ALOS-INDONESIA POL-INSAR EXPERIMENT (AIPEX): REDD-INDONESIA READINESS PHASE

PI No 402

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ABSTRACT

The main goal of AIPEX was to support one of ALOS mission objectives: "**Regional Observation** - to perform regional observation for 'sustainable development' (harmonization between Earth environment and development)". At the same time, the result could be maximally utilized for local preparation of the Post Kyoto Protocol, especially for readiness phase of REDD (Reducing Emissions from Deforestation and Forest Degradation), as part of the Land Use, Land Use Change and Forestry (LULUCF) sector.

Keywords: PoL-InSAR, SAR Calibration, REDD-Indonesia.

1. INTRODUCTION

The main scenario of this exercise was to optimally use the golden opportunity to work with PLR data of ALOS/PALSAR. PLR was the first full polarimetric L-Band spaceborne SAR available in the world. While focusing on this scenario, the research looks for ways capable of meeting ALOS Science Plan, Post Kyoto Protocol and local/domestic needs. This combined approach can synergistically spawn new, cross-fertilized, science and commerce application of PolSAR and POLinSAR in the future. REDD (Reducing Emissions from Deforestation and Forest Degradation), which was adopted in 2008 by UNFCCC (United Nations Framework Convention on Climate Change), became the immediate local application. Due to the high rate of forest lost in Indonesia [1] as given in Fig.1, the Government of Indonesia (GoI) signed cooperation with the Government of Norway (GoN) in 2009 to voluntarily implement this REDD scheme. Moratorium of forest conversion will be implemented for two years started from 2011. However, since the existing National Forest Inventory (NFI) was not designed for REDD application, additional technique will be required for MRV (Monitoring, Reporting, and Validation) purpose. Implementation of REDD, therefore, requires a development of efficient and cost effective MRV standard, and a local capacity development to apply this standard. The two main targets of MRV are *area change* and *carbon stock*. While area change requires very high resolution (VHR) imageries to monitor logging track, carbon stock is estimated indirectly from above ground biomass (AGB). AGB, furthermore, is derived from tree height as given in Good Practice Guidelines for Land Use, Land Use Change and Forestry of IPCC [2]. Polarimetric SAR interferometry (Pol-InSAR) analysis was applied in this exercise, as an experiment to determine forest height from spaceborne SAR (ALOS/PALSAR satellite, JAXA, Japan). In order to reduce the cost of VHR imageries, Indonesia's micro-satellite with optical sensor imager is scheduled to be launched in 2011 (3-channels, equatorial orbit) and 2013 (4-channels, polar orbit). These satellites are fully funded by GoI. Parallel to this activity, another satellite with X-Band SAR sensor is planned to be launched in 2014 at the equatorial orbit.

AIPEX was part of JAXA's Second Research Announcement and implemented in two phases. The first phase was implemented from 2007-2009, and the second phase from 2009-2011. The first phase was concentrated on the calibration study of PLR imagery of ALOS/PALSAR and the completion of the processing chain of Pol-InSAR analysis. While in the second phase was targeted to the application of validated Pol-InSAR analysis in the selected test-sites. During this last phase, Indonesia voluntarily started the REDD Readiness Phase (2009-2012). This exercise, therefore, is intended to support the MRV preparation of REDD-Indonesia [3]. In this context, this paper briefly updates the status of AIPEX final result with the following two main objectives: (1) to present the result of validated Pol-InSAR analysis to estimate carbon stock through forest height, and (2) to provide update on the progress of VHR imagery satellites for area change monitoring.

Figure 1. Forest lost in Indonesia 2000-2005

2. MATERIAL AND METHOD

2.1 Study Area

The location of the test site for the study area of Pol-InSAR analysis in Indonesia was constrained by the space segment and the "ground" segment. The space segment was related to the availability of ALOS/PALSAR Pol-InSAR pair imageries in repeat-pass mode. The pair required a full polarization SAR data acquired in PLR mode for ALOS/PALSAR. Default PLR mode has incidence angle of 21.5 deg. (PLR-215). JAXA's Basic Observation Strategy (BOS) limits PLR-215 acquisition in experimental status and operated only every two years. Furthermore, due to imaging geometry and satellite orbit, PLR-215 mode has a coverage gap between the adjacent orbits in the low latitude (tropical) region. To fill this gap another PLR mode was operated by JAXA with 23.1 deg. incidence angle (PLR-231). PLR-215 was acquired in 2007 and 2009, while PLR-231 was acquired in 2009 and 2010. The "ground" segment was dictated by the availability of tree height measurement plot for verification/validation of Pol-InSAR result. Timber plantation was chosen due to the high possibility for the availability of recent inventory plot data. A first attempt status of Pol-InSAR analysis governed also the selection of the test site to the homogenous timber plantation in comparison to the relatively complex natural forest.

