Revisiting PALSAR ScanSAR calibration: assessing the [07/2008] SIGMASAR processor upgrade

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Abstract
A first assessment of the radiometric calibration of ALOS PALSAR ScanSAR data was undertaken within the first phase of the ALOS PI project (2007/2008) and covered in the PI report ***Assessment of PALSAR ScanSAR calibration and impacts for wetland applications"*** *[1] to JAXA. The study indicated good absolute (temporal) radiometric stability of ScanSAR data (0.26 dB), but strong systematic artefacts (0.6-1.9 dB) in the calibration between the individual scans within the scenes.*
The PALSAR antenna pattern was updated in the SIGMASAR processor in July 2008 to address the above anomalies, and the objective of this study is thus to assess the absolute radiometric stability and relative, scan-to-scan, calibration accuracy of PALSAR ScanSAR data processed after the upgrade.

Keywords: ScanSAR, wetlands, calibration.

1. INTRODUCTION

One major aim of the ALOS PALSAR applications program, undertaken within the Kyoto & Carbon Initiative Wetlands Theme, is to map and monitor seasonal inundation patters in major wetlands and river basins around the world using time-series of PALSAR data acquired in ScanSAR mode. To accommodate this type of analysis, the ScanSAR data need to display stable radiometric performance between the scenes over time, as well as consistent calibration between each of the five scans in the wide-swath ScanSAR scene.

This study is set out to provide a **comparison of the radiometric performance** of PALSAR ScanSAR data (Wide Beam 1 - WB1) processed **before and after** the July-2008 **upgrade** of JAXA's SIGMASAR processor. The study addresses

- absolute radiometric calibration
- temporal stability (between scenes)
- relative radiometric (scan-to-scan) calibration.

2. CALIBRATION ANALYSIS

2.1. Reference point selection

The ScanSAR swath is 360 km and consists of five separate scan beams of different widths. Figure 1 shows the extents of the scans and their respective overlap zones. The radar illumination direction is from right to left (i.e. scan #1 is near range, scan #5 is far range).

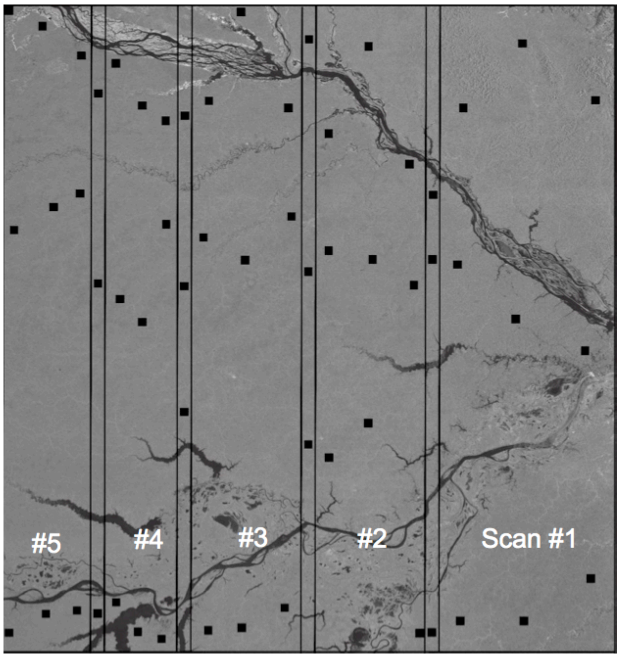

Figure 1. *ScanSAR sub-beams and location of homogeneous and stable (dryland) forest reference points. Radar illumination from right to left.*

The study area is a homogeneous tropical rain forest region in the central part of the Amazon river basin in Brazil, over which a time series of 18 ScanSAR scenes (scene ID 421/3650) acquired between January 2007 and September 2010 were available. Four of the scenes were processed with both the old and the upgraded versions of the JAXA "SIGMASAR" processor, and the remaining 14 with the upgraded processor only.

