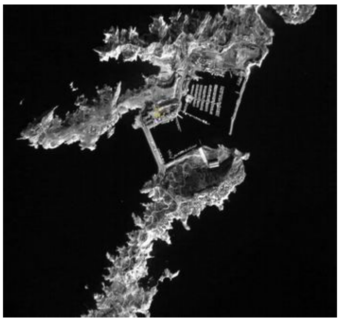
Final calibration/validation report

PRISM



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1 INTRODUCTION

1.1 Purpose of this document

Purpose of this document is to report to ESA final results collected during ALOS / PRISM data verification and calibration/validation period.

This document is a deliverable of the Phase C of the project "ALOS CAL/VAL", governed by the contract N°19284/06/I-LG, agreed between the European Space Agency and GAEL Consultant.

1.2 Document plan

- Chapter 1 Introduction and results summary,
- Chapter 2 Presents results from product geo location accuracy
- Chapter 3 Presents results from stereoscopic capability validation item,
- Chapter 4 Presents results on image quality, especially from modulation transfer function measurements

1.3 Applicable documents

[AD-1] *AMALFI Multi-Mission Facility – Contract*
19284/06/I-LG
February 13th, 2006
European Space Agency – ESRIN

1.4 Reference documents

[RD-1] *ALOS optical data verification*
Verification and Implementation Plan
GAEL-P224-DOC-002
Issue 1, Revision 3 – March 16th, 2006
GAEL Consultant

[RD-2] *ALOS-Product-Description*
GAEL-P224-DOC-003
Issue 1, Revision 0 – July 07th, 2005
GAEL Consultant

[RD-3] *ALOS/PRISM Level 1 product format description*
NEB 00016
Rev G - August, 2005
JAXA

[RD-4] *ALOS algorithm description*
NEB 01006
Rev J - October, 2006
JAXA

[RD-5] *ALOS CAL/VAL - PRISM Consolidated verification report*
GAEL-P237-DOC-005
Issue 1, Revision 0 – December 20th, 2006
GAEL Consultant

[RD-6] *ALOS On-Orbit MTF assessment*
RT 1/11824-DOTA
F.Viallefont D. Leger
ONERA

[RD-7] *Support to GAEL Consultant for the assessment of PRISM sensor model*
A.Gruen, S. Kocaman, K. Wolf.
ETH Zurich

[RD-8] Saunier S., Goryl. P and al
The contribution of ESA to the ALOS PRISM / AVNIR-2 commissioning phase
IGARSS 2007 proceedings.

[RD-9] Gruen, A., Kocaman, S., Wolff, K.,
Calibration and validation of early ALOS/PRISM images.
Journal of the Japan Society of Photogrammetry and Remote Sensing,
no.1/2007, pp. 24-38.

[RD-10] Helder, D, Choi T, Rangaswamy, R,
In-flight characterization of spatial quality using point spread functions
Post-launch Calibration of satellite sensors – Morain & Budge (eds)
ISPRS Book Series – Volume 2.pp 151-170.

1.5 Abbreviations and Acronyms

This section controls the definition of all abbreviations and acronyms used within this document. Special attention has been paid to adopt abbreviations, acronyms and their definitions from international standards as ISO, ANSI or ECSS.

ADEN	Alos Data European Node
ALOS	Advanced Land Observing Satellite
ANSI	American National Standards Institute
AUIG	ALOS User Interface Gateway
AVNIR-2	Advanced Visible and Near Infrared Radiometer type 2
CAL/VAL	Calibration and Validation
CCD	Couple Charge Device
CEOS	Committee on Earth Observation Satellite
DEM	Digital Elevation Model
DSM	Digital Surface Model
ECI	Earth Center Inertial coordinates
ECR	Earth Centered Rotating coordinates
ECSS	European Cooperation for Space Standardization
ESA	European Space Agency
CCD	Charge Couple Device
GCP	Ground control point
GPS	Global Positioning Satellite
GPSR	GPS Receiver
GRP	Ground Reference Point

ISO	International Organization for Standardization
JAXA	Japan Aerospace Exploration Agency
MTF	Modulation Transfer Function
NASDA	National Space Development Agency of Japan
PCD	Payload Correction Data
PI	Principal Investigator
PRISM	Panchromatic Remote-sensing Instrument Stereo Mapping
TKSC	Tsukuba Space Center
X direction	Convention for geo location assessment (Easting/ Across track) direction
Y direction	Convention for geo location assessment (Northing/ Along track) direction

1.6 Summary

In the continuity of the verification plan [RD-5], this document is proposing a compilation of the last calibration validation results. This work has been done in the frame of an ESA-ADEN support to ALOS optical instruments commissioning phase.

