiative provided the opportunity to consider the use of SAR data within the Brazilian forest monitoring system, particularly given the high persistence of cloud in the Amazon region. The provision of these data on a regular basis has allowed operational procedures for L-band detection of deforestation to be developed.

The results obtained so far indicate that ALOS PALSAR imagery has a potential to detect only part of the deforestation polygons that are normally published as deforestation alerts. However, as the deforestation detection has to be operational and expedited, we need an uncomplicated approach, based on ScanSAR – HH polarization, multi-temporal data.

The proposed method provides an automated and optimized processing of ALOS PALSAR K&C ScanSAR HH polarization data. It allows efficient extraction of segments and subsequent identification of recent deforestation. 80 % of areas associated with degradation identified by DETER were mapped using the ScanSAR, with areas larger than 1 km and associated with early degradation stages and clear cuts more readily identified.

The use of multi-temporal ScanSAR data within DETER and PRODES is therefore advocated, largely because the problems associated with cloud cover are avoided and early forest degradation can be detected prior to clear cutting. The ScanSAR data would also contribute to the generation of deforestation warnings, thereby increasing ability to control deforestation on the ground. For this purpose, the radar database and image processing should be further integrated into the TerraAmazon system, which is a computational platform based on open source TerraLib technology [18]. This allows use of imagery from multiple dates and sensors, sharing of tasks relating to image analysis and classification and systematising the Amazon deforestation satellite monitoring database to operate DETER and PRODES.

The integration of ScanSAR data within a forest monitoring systems should be straightforward as the image database and computational frameworks are in place. However, research needs to be undertaken to develop methods that reduce the impact of topography, seasonal flooding and variations in surface moisture, with these considering detailed digital elevation models to compensate for terrain effects and meteorological data from satellites to adjust for moisture variations. Methods for automated classification and change detection also need to be advanced.

The combination of spatial resolution (100 m), image swath (350 km) and acquisition frequency (45 days, 8 orbits/year) makes PALSAR ScanSAR HH polarization the better choice to support the DETER system, at least in this development stage. However, as suggested by related works, HV polarization is more sensitive to changes in biomass [19] and more useful for differentiating forest structural stages from other land cover classes [4]. These data should therefore be considered further for detecting deforestation. To detect deforestation areas smaller than 1 km^2, finer spatial resolution images from PALSAR, as Fine Beam Single (FDS, 10m) or Dual polarization (FDB, 20m) mode could also be used as an additional source of information for detecting deforestation or to validate the ScanSAR classification.

Another benefit from being part of ALOS K&C Initiative and conduct this project, it the construction of a radar culture, not only at the scientific level, but also in an operational basis with implications on the public awareness about the technological capability of remotely sensed monitoring of the deforestation process in Brazil. This is especially important considering that the Brazilian Spatial Program is planning to develop radar sensors onboard of Brazilian satellites in the next decade.

Acknowledgements and Image Copyrights

The authors would like to thank the INPE´s Forest Monitoring System Team that includes Maria Isabel S. Escada, Camilo D. Rennó, Luis E. P. Maurano, Antonio Miguel V. Monteiro, and João Vianei Soares for technical and financial support. We also thank to IBAMA and Cenários and LUA Projects for the fieldwork partnership. This work has been undertaken within the framework of the JAXA Kyoto & Carbon Initiative. ALOS PALSAR data have been provided by JAXA EORC.

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