All 22 scenes were co-registered and 60 reference areas consisting of dryland (terra firme) forest were selected. The reference points were distributed across the image range, with 9 points in each scan and three in each of the scan overlap zones, as shown in Figure 1. Care was taken to select homogeneous and stable points which were non-flooded in all of the scenes. The radar backscatter coefficient was computed as:

$\sigma^0 = 10 * \log_{10}[DN^2] + CF$, where CF = -83.0 dB

2.2. Absolute calibration and temporal radiometric stability

Table 1a shows the mean backscatter values for the terra firme forest (averaged over all 60 reference points) for the four scenes processed with the **old version** of the SIGMASAR processor (processing date 20071001). The mean forest σ^0 for the four scenes is -8.57 dB, with a standard deviation of 0.17 dB between the scenes in the time series. Although the number of scenes here is insufficient to make any general statements, the values are consistent with those of an earlier study of the old processor [2] where 28 scenes over three different areas were analysed, indicating a mean forest σ^0 -8.53 dB, with a standard deviation of 0.26 dB.

Table 1a. *Dryland forest σ^0 statistics for scenes processed with old processor version.*

SIGMASAR prior upgrade		
Obs. date	Mean σ^0	St.dev (within-scene)
20070507	-9.53	0.44
20070622	-9.63	0.34
20070807	-9.89	0.29
20070922	-9.67	0.28
Mean (all)	**-8.57**	
St.dev (between-scenes)	**0.17**	

Table 1b shows corresponding results for the 18 scenes processed by the **upgraded version** of the processor. The between-scene standard deviation – which is a measure of the temporal stability of the PALSAR sensor – is 0.21 dB, which is consistent with the 0.17-0.26 dB measured for the old processor. This result is also to be expected, as the processor upgrade is not related to the temporal stability of the SAR itself.

The mean backscatter value on the other hand, is a measure of the absolute calibration accuracy of the SIGMASAR processor and a comparison of the average forest backscatter values computed before and after the processor upgrade shows a difference of more than 1.0 dB. Notable is that the upgraded processor data show lower (darker) values, with an average forest σ^0 of about -9.5 dB, which is 1-2 dB lower than what is commonly reported as a typical L_{HH}-band backscatter value for tropical forest.

Table 1a. *Dryland forest σ^0 statistics for scenes processed with upgraded processor.*

SIGMASAR v.07/2008		
Obs. date	Mean σ^0	St.dev (within-scene)
20070507	-9.53	0.44
20070622	-9.63	0.34
20070807	-9.89	0.29
20070922	-9.67	0.28
20071107	-9.48	0.21
20080509	-9.50	0.46
20080809	-9.81	0.23
20080924	-9.66	0.28
20081109	-9.55	0.32
20081225	-9.23	0.34
20090327	-9.24	0.37
20090512	-9.29	0.44
20090627	-9.54	0.34
20090927	-9.70	0.25
20091228	-9.40	0.30
20100330	-9.44	0.29
20100630	-9.85	0.28
20100930	-9.92	0.28
Mean (all)	**-9.57**	
St.dev (between-scenes)	**0.21**	

2.3. Relative (scan-to-scan) radiometry

An overview of the calibration performance of each of the five scans is given in Table 2, with the old and new processor results shown in the top and bottom parts, respectively.

The values in the tables indicate the "delta-σ^0 " differences between the scan points (the 9 points in each scan averaged "vertically" to 3 points) and the 60-point average of the scene, revealing some radiometric patterns which seem consistent for each scan over time. The values have been colour-coded so that blue cells indicate reference points that are 0.1 dB or more above (brighter) the scene average, red cells are values 0.1 dB or more below (darker) than the average, while uncoloured cells show points within +/-0.1 dB of the scene (forest) mean.

As was presented in [1] and [2], ScanSAR processed prior to July 2008 displayed significant calibration anomalies between the different scans. The top table shows how scan #1 and the overlap zones between scans #1/2 and #2/3, are about 0.20 dB darker than the scene averages, and that the far range part of scan #5 (left-most column in table), shows a sharp drop of about 0.5 dB compared to the centre and near range part of the scan.

These patterns of bright and dark "banding" are apparent in the old-processor ScanSAR scene in Figure 3a, which has been contrast stretched excessively to illustrate the effect. The figure also shows the backscatter profiles plotted across the scene, which confirm the banding effect.