The verification of PRISM product quality has been conducted in the field of geometry and image quality. Regarding the geometry, this report demonstrates that product quality has improved with time and processing. JAXA is improving the platform orbit and control, the sensor model parameters have been adjusted and are now close to the reality. The pointing accuracy is maintained within the pixel. The assessment of the geo-location model embed within user product let us think that the accuracy may again been improved; for products acquired in March of Year 2007 and processed in April of April 2007, the verification highlights that the accuracy is now reaching 20 meter RMS for nadir and backward views and 70 meters for forward view

One objective of PRISM instrument is the cartography at 1:25000 scale of our Earth. The reliability of the Digital Surface Model (DSM) generated using PRISM triplet views is required. The study 'stereoscopic capability' demonstrates that in using a sophistical methodology a DSM with a z-accuracy of about 1 meter may be reached.

The limit of the DSM accuracy looks to remain the image quality. Some technical results on PRISM spatial resolution are given; the computation of modulation transfer function has confirmed results obtained in previous stage; the MTF along track at the Nyquist frequency of the backward view would be around 0.07, whereas the MTF across track is reaching 0.20. The results for Nadir and Forward are different and are not agreeing together.

JPEG compression or odd/even detector calibration leads to degrade the signal. When computing the edge spread function, we observe lot of noise that make difficult interpolation procedure, in addition the detector linearity is not observed because of distortions due to JPEG, so that straightforward parametric model cannot be used to estimate MTF.

2 PRODUCT GEOMETRY

The evaluation and measurement procedures have been set up in order to characterize the accuracy of product geolocation.

These studies mainly focused on end-user products (value added products); PRISM 1b2 product level, geo referenced (1B2R) or geo coded (1B2G) when systematic corrections are applied.

The methodology does not require the use of physical sensor model, the information on geo location is computed **using polynomial functions** defined according to coefficient embedded within the CEOS format.

The purpose of these activities were to appreciate the improvement of product quality along with calibration and validation period and to initiate some specific control procedures for quality monitoring.

The studies on the geo location of PRISM products are split into three main categories; 'dense' ,'triplet and 'along path'.

- The 'dense' study used as reference data, the GPS measurements which are densely spread over the area of interest defined by the related PRISM scene,
- The 'triplet' study used as reference data, the GPS measurement as well, but sufficiently spaced to cover the observations of each radiometer at the same time (Backward, Nadir, Forward views),
- The 'along path' used as reference data post processed IKONOS data located on the one hand at the northern hemisphere (Turkey) and on the other hand at the southern hemisphere (South Africa).

2.1.1 The geo-location accuracy of 1b1/1b2 product level – 'dense' study

Purpose of this validation item is to check for a short acquisition period, the geolocation accuracy of 1B1 and 1B2R (geo referenced) product level, the co registration between the three views and the alignment between Charge Couple Devices (CCDs). In this frame, the verification of the accuracy of the 1B2G product level (geo-coded) has also been performed.

Method

The study is focused on geometric quality assessment of 1B1,1B2R and 1B2G product levels.

For 1B1 product level, image data are provided separately on a CCD basis. The geo location accuracy of each CCD and for a given PRISM views is assessed. **Image orientation model based on polynomial coefficients** is checked. Orientation parameters are not estimated. We expect coherent results between CCDs and views.

For 1B2R product level, the accuracy of the three views is assessed. Image orientation model is also based on polynomial coefficients. **Some additional Ground Reference Points (GRPs) are used to refine the model** and to appreciate residual error after modeling. For 1B2G product level, the procedure remains similar, the same Ground Control Points (GCP) are used, the model cannot not be refined using GRPs since product is already geocoded.

The method for geo location assessment is semi-automatic; an operator sets (GCP) manually on the working data. GCP geographical coordinates are matched with the ones belonging to the reference data. Operator adjusts the GCP location for ensuring the best matching between the both views.

Reference data is mainly from GCPs measurements collected during several campaigns over the Ile de France and La Crau test fields. Post processed image data from SPOT4 and IKONOS is also used. The reference Digital Surface Model resolution is coarse (90 m). To discard as much as possible the influence of terrain relief, GCPs with a low altitude located over flat terrain are used.

The method leads to statistical results on displacements. Displacements according to the X axis are defined along with the cross track direction in case of 1B1or 1B2R product levels. With the same principle, displacements according to the Y axis are defined along with the along track direction or the northing direction.