Based on the above two constrains, hunting for Pol-InSAR test sites were first made by deliberately select timber plantation throughout Indonesia, and then checked if the repeat-pass Pol-InSAR pairs (PLR-215 and PLR-231) archive imageries were available. The final test site resulted from this approach was located in Jambi Province of Indonesia, and presented in Fig.2.

2.2 Data

In line with the above approach, data requirements for AIPEX were Pol-InSAR pair spaceborne SAR imageries (space segment) and inventory plot measurement data ("ground" segment). The available inventory plot data marked with blue color is presented in Tab. 1, while the related PLR-215 Pol-InSAR pair imageries is presented in Tab.2, marked by yellow color.

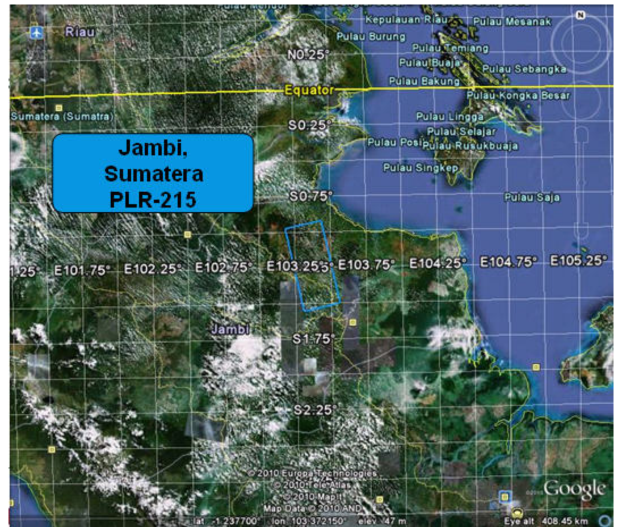


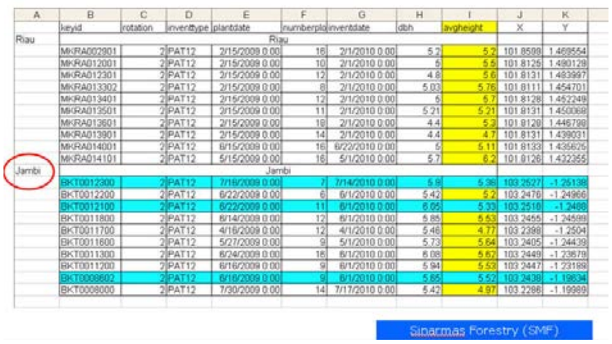
Figure 2. AIPEX Test Site in Sumatera, Indonesia

2.3 Method

With reference to MRV requirements, the method applied in this exercise was divided into three parts: (1) SAR-Calibration, (2) derivation of forest height (FHE) from Pol-InSAR analysis for carbon stock, and (3) building of national spaceborne VHR imageries for area change application.

Pol-InSAR Analysis. The existing available methods for FHE estimation are LIDAR and SAR. While LIDAR is mostly airborne, SAR are available both airborne and spaceborne. Airborne SAR system is operated as Dual-Band InSAR (DB-InSAR) such as OrbiSAR-1 [4] or Geo-SAR. The spaceborne SAR system is operated in repeat pass Pol-InSAR (ALOS/PALSAR) or single pass Pol-InSAR (Tandem-X) [5]. ALOS/PALSAR was selected in this exercise as the L-Band SAR is considered to be more suitable for FHE. Furthermore, the BOS scheme allows good coverage for the entire Indonesia. Although, problem exists in the tropical region, due to coverage gap for PLR swath. Repeat pass Pol-InSAR analysis was applied by using POLSARPRO ver. 4.14 to derive FHE. The processing chain is described briefly in Fig. 3 below. The analysis was dictated by two critical go no-go tests (marked with red color): SAR-Calibration (SAR-Cal) and Baseline. SAR-Cal was intended to check the suitability of PLR imageries for vegetation analysis at the end user level. While baseline step will reject to process the PLR pair if problem related to temporal or spatial baseline exist. The analysis involved slant and ground range operation, but using PLR single look complex (SLC/Level 1.1) imagery as the only main input. MapReady ver. 2.17 was used for ground range operation to relate PLR pair imageries with forest inventory plot in the ground. In the other hand, POLSARPRO required slant range version for height inversion and analysis. Height inversion involved four approaches: (1) polarimetric phase center height estimation, (2) DEM differencing algorithm, (3) coherence amplitude inversion procedure, and (4) ground phase estimation (HH-VV) and RVOG inversion procedure.