Table 2. *Scan-to-scan calibration. Values indicate the difference between the dryland forest reference points σ^0 and the scene average [reference point σ^0] – [scene average σ^0]*
Top: old processor data. Bottom: upgraded processor data.

Prior to upgrade

Processing date		Scan 5				Scan 4				Scan 3				Scan 2				Scan 1		
Oct 1 2007	20061104	-0.56	-0.16	0.04	0.05	0.28	0.32	0.33	0.11	0.07	-0.24	-0.17	0.06	0.02	0.24	0.09	0.00	0.10	-0.25	-0.34
Oct 1 2007	20070507	-0.71	-0.08	0.14	0.01	0.43	0.44	0.37	-0.01	0.17	0.18	0.03	-0.22	-0.01	0.47	0.02	-0.43	-0.20	-0.32	-0.26
Oct 1 2007	20070622	-0.89	-0.06	0.28	0.08	0.50	0.56	0.45	0.03	0.31	0.34	0.04	-0.07	0.07	0.52	-0.06	-0.43	-0.30	-0.60	-0.76
Oct 1 2007	20070807	-0.30	0.30	0.45	0.19	0.42	0.47	0.40	-0.02	0.30	0.30	-0.05	-0.23	-0.21	0.37	-0.32	-0.62	-0.44	-0.61	-0.42
Oct 1 2007	20070922	-0.73	0.05	0.10	0.13	0.43	0.64	0.54	0.16	0.47	0.51	0.05	-0.10	0.06	0.49	-0.11	-0.46	-0.52	-0.79	-0.95
	Mean	**-0.64**	**0.01**	**0.20**	**0.09**	**0.41**	**0.49**	**0.42**	**0.05**	**0.26**	**0.22**	**-0.02**	**-0.11**	**-0.01**	**0.42**	**-0.08**	**-0.39**	**-0.27**	**-0.51**	**-0.55**