The geo location results are always expressed in metre unit.

Working data

The following ALOS / PRISM dataset sample, acquired over Paris (2.68°E, 44.42°N) and La Crau (5.184°E, 43.51°N) target zones has been used for 'dense' study.

Observation date	Processing date	File identifier	Processing sw	Testfields
12-avr-07	24-avr-07	ALPSMB060152780 ALPSMN060152725 ALPSMF060152670	4500307004	La Crau
26-nov-06	24-avr-07	ALPSMB059862675 ALPSMN059862620 ALPSMF059862565	4500307004	Paris

table 1 - Dataset used for 'dense' study.

Results

BACK	CCD1	CCD2	CC3	CCD4
RMS X	4,275	28,245	15,177	8,8
RMS Y	5,429	35,848	13,79	4,546
RMS	**6,91**	**45,638**	**20,506**	**9,905**
h	49	100	57	0
NADIR	CCD1	CCD2	CC3	CCD4
RMS X	22,867	22,419	28,336	25,997
RMS Y	9,141	3,895	3,474	5,253
RMS	**24,627**	**22,755**	**28,548**	**26,523**
h	69,4	68	208	251,875
FOR	CCD3	CCD4	CCD5	CCD6
RMS X	38,703	48,757	39,338	n/a
RMS Y	62,316	55,643	59,811	n/a
RMS	**73,357**	**73,982**	**71,588**	n/a
h	51	45	40	n/a

table 2 – 'dense study' results for 1b1 product level (metre unit).

NADIR View	
Mean X	-578,83
Mean Y	-503,96
Mean	796,26
Standard deviation X	173,23
Standard deviation Y	251,07
Standard deviation	219,15
h	50
RMS error X	604,2
RMS error Y	563,04
RMS error	825,87

table 3 - 'dense study' results for 1b2G product level (metre unit).

		Back	Nadir	For
RMS 0 GRP	RMS X	6,799	5,942	33,021
	RMS Y	49,316	3,404	85,291
	RMS	**49,782**	**6,848**	**91,46**
RMS 1 GRP	RMS X	4,946	4,188	3,592
	RMS Y	17,626	5,151	12,535
	RMS	**18,307**	**6,638**	**13,04**
RMS 2 GRP	RMS X	4,765	2,205	3,537
	RMS Y	20,928	3,123	13,505
	RMS	**21,463**	**4,136**	**13,96**
RMS 3 GRP	RMS X	1,774	2,971	4,867
	RMS Y	3,163	2,43	7,953
	RMS	**3,627**	**3,838**	**9,324**

table 4 – 'dense study' results for 1b1 product level (metre unit).

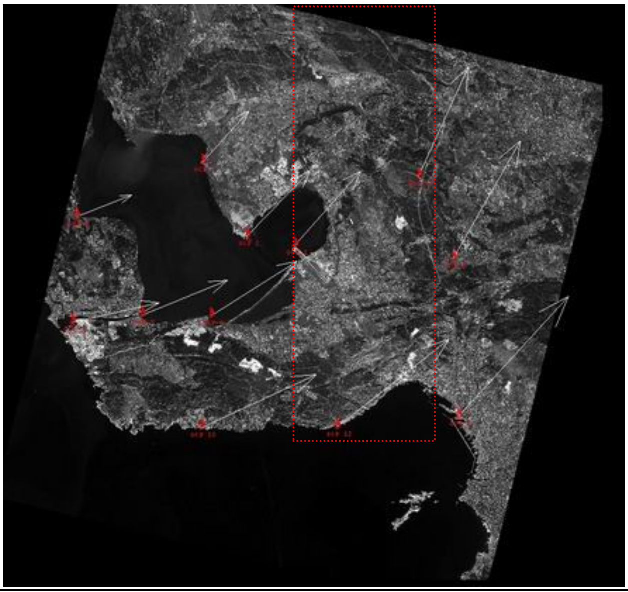


fig. 1 - Error Vector fields (x10) overlay image from 1B2G product level.

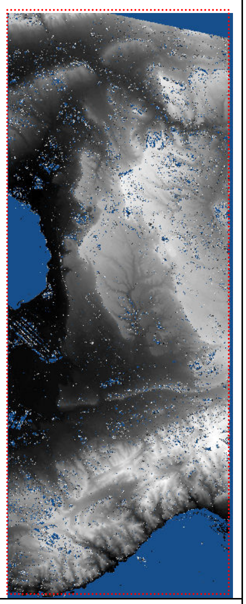


fig. 2 - Illustration of the terrain relief.