Tabel 1. Inventory Plot Data



A	B	C	D	E	F	G	H	I	J	K
	keyid	rotation	inventtype	plantdate	numberplo	inventdate	dbh	avgheight	X	Y
Riau					Riau					
	MKRA002901	2	PAT12	2/15/2009 0:00	16	2/1/2010 0:00	5.2	5.2	101.8598	1.469554
	MKRA012001	2	PAT12	2/15/2009 0:00	10	2/1/2010 0:00	5	5.5	101.8125	1.490128
	MKRA012301	2	PAT12	2/15/2009 0:00	12	2/1/2010 0:00	4.8	5.6	101.8131	1.483997
	MKRA013302	2	PAT12	2/15/2009 0:00	8	2/1/2010 0:00	5.03	5.76	101.8111	1.454701
	MKRA013401	2	PAT12	2/15/2009 0:00	12	2/1/2010 0:00	5	5.7	101.8128	1.452249
	MKRA013501	2	PAT12	2/15/2009 0:00	11	2/1/2010 0:00	5.21	5.21	101.8131	1.450068
	MKRA013601	2	PAT12	2/15/2009 0:00	18	2/1/2010 0:00	4.4	5.3	101.8128	1.446798
	MKRA013901	2	PAT12	2/15/2009 0:00	14	2/1/2010 0:00	4.4	4.7	101.8131	1.439031
	MKRA014001	2	PAT12	6/15/2009 0:00	16	6/22/2010 0:00	5	5.11	101.8133	1.435625
	MKRA014101	2	PAT12	5/15/2009 0:00	16	5/1/2010 0:00	5.7	6.2	101.8126	1.432355
Jambi					Jambi					
	BKT0012300	2	PAT12	7/18/2009 0:00	7	7/14/2010 0:00	5.9	5.36	103.2527	-1.25138
	BKT0012200	2	PAT12	6/22/2009 0:00	6	6/1/2010 0:00	5.42	5.2	103.2476	-1.24966
	BKT0012100	2	PAT12	6/22/2009 0:00	11	6/1/2010 0:00	6.05	5.33	103.2518	-1.2488
	BKT0011800	2	PAT12	6/14/2009 0:00	12	6/1/2010 0:00	5.85	5.53	103.2455	-1.24599
	BKT0011700	2	PAT12	4/16/2009 0:00	12	4/1/2010 0:00	5.46	4.77	103.2398	-1.2504
	BKT0011600	2	PAT12	5/27/2009 0:00	9	5/1/2010 0:00	5.73	5.64	103.2405	-1.24439
	BKT0011300	2	PAT12	6/24/2009 0:00	16	6/1/2010 0:00	6.08	5.67	103.2449	-1.23679
	BKT0011200	2	PAT12	6/16/2009 0:00	9	6/1/2010 0:00	5.94	5.53	103.2447	-1.23189
	BKT0008602	2	PAT12	6/16/2009 0:00	9	6/1/2010 0:00	5.65	5.52	103.2438	-1.19634
	BKT0008000	2	PAT12	7/30/2009 0:00	14	7/17/2010 0:00	5.42	4.97	103.2286	-1.19989

Sinarmas Forestry (SMF)

Tabel 2. PLR Pol-InSAR Pairs Imageries

#	ID	Date	P/F	PLR
1	ALPSRP066750030	20070426	488/30	215/M
2	ALPSRP060040030	20070311	488/30	215/S
3	ALPSRP027787150	20060802	383/7150	215/M
4	ALPSRP034497150	20060917	383/7150	215/S
5	ALPSRP176877130	20090520	435/7130	231/M
6	ALPSRP230557130	20100523	435/7130	231/S
7	ALPSRP063537170	20070404	438/7170	215/M
8	ALPSRP070247170	20070520	438/7170	215/S
9	ALPSRP170897170	20090409	438/7170	215/M
10	ALPSRP224577170	20100412	438/7170	215/S

Note: P/F = Path/Frame, M = Master, S = Slave

Area Change. During this exercise, initialization to set up national capacity for VHR satellite imagery (SAR and optic) was started. LISAT (LAPAN-IPB-Satellite), a micro-satellite with optical line-CCD sensor, is being jointly developed by LAPAN (National Institute of Aeronautics and Space) and IPB (Bogor Agricultural University). The main mission is food security, with the secondary mission is natural resources including REDD. The construction of this satellite is in progress, started from 2008 and fully funded by GOI budget, as displayed in Fig. 4. At the same time, second satellite namely Climate-SAR (C-SAR) with SAR sensor, was initiated at the end of 2010. This satellite will be jointly developed with UK Space Agency. Agreement between UK Space Agency and LAPAN is scheduled to be signed in 1 February 2011, with approximate launch schedule of 2014.