After upgrade

Proc. date	Acq. Date	Scan 5				Scan 4				Scan 3				Scan 2				Scan 1		
Mar 31 2010	20061104	-0.48	-0.54	-0.47	-0.33	-0.34	-0.47	-0.45	-0.44	-0.40	-0.79	-0.29	0.37	0.23	-0.01	0.56	0.86	1.10	0.88	1.02
Mar 31 2010	**20070507**	-0.90	-0.56	-0.42	-0.46	-0.19	-0.23	-0.18	-0.29	-0.11	-0.21	0.06	0.23	0.35	0.43	0.48	0.38	0.60	0.42	0.60
Mar 31 2010	**20070622**	-0.68	-0.39	-0.23	-0.40	-0.12	-0.15	-0.13	-0.28	-0.08	-0.19	-0.12	0.20	0.25	0.41	0.37	0.34	0.52	0.28	0.40
Mar 31 2010	**20070807**	-0.68	-0.33	-0.20	-0.34	-0.18	-0.14	-0.08	-0.25	0.09	-0.04	0.03	0.22	0.20	0.42	0.27	0.31	0.37	0.07	0.26
Mar 31 2010	**20070922**	-0.67	-0.34	-0.34	-0.29	-0.14	-0.02	0.01	-0.13	0.11	0.00	-0.07	0.20	0.28	0.37	0.31	0.32	0.29	0.03	0.08
Mar 31 2010	**20071107**	-0.38	-0.19	-0.21	-0.24	-0.06	-0.02	0.00	-0.14	0.00	-0.06	-0.08	0.21	0.27	0.29	0.25	0.32	0.28	-0.13	-0.11
Mar 31 2010	**20080509**	-0.75	-0.54	-0.40	-0.50	-0.20	-0.42	-0.29	-0.40	-0.13	-0.23	0.01	0.28	0.33	0.41	0.51	0.41	0.72	0.44	0.75
Mar 31 2010	**20080809**	-0.53	-0.23	-0.24	-0.32	-0.11	-0.07	0.03	-0.16	0.05	0.00	-0.07	0.18	0.20	0.37	0.25	0.21	0.32	0.02	0.09
Mar 31 2010	**20080924**	-0.63	-0.32	-0.34	-0.22	-0.11	-0.09	-0.11	-0.18	0.07	-0.11	-0.08	0.26	0.30	0.40	0.29	0.25	0.35	-0.01	0.29
Mar 31 2010	**20081109**	-0.68	-0.41	-0.34	-0.31	-0.11	-0.12	-0.15	-0.21	0.06	-0.05	-0.14	0.28	0.30	0.40	0.48	0.38	0.38	0.08	0.16
Mar 31 2010	**20081225**	-0.74	-0.56	-0.22	-0.29	-0.14	-0.10	-0.19	-0.20	-0.01	-0.13	-0.07	0.48	0.24	0.36	0.49	0.36	0.44	0.13	0.15
Mar 31 2010	**20090327**	-0.79	-0.43	-0.27	-0.37	-0.18	-0.14	-0.14	-0.25	-0.14	-0.19	-0.04	0.19	0.25	0.34	0.34	0.34	0.68	0.33	0.50
Mar 31 2010	**20090512**	-0.88	-0.56	-0.41	-0.51	-0.22	-0.28	-0.03	-0.23	-0.12	-0.14	0.08	0.14	0.19	0.51	0.40	0.35	0.86	0.37	0.50
Mar 31 2010	**20090627**	-0.62	-0.38	-0.27	-0.39	-0.12	-0.21	-0.04	-0.26	-0.09	-0.15	-0.19	0.10	0.16	0.39	0.38	0.30	0.62	0.33	0.43
Mar 31 2010	**20090927**	-0.58	-0.26	-0.19	-0.17	0.04	-0.06	-0.07	-0.10	0.00	-0.07	-0.14	0.20	0.36	0.33	0.26	0.31	0.36	-0.11	-0.11
Mar 31 2010	**20091228**	-0.65	-0.42	-0.41	-0.27	-0.12	0.08	-0.05	-0.19	0.15	0.03	-0.06	0.15	0.23	0.29	0.38	0.41	0.47	-0.01	-0.01
Mar 31 2010	**20100330**	-0.66	-0.39	-0.29	-0.25	-0.10	-0.05	-0.03	-0.27	0.04	-0.09	-0.07	0.31	0.27	0.25	0.21	0.24	0.43	0.08	0.38
Oct. 12 2010	**20100630**	-0.58	-0.24	-0.30	-0.32	-0.14	-0.15	-0.10	-0.18	0.03	-0.05	-0.15	0.25	0.25	0.49	0.25	0.24	0.37	0.09	0.24
Oct. 12 2010	**20100930**	-0.64	-0.28	-0.28	-0.32	-0.11	0.01	-0.08	-0.17	0.17	0.15	-0.09	0.28	0.24	0.38	0.33	0.32	0.34	-0.19	-0.06
		-0.66	**-0.39**	**-0.31**	**-0.33**	**-0.14**	**-0.14**	**-0.11**	**-0.23**	**-0.02**	**-0.12**	**-0.08**	**0.24**	**0.26**	**0.36**	**0.36**	**0.35**	**0.50**	**0.16**	**0.29**

>0.1 dB over mean
within +/- 0.1 dB of mean
<-0.1 dB over mean

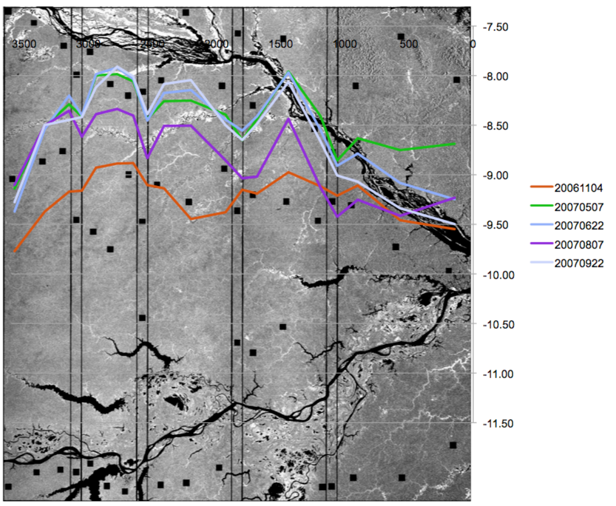

Figure 3a. *Old processor data: Significant radiometric variations between scans. Scene backscatter profiles overlaid. The background ScanSAR scene has exaggerated contrast stretch for illustration.*