For 1b1 product results from each camera are not consistent (table 2). A high variability contaminated backward view, for the over view results remains stable (fig. 3). Even on nadir view image for which the effect of parallax could be neglected a misalignment between ccds is observed.

For 1b2R product level ('path-oriented'), we observe that

- the **geo location of the forward view (91m RMS)** is again greater than the one of nadir and backward views (respectively 6.8m and 49.782 m RMS)
- after refinement of polynomial model using 3 GRPs , the accuracy of nadir and backward is reaching about 1.5 pixel whereas, the one of forward view remain below the operational goal.

The alignment between ccd number 4 and 5 belonging to forward view looks more difficult to model.

For 1b2G product level ('geo coded'), the assessment results are not as we may expect. The geo location accuracy is about 800 m. It may be due to a processing error from level1b2R to level1b2G.

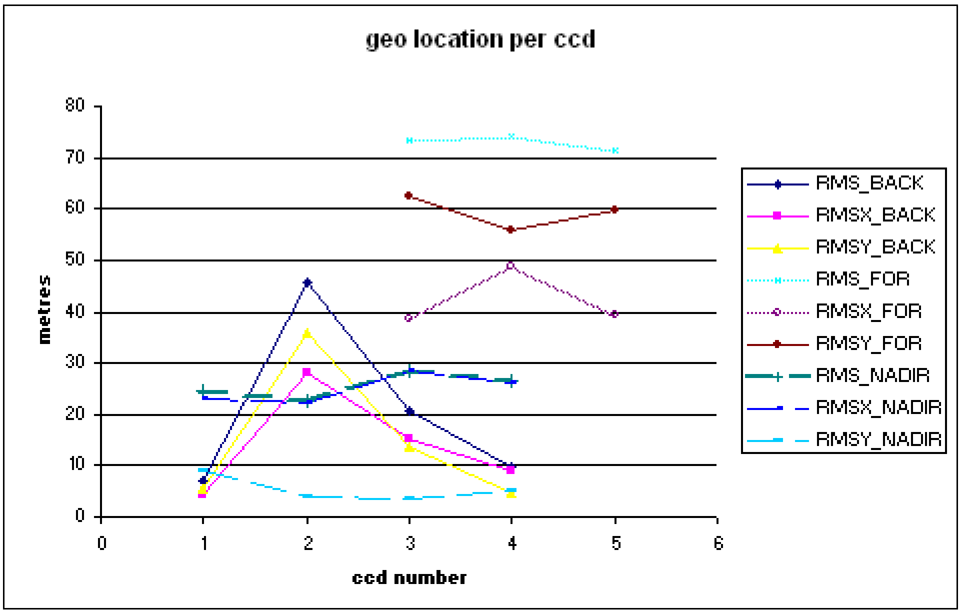


fig. 3 - the ccd geo location per each radiometer.

<u>Test field</u>

Ile de France

Site (2.68°E, 44.42°N) is located at the eastern part of Paris suburb area. Located close to GAEL Consultant, after several GPS campaigns about 30 GCPs have been collected. The site displays mean size urban areas, agricultural fields and forest landscape. The airport of Melun-Villaroche (**Erreur ! Source du renvoi introuvable.**) forms a good site, for specific control, the track takeoff direction is perfectly aligned with satellite track orientation.

La Crau

The site (5.184°E, 43.51°N) is located all around "étang de Berre". The terrain elevation varies from 0 up to 300 metres. The landscape can be hilly (fig. 2) and displays agricultural fields, pine forest, various airports, sea port and more generally coastal area. The GCPs are selected such as their altitude does not exceed 50 metres (fig. 1). The reference data are based on few GPS measurements and post processed SPOT4 data.

2.1.2 The geolocation accuracy of 1b2R product level – triplet study

The purpose of this validation is to assess 1B2 product geo-location for data acquired in triplet mode. Underlined verification is the checking **of radiometer alignments and the evaluation of prost processed pointing**.

<u>Method</u>

We consider a dataset sample from the three PRISM views acquired at the same time (scene center time is 11:03:41.420 UT). Geographical distance between Image data from backward / forward views and image data from nadir view is about 350 km.