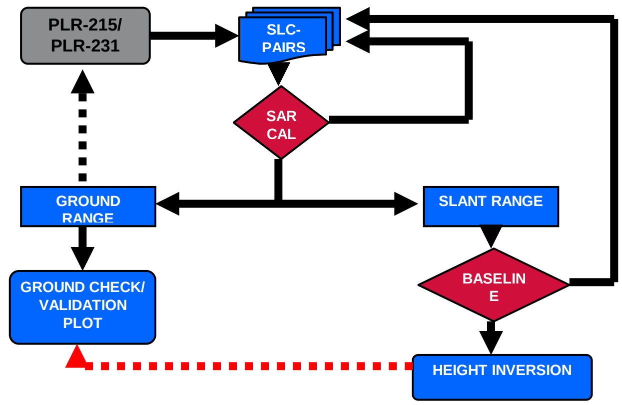


Figure 3. Pol-InSAR Analysis Processing Chain

Figure 4. LAPAN-IPB Satellite (LISAT)

3. RESULT AND DISCUSSION

3.1 SAR Calibration

SAR measured scattered matrix M may be expressed as Eq. 1 [6]:

$$\begin{pmatrix}M_{HH} & M_{HV}\\ M_{VH} & M_{VV}\end{pmatrix}=A(r,\theta)e^{j\varphi}\begin{pmatrix}1 & \delta_2\\ \delta_1 & f_1\end{pmatrix}\begin{pmatrix}\cos\Omega & \sin\Omega\\ -\sin\Omega & \cos\Omega\end{pmatrix}\begin{pmatrix}S_{HH} & S_{HV}\\ S_{VH} & S_{VV}\end{pmatrix}\begin{pmatrix}\cos\Omega & \sin\Omega\\ -\sin\Omega & \cos\Omega\end{pmatrix}\begin{pmatrix}1 & \delta_3\\ \delta_4 & f_2\end{pmatrix}$$

where $A(r,\varphi)$ – averall gain, $e^{j\varphi}$ – propagation factor describing round-trip phase, Ω – one-way Faraday rotation angle, δ_1, δ_2, δ_3, δ_4, – cross-talk terms for transmit and receive distortion matrices, f_1 and f_2 – channel imbalances. The presence of thermal noise in the measurements of matrix M is neglected here. It is well known that measured scattering matrix differs from the original one because of distorting influence of the radar equipment, influence of propagation media and signal processing at processing facilities. Taking in mind the fact that all the inaccuracies of processing stage may be tested and removed with high accuracy, the remaining two factors are originally unknown and should be removed before the application-oriented data analysis.

The signal of long wavelength spaceborne SAR systems like as L-band ones, experiences distorting influence of ionosphere. The polarization plane of the electromagnetic wave with linear polarization, traveling in ionosphere plasma in the presence of geomagnetic field, changes the orientation. According to [2], the level of Faraday rotation Ω for one-way propagation, in radians, is in Eq. 2:

$$\Omega = \frac{\mu_0 |e|^3}{4\varepsilon_0 \pi^2 m^2 f^2} * \int_s |F(\varphi,\lambda)| * \cos(\theta) * N(s) ds \quad (2)$$

where e and m are electron charge and mass, ε_0 and μ_0 - dielectric and magnetic permeability of free space, f - carrier frequency, N(s) - profile of electron concentration along the path s, φ, λ –geographic latitude and longitude, F(φ, λ) –magnetic field function and θ is angle between magnetic field vector and direction of signal propagation. Supposing the magnetic field is constant in the range of altitudes 200-400 km around maximum of electron concentration in ionosphere and inserting numerical values of constants used, Eq.2 could be transformed as Eq. 3:

$$\theta = \frac{2.378*10^4}{f^2} * |F(\varphi,\lambda)| * \cos(\Omega) * TEC / \cos(\alpha) \quad (3)$$

where TEC is total electron content in vertical column of ionosphere above the area of observation, α is SAR observation angle. For the polar orbit of the satellite above the maximum of the electron concentration profile and total electron content TEC=$5*10^{17}$ m^{-2} rough estimations shows that in L-band one-way rotation angle may reach 30^0. Faraday rotation will be small in the equatorial area, where the angle θ is close to 90^0.

Because of Faraday rotation, the scattering matrices values were corrupted as described in Eq. 4 (for this moment equipment distortion matrices is not considered):

$$\begin{aligned} M_{HH} &= S_{HH}\cos^2\Omega - S_{VV}\sin^2\Omega \\ M_{HV} &= S_{HV} - (S_{HH} + S_{VV})\sin\Omega\cos\Omega \\ M_{VH} &= S_{VH} - (S_{HH} + S_{VV})\sin\Omega\cos\Omega \\ M_{VV} &= S_{VV}\cos^2\Omega - S_{HH}\sin^2\Omega \end{aligned} \quad (4)$$

Both co-polarized components become lower than nominal values as well as cross-polarized components now are not equal. As many calibration techniques are based on the target reciprocity ($M_{HV}=M_{VH}$), in such a conditions they cannot be applied for the estimation of the distortion matrices and subsequent correction of the measurements. On the other hand, Faraday rotation angle may be estimated correctly and removed if we have polarimetric SAR observations with instrument distortions removed (the calibration of the data is done preliminary). The approach selected by JAXA is based on the fact that PALSAR equipment may be calibrated if SAR measurements are made in Faraday rotation free conditions. Therefore, for calibration activities, JAXA placed corner reflectors in Amazon rainforest area, near equator, where the Faraday effects are very small (see Eq 3). As the result, the distortion matrices measured is provided in the leader file of the image as presented in Tab. 3 below.