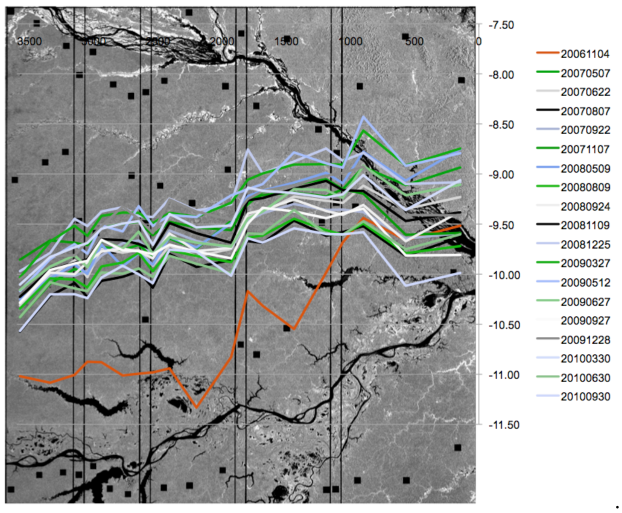

Figure 3b. *Processor after upgrade: Radiometric variations between scans improved. "Natural" near-far range σ^0 variation re-established. The background ScanSAR scene has same exaggerated contrast stretch as Fig. 3a, but no banding visible.*

The bottom part of Table 2 shows the scan-to-scan calibration after the July-2008 upgrade of the processor antenna pattern. The banding artefacts appear to have been largely removed and replaced by a systematic trend with decreasing backscatter values in the direction from near range to far range (right to left). This near-far range trend (of approximately 1 dB) is a result of the large variation of the incidence angle in the 350-km ScanSAR swath (20.1°–36.5°) and corresponds to what can be expected for a σ^0 image.

Figure 3b visualises the same information, with the backscatter profiles for the 18 scenes showing a consistent backscatter behaviour over time (between 2007 and 2010). The Fig. 3b background image has been contrast stretched with the same magnitude as that of Fig. 3a, but displaying no apparent banding.

It can be noted that figures 3a and 3b both contains one outlier profile (red curves), which does not follow the patterns of the other scenes neither before. nor after the processor upgrade. This corresponds to a scene acquired in 2006, during which tuning of the PALSAR instrument was not yet completed.

3. CONCLUSIONS

The results indicate that the July 2008 update of the PALSAR antenna pattern to the SIGMASAR processor resulted in the following:

Temporal stability: ～0.21 dB between 18 scenes acquired between 2007/01 and 2010/09. This is independent of the processor upgrade, and corresponds to similar values obtained with old processor.

Absolute radiometric calibration: The processor upgrade resulted in an overall σ^0 decrease of ～1 dB. The average backscatter level for dryland forest was measured to about -9.5 dB, which is 1-2 dB lower than commonly reported for tropical forest for L_{HH} band in the literature. It is recommended that JAXA investigate the cause of this and potentially update the calibration constant (currently -83.0 dB) for ScanSAR.

Relative (scan-to-scan) calibration: The processor upgrade resulted in significantly improved within-scene calibration. All banding artefacts observed in data processed prior to July 2008 were removed and a "natural" near-far range backscatter variation of about 1 dB was re-introduced.

4. ACKNOWLEDGEMENTS

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5. REFERENCES

[1] Rosenqvist, A. "Assessment of PALSAR ScanSAR calibration and impacts for wetland applications". ALOS PI report #217, Feb. 2008.

[2] Rosenqvist, A. "PALSAR ScanSAR absolute and relative calibration issues for K&C wetlands applications". ALOS Calibration and Validation Science Team meeting (CVST#7), JAXA TKSC, June 17-20, 2008.