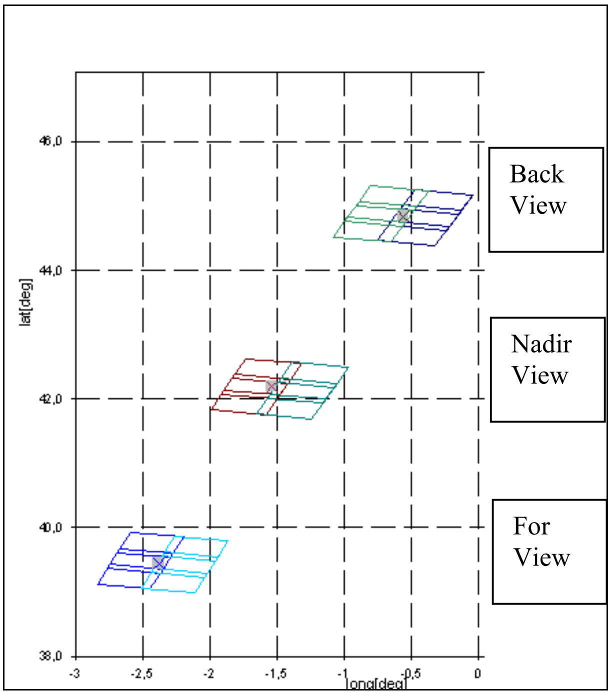


fig. 4 - PRISM scene location for study on triplet mode

The 'Triplet' study focused on the assessment of 1B2R product level geo location.

The image orientation procedure has been performed using polynomial coefficients such as provided with product (leader file (Ancillary 1, map projection)).

Method leads to a statistical displacement results in term of easting and northing between the PRISM 1B2 geo coded image and a corresponding reference one.

Without Ground Reference Point (GRP), the actual image orientation procedure is not accurate; it leads to strong first order displacements and it makes difficult to appreciate internal geometry of image data.

To overcome this issue, few exterior orientation parameters (translation, similitude, rotation) are estimated in order to compensate error due to polynomial transformation. In doing this**, an improved image orientation procedure** is used and a new product geo location assessment is performed.

The method for controlling image geo-location is similar to the one used previously.

Working data

Dataset has been delivered by JAXA to ESA. Data have been observed from the ALOS path number 335. Following ALOS / PRISM dataset sample used is listed in table (table 5) just here after.

Observation date	Processing date	File identifier	Processing sw
14-août-06	18-août-06	ALPSMB029522750 ALPSMN029522750 ALPSMF029522750	36012056007

table 5 - Dataset used for 'triplet' study.

Results

Due to image quality, identification procedure of GCP over image data from backward view has revealed to be sometimes confused. It may impact results consistency.

Image orientation procedure is more accurate for data from Nadir view than for data from Backward and Forward views.

Geometric distortions such scaling and bending impact more seriously image from theses views. Three ground reference points added for refined image orientation procedure improve significantly image geo location.

In doing this, we observed that compensation of external errors through correction of polynomial behavior remains not sufficient and **sub pixel accuracy goal is not achieved**.

Results are listed just here after, the geolocation error is indicated without GRP and, when adding one GRP for compensation of external errors (table 6).

When one GRP is added, following observations can be done:

- the error in x direction reaches up to 22.67 m (RMS) and remains stable along with PRISM views,
- the error in y direction is varying from 14.62 m (RMS) up to 42.12 m (RMS) along with radiometer and cannot be compensated using rotations.

PSM View	GRP	RMS	RMS dx	RMS dy	Mean
BACKWARD	0	744,40	572,12	476,26	754,62
	1	33,93	20,17	27,29	40,36
NADIR	0	274,48	126,75	243,48	293,18
	1	26,97	22,67	14,62	88,27
FORWARD	0	759,09	621,65	435,60	724,61
	1	45,95	18,37	42,12	60,02

table 6 - ‘Triplet study’ results (metre unit).

We got difficulties to orientate the three radiometers in modeling as much as possible the errors. This assessment have been performed on product **processed with an old processing version software**. This verification should be played back with a new dataset.

2.1.3 The geolocation accuracy of 1b2R product level – along path study

The objective of the ‘along path’ study is to observe if the product geo location accuracy remains stable during a long acquisition period. Especially when comparing stability of the model for product acquired over northern and southern hemisphere.

In addition, PRISM pointing alignment parameters have been updated four times between January and April 2007. Several modifications of processing software have occurred in order to improve the geometric model. Indeed, the other objective is to follow the product geo location accuracy along with processing version.

<u>Method</u>

The assessment technique remains unchanged to the one explain just here above. The specificities of the method, is that target zones are located within northern hemisphere (Turkey, Tarsus) and southern hemisphere (South Africa, Le Cap). Data have been observed from the ALOS path number 263.