Table 3. PALSAR distortion matrices elements

Matrix element	Re	Im
t11	1.0000000	0.0000000
t12	0.0024270	0.0129302
t21	-0.0114724	-0.0062282
t22	0.9572169	0.3829563
r11	1.0000000	0.0000000
r12	-0.0062634	0.0070829
r21	-0.0062971	0.0080267
r22	0.7217117	-0.0236768

In addition, Quegan calibration algorithm [7] was used to evaluate cross-talk terms and calibration targets were used for the estimation of imbalance. These distortion matrices on transmit and receive were used to compensate the corrupting influence of equipment. All the polarimetric data delivered to users by JAXA are corrected for the instrument inaccuracies.

Analysis of presence of Faraday rotation on PALSAR data was estimated first by using model information about ionosphere properties for the location of ITS-A test site and the related observation time. TEC values may be evaluated using IRI2007 model from International Reference Ionosphere website http://omniweb.gsfc.nasa.gov/vitmo/iri_vitmo.html. Information about magnetic field (field intensity components, in nanoTeslas) was provided by Earth geomagnetic field model WMM2005 obtained from http://www.ngdc.noaa.gov/seg/WMM/wmm_cdownload.shtml. The direction of SAR observation was calculated from ALOS state vector in SAR Leader file and PALSAR look angle.

Faraday rotation effect and quality check (Quegan algorithm) of polarimetric data were applied for calibration purpose on two PLR level 1.1 scenes of 2007.

The result showed that the Faraday angles derived from models and measured PALSAR scenes were small in general and close enough to each other for both scenes (Tab. 4). The two-way Faraday rotation angle is remarkably small and should not distort the normalized radar cross section (NRCS) or σ^0 measurements significantly. An example of the source image (2007/05/08) and respective maps of $Arg\left(M_{rl}M_{lr}^*\right)$ distribution are presented on Fig. 5 below.

Table 4. Two-way Faraday rotation angle estimation.

Date	Lat deg	Long deg	UTC, hrs	2θ (image) deg	2θ (model) deg
07/05/08	0.516	101.9	15.85	-0.96	-4.6
07/06/06	0.517	102.5	15.82	-0.72	-1.6

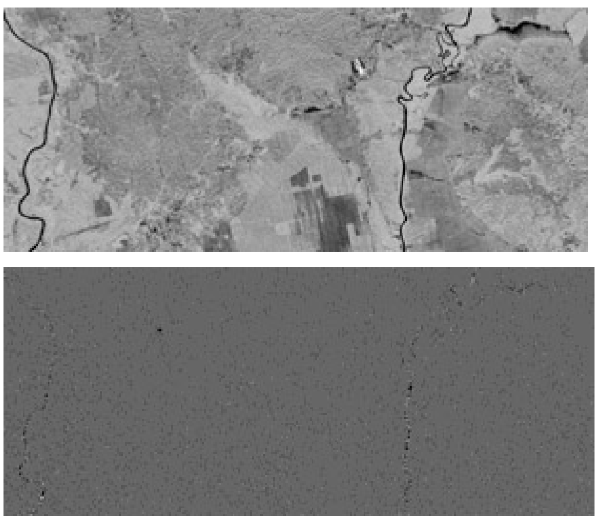


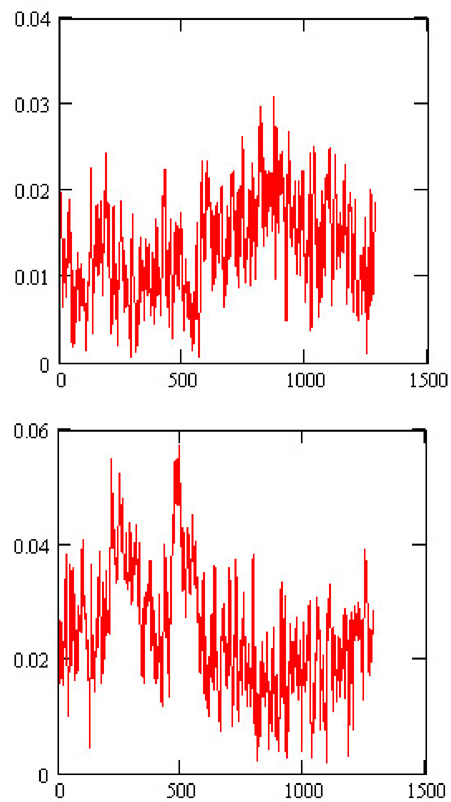
Figure 5. Amplitude image (top) and a map of $Arg\left(M_{rl}M_{lr}^*\right)$ (bottom)

On the maps of $Arg\left(M_{rl}M_{lr}^*\right)$ no any monotonous variations of intensity were found, which confirms indirectly the good quality of PALSAR polarimetric data. Some noisy features visible are explained by low level of signal from water surfaces and reduced signal to noise ratio.

As the Faraday rotation effect is very low in the PALSAR image of Indonesia, it allows checking the quality of polarimetric data by using some popular techniques like Quegan algorithm. Some popular free software packages, available in Internet, may be used for calibration purposes. For example, a number of polarimetric calibration techniques was implemented in POLSARPRO software. Among them are Quegan, Papathanassiou and Ainsworth algorithms. The Quegan algorithm was chosen and tried to estimate distortion matrices components in a way which was done in POLSARPRO. The software was modified to generate range profiles of the scattering matrices elements as well as range distribution of surface scattering matrices elements. The scene of 20070505 was uncalibrated preliminarily (the distortion matrices from the Tab. 3 were restored in the data).

A total of 800 lines from the beginning of the scene were processed, and the evaluation results were averaged so the range profiles could be generated. Since Quegan algorithm provides relative calibration, the r11 and t11 terms were set to be 1. The range plots of amplitude values for cross-talk terms on receive (r12,r11) and transmit (t12,t21) as well as imbalance on transmit t22 are plotted Fig. 6.

A comparison was then made between the average modules of the terms from plots in Fig. 6 with JAXA values from Tab. 3. The comparison results are presented in Tab. 5. The values obtained are close to JAXA values, what means that the calibration numbers extracted of the PALSAR data for the test site are correct. At the same time, JAXA distorting matrices, which were used to calibrate PALSAR data, are applicable for calibration the PALSAR data obtained over Indonesia. There is no need to uncalibrate PALSAR data and to recalibrate them again.



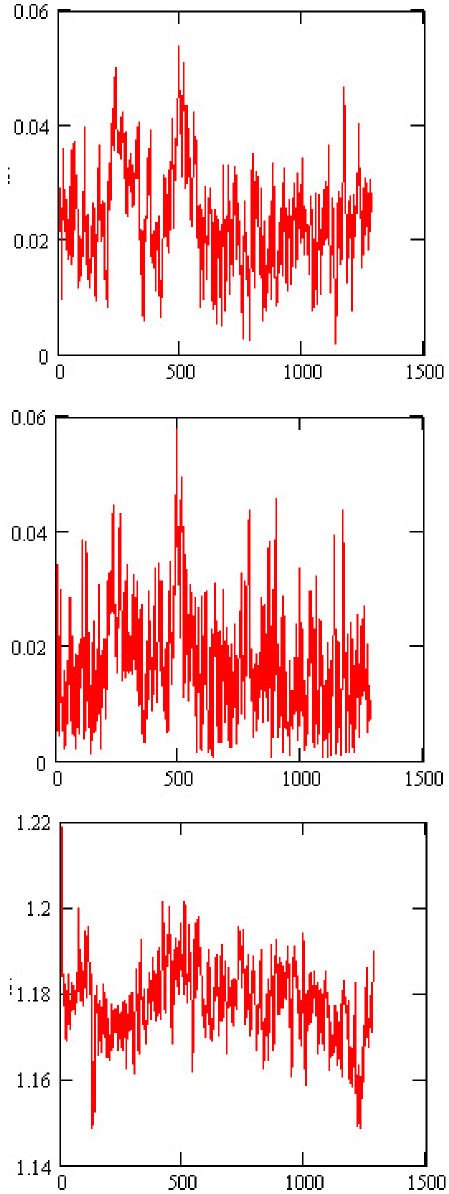


Figure 6. The range plots of amplitude values for cross-talk terms on receive (r12,r11) and transmit (t12,t21) as well as imbalance on transmit t22, displayed subsequently from top to bottom.

Table 5. Estimated average amplitudes of PALSAR distortion matrices elements.