Working data

Observation date	Processing date	File identifier	Processing sw
1-sept-06	17-janv-07	ALPSMB032132915	3601005606
	24-avr-07	ALPSMN032132860	4500307004
	23-mai-07	ALPSMF032132805	45003070005
1-sept-06	17-janv-07	ALPSMB032132915	3601005606
	24-avr-07	ALPSMN032132860	4500307004
	23-mai-07	ALPSMF032132805	45003070005
19-avr-07	23-mai-07	ALPSMF065682805 ALPSMN065682860 ALPSMB065682915	45003070005
19-avr-07	23-mai-07	ALPSMF065684230 ALPSMN065684285 ALPSMB065684340	45003070005

table 7 - Working dataset and processing software version.

Results

Processing software and improvement of quality

For product acquired in September, the consecutive assessments along with processing version, highlighted that **processing software upgrades did not improve the geolocation accuracy of product acquired prior to the date of improvements.** However**,** the processing software updates improve the product quality for the on going observations.

From the along path study, we observe

- **Geo location error increases along with time**; and geolocation of product from South Africa is less accurate;
- The deviation between the both northern and southern hemisphere products is about **20 m for backward and nadir view,**
- This same deviation reaches **50 m RMS for the forward view**
- The displacement errors increase simultaneously according to X and Y axis

Along with processing software version, the accuracy improvements is observed for couple of products acquired over Turkey but not for product acquired over South Africa; for these products the RMS in Y direction increases systematically.

However, the quality of image internal geometry has changed and is now more consistent. **The analysis of residual error when accounting for terrain relief highlights** a linear relationship between the Euclidian norm of displacement errors and the altitudes. The linear dependency is obvious for product acquired in April 07' , the correlation coefficient reach 0.82 (fig. 6).

It is more difficult to conclude for product acquired in September 06' and no linear dependency is observed (fig. 5). Even if, for the both assessment the same sample of GCPs has been used.

These two observations let us think that the internal geometry has improved with time and processing updates.

	TURKEY		SAFR	
File id	ALPSMB032132915	ALPSMB065682915	ALPSMB032134340	ALPSMB065684340
h	35	40	58	57,94
RMS X	5,631	5,417	25,957	26,585
RMS Y	108,753	101,701	108,634	130,466
RMS	108,899	101,845	111,692	133,147
RMS Corrected altitude And Bias	3,244	2,618	3,48	4,3
File id	ALPSMN032132860	ALPSMN065682860	ALPSMN032134285	ALPSMN065684285
h	54	36	69,4	66,52
RMS X	7,684	8,993	37,244	29,602
RMS Y	72,17	71,155	84,74	102,306
RMS error	72,578	73,288	92,564	106,502
RMS Corrected from Bias RMS	2,401	3,593	2.945	2.821
File id	ALPSMF032132805	ALPSMF065682805	ALPSMF032134230	ALPSMF065684230
h	50	35	62	66
RMS X	3,86	3,68	55,328	53,718
RMS Y	125,22	122,63	132,275	161,691
RMS	125,28	122,69	143,38	170,637
RMS Corrected altitude And Bias	3,96	4,64	6,1	4,19

table 8 - Along path study results.