Matrix element	Averaged range values	JAXA value
R12	0.013	0.009
R21	0.024	0.01
T12	0.024	0.013
T21	0.017	0.012
T22	1.18	1.03

The last calibration test is analysis of range distribution of σ^0. In the case of homogeneous surface like as forests, especially rain forests this distribution is useful for antenna pattern measurements. After the antenna pattern was taken into account during the image generation, the remaining variations may serve as an indication of calibration problems. Fig. 7 below displays the dependence of σ^0 in decibels with respect to range bin. Range values 0-1280 represent entire range line of PALSAR data in a given scene. There is no obvious trend in range for cross-polarized components. There is subtle decrease of σ^0 in co-polarized components. It is within the specifications declared in [6], where 1 dB absolute calibration error is acceptable for vegetation mapping and monitoring, when biomass density may be mapped with 25% accuracy and Leaf are Index +-0.5 within range 0-2. In general, the JAXA calibration quality of PALSAR data acquired over Indonesia test site is good for vegetation studies. Level of Faraday rotation in these PALSAR images is small to have a corrupting effect for the goals of AIPEX exercise.

3.2 Pol-InSAR Analysis

The SAR-Cal as the first step in Pol-InSAR analysis was applied jointly with the Institute of Radio-engineering and Electronics, Russian Academy of Science (IRE/RAS), on several PLR-215 SLC imageries of Indonesia and completed in 2008. The result is positive as given above and PLR image could be used for vegetation analysis purpose [8]. It was then followed by a first attempt for complete processing chain of POL-InSAR analysis by using one of 46-days repeat pass PLR-215 imagery pair (image #1 and #2 of Tab.2). This attempt was completed for natural forest target in 2009 but without validation, as the main focus was on the processing chain. Upon completion of this exercise, searching for Pol-Insar pairs coincided with the available forest inventory plot data was started. The search was directed to the plantation forest. As the result three image pairs were selected from image archive: image pair P-1 (#5 and #6) of 1-year repeat pass, image pair P-2 (#7 and #8) of 46-days repeat pass, and image pair P-3 (#9 and #10) of 1-year repeat pass.

Existing experience has shown that POL-InSAR analysis is highly influenced by temporal decorelation [9]. The first Pol-InSAR trial in timber plantation with image pair P-1 (PLR-231/1-year T-Baseline), was fail to pass the baseline test and could not be processed further. Image pair P-3 (PLR-215/1-year T-Baseline) was then selected for the second trial. Pol-InSAR analysis of this pair was successfully completed, despite of 1-year temporal baseline, and the result is displayed in Fig. 8. Fig. 8 top presents the position of inventory plot in ground range for verification/validation purpose. Height inversion result example from one inventory plot is displayed in Fig. 8

bottom, which was in slant range. The successful completion of Pol-InSAR analysis processing chain gives good promising application of the existing ALOS/PALSAR image archives for REDD purpose. The only problem remaining is Pol-InSAR analysis result was displayed in slant range. It needs to be displayed in ground range to be linked with operational application such as REDD.

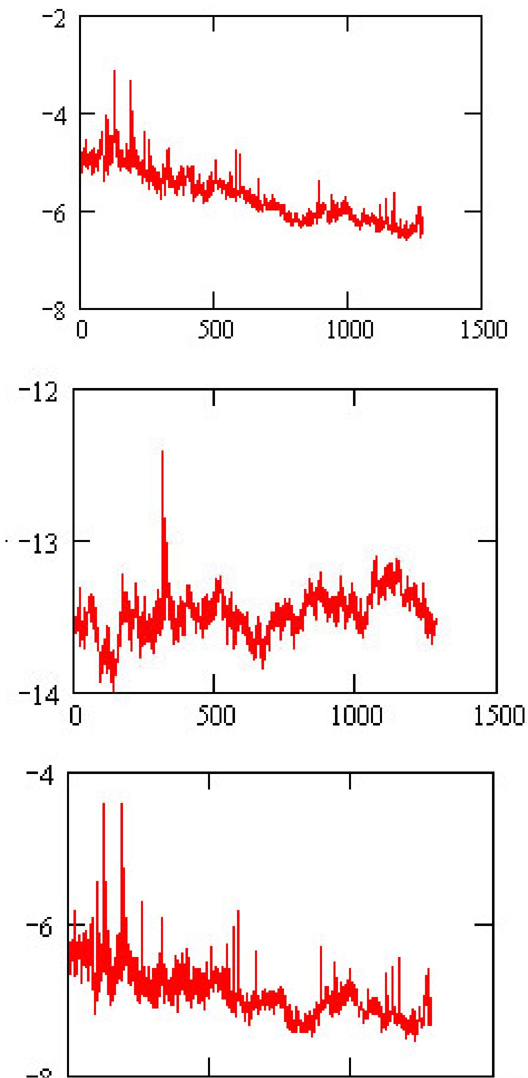


Figure 7. Range distribution of surface σ^0 at HH, HV (VH) and VV from top to bottom.

In terms of POLSARPRO operation, two conditions are required to be displayed in ground range: (1) PLR image subset process, and (2) data analysis step after the completion of height inversion process. Difficulty was high to subset the slant range image in order to be coinciding with the target AOI (Area of Interest). While in data analysis step, no direct link could be made with actual ground coordinate as all result is displayed in slant range. MapReady has provided import/export for working with internal file of POLSARPRO, but the existing utility is limited to processing of single SLC/PLR image for Pol-SAR analysis. It should include, in the future version if possible, for additional utility to work with dual SLC/PLR image pair for Pol-InSAR analysis, especially related to the above two mentioned conditions.

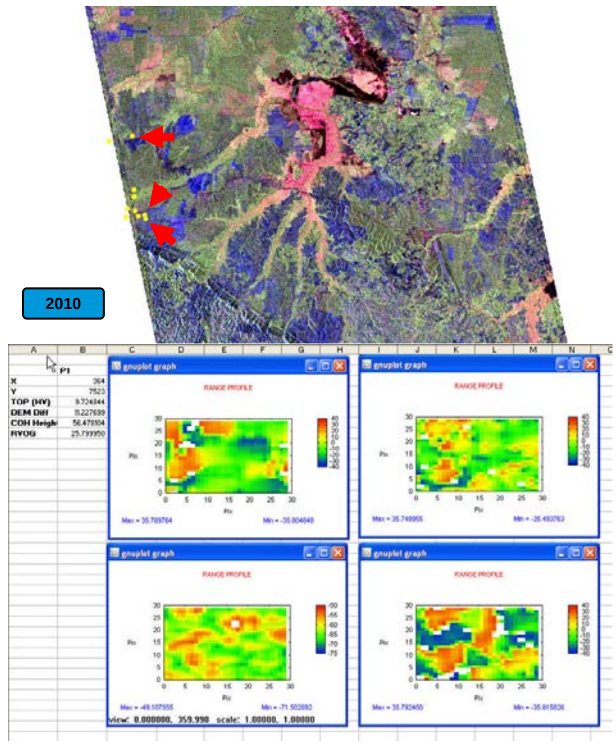


Figure 8. Pol-InSAR Analysis Result (P-3 Pair)

Due to this slant range issue, data analysis of Pol-InSAR result could not be precisely linked to the inventory plot data. However, the result of estimated forest height as given in Fig. 5 bottom, already provide the good opportunity for immediate REDD application in this readiness phase. The utility for slant to ground range mode to support Pol-InSAR analysis, therefore, is in urgent need

3.3 Area Change

The plan to have a VHR imager in a national micro satellite was realized by the flight test in 1-3 November 2010 of 3-channels Engineering Model (LISAT-EM3) and presented in Fig. 9 top. This test flight flew two types of cameras in tandem: area-CCD and line-CCD [9]. Area-CCD camera was used as control to compare the result of line-CCD camera (LISAT EM-3). Fig. 9 middle displays example of area-CCD result, and LISAT-EM3 simultaneous acquisition result (one channel example) of the same target is presented in Fig. 6 bottom. The picture shows the ability of LISAT-EM3 to record enough detail such as the periphery of the rice field target. The assumption is the ability to detect rice field periphery will allow the detection of logging track in REDD application. However, this ability will require a long focal length to be applied in orbital altitude of LISAT-FM3 (3-channels Flight Model). The constraint of micro satellite mass and dimension determine the weight and focal length of the planned camera lens. While the dimension is fixed, the mass of the micro satellite will be increased to its maximum (100 kg), to accommodate the weight of the lens. LISAT-FM3 is planned to be launched in piggy back on September 2011 by Indian rocket launcher for equatorial orbit.

Figure 9. LISAT EM-3 Test Flight

Upon successful operation of LISAT-FM3, the test flight for LISAT-EM4 (4-channels) will be next plan in 2012. It then will be followed by integration into another micro satellite (LISAT-FM4) for launch in 2013 in polar orbit.

In REDD-Indonesia readiness phase context, LISAT-FM3 will be operating in equatorial orbit one year ahead prior to 2012. This will give enough time for capacity building related to area change exercise, as the satellite will have a total of 14 pass per day. This will provide an abundant VHR satellite imagery to be analyzed. The complete coverage of the national forest in VHR imageries will become the baseline for systematic area change monitoring.

4. CONCLUSION

1. The attempt to apply POL-InSAR analysis in Indonesia for forest height of timber plantation was successfully completed.
2. Based on this progress the possibility of Pol-InSAR application in REDD will be explored further during the existing REDD Readiness Phase (2009-2012).
3. Since POL-InSAR height inversion result is in slant range, it has some difficulty for immediate application to REDD-MRV. MapReady should consider to provide additional utility to geo-code input and output of POL-InSAR forest height inversion result for immediate REDD-MRV application.
4. The availability of both POLSARPRO and MapReady, as an open source software will be a backbone for global POL-InSAR application, as demonstrated in this paper.

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