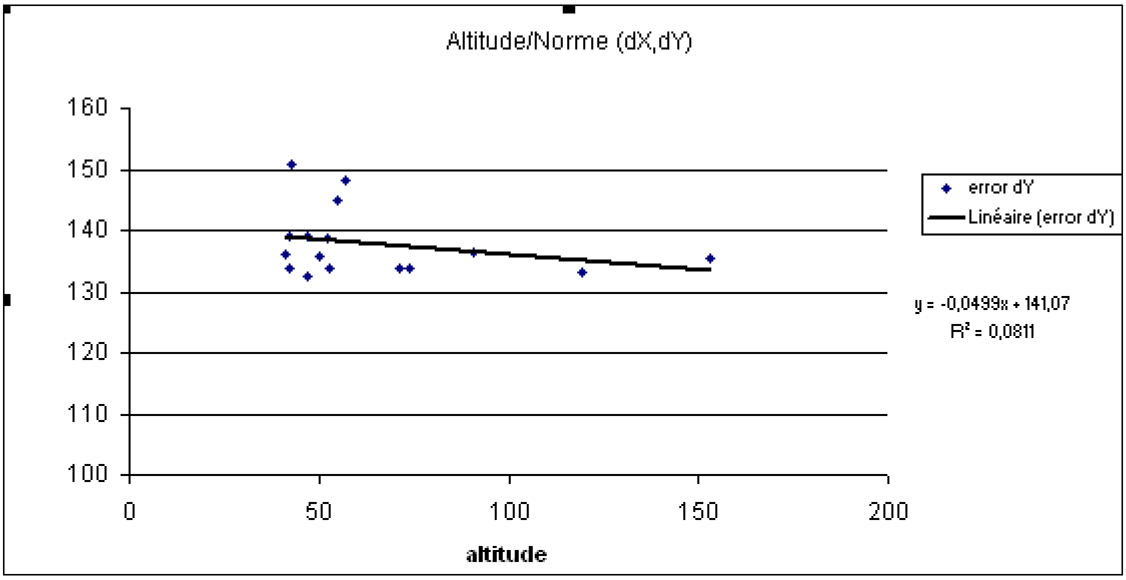


fig. 5 - Trend analysis, norm of displacement errors along with altitude, ALPSMN032….

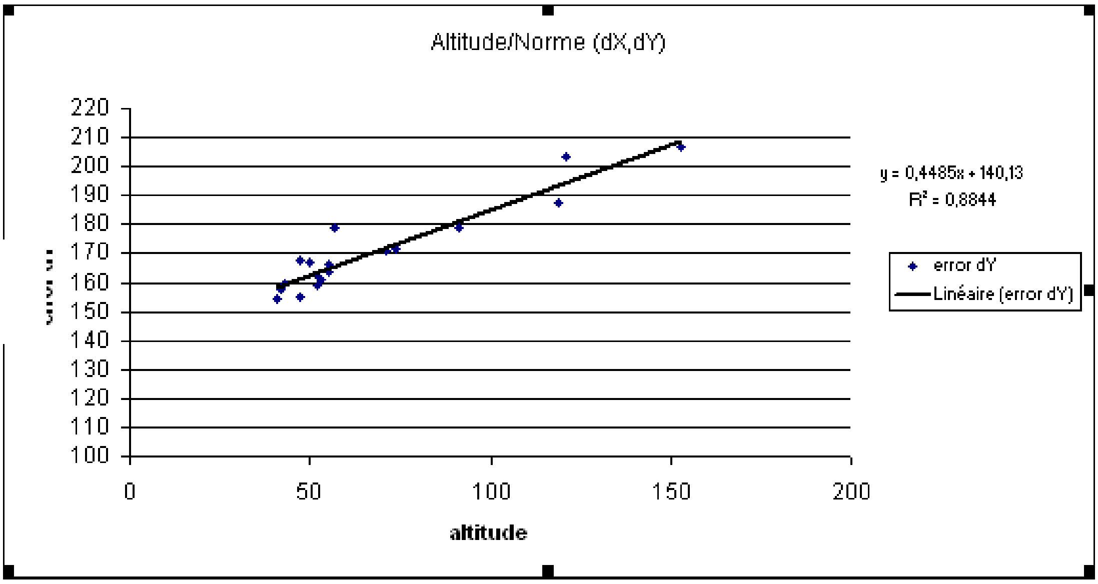


fig. 6 - Trend analysis, norm of displacement errors along with altitude, ALPSMN065….

Test field

Tarsus

Reference data used for this validation exercise is a dataset from IKONOS sensor. Product is orthorectified using digital elevation model (20 m grid).

Site (35.347°E, 36.76°N) is located over ADANA city in Turkey. The site mainly displays crop fields and small urban areas. The field limits can be clearly defined The terrain relief is flat. The site elevation, for region defined as the overlap area between IKONOS and ALOS / PRISM data is about 30 metres.

Le cap

Reference data used for this validation exercise is a dataset from IKONOS sensor. Product is orthorectified using digital elevation model (20 m grid).

Site (18.391°E, -34.034°N) is located over Le Cap city in South Africa. The site mainly displays urban, residential area with very well defined limit between city structures. The site elevation, for region defined as the overlap area between IKONOS and ALOS / PRISM data is about 60 metres. Main limitation of such site is the weather, image are often cloudy.

2.1.4 Synthesis

The first assessment performed at the beginning of the mission demonstrated that the geo location was reaching about 8 km (RMS). The product - ALPSMN018714285 - processed on July 2006 with software version 036010056006 and for which acquisition period was June 1 06' was of **poor geo location accuracy**, **the RMSE was 7876 m, RMSEX 1826.897 m and RMSEY 7661.338 m.** When correcting the product from bias (translation), the RMSE reaches 4.957 m, **RMSEX 3.412 m and RMSEY 3.596 m.**

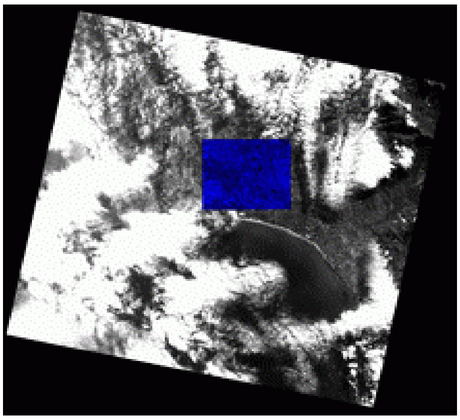


fig. 7 - IKONOS data (blue) overlay PRISM data.

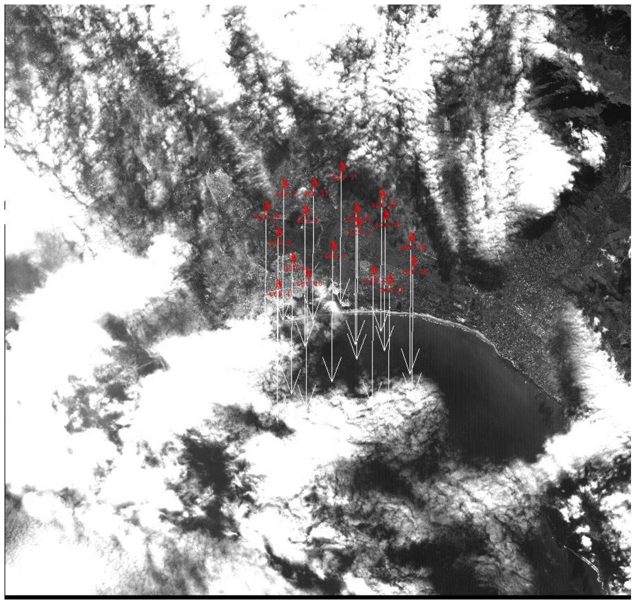


fig. 8 Error vector fields

After several updates of PRISM geometric model and pointing alignment parameters performed by the Japanese agency JAXA, the product accuracy has improved.

These studies demonstrate that the product geolocation accuracy is now within 100m (RMS). **The 1B2R one** (for product acquired with NADIR view and located over south Africa) **is now 106.52 m (RMS) RMSEX 29.602 m and RMSEY 102.306 m**. When applying external orientation procedure, residual errors analysis magnifies taht the accuracy **reaches 2.820 m**, it is very close to the sub pixel accuracy.

3 STEREOSCOPIC CAPABILITY

This validation item is more detailed in [RD-5].

3.1 Digital Surface Model production with PRISM stereo views

The objective of the calibration/validation activities was to produce a digital surface model using PRISM views and estimate its accuracy.

Method

ETH Zurich Laboratory managed the verification stage dealing with the evaluation of PRISM stereoscopic capability. The reference data used for this validation exercise are from ESA geometric test field based in Italy, Piemont (44.5°N ,7.3°E) and located at the edge of Mont Vizo (Alpes).

Such as seen previously, image orientation procedure based on polynomial method does not offer satisfactory results for calibration purposes. Prior to DSM generation, an accurate image orientation procedure must be applied through the estimation of the **internal and external orientation parameters**.

The external orientation modeling takes into account physical properties of the sensor and satellite position.. As part of adjustment, the Direct GeoReferencing (DGR) Model (DGR) and the Piecewise Polynomial Model (PPM) (with stochastic exterior orientation) approaches are adopted for modelling the sensor trajectory. Camera interior orientation parameters are not given to the community. Estimation of these parameters is performed through self-calibration procedure during bundle adjustment.

A part of 39 GCPs (recorded with differential GPS techniques) are used as check points, and the other ones as control points for refinement of bundle adjustment procedure and estimation of exterior (and possibly) interior orientation parameters. GCP coordinates are introduced as observations into the adjustment and constrained stochastically, according to their measurement and definition accuracy.

Working data

Following ALOS / PRISM dataset sample has been used for sensor model validation. Dataset has been delivered by JAXA to ESA. Study has focused on 1B1 product level.

Observation date	File names	Orbit Data Precision	Attitude Data Precision
4-sept-06	ALPSMB032582755 ALPSMF032582645 ALPSMN032582700	Precision	OnSitePrecision

table 9 - Dataset used for stereoscopic capability assessment.

Results

ETH methodology and results for calibration validation of PRISM sensor model are more detailed in [RD-9]. table 10 lists results of exterior and interior orientation procedures according to sensor model used; DGR and PPM-2, for five(5) and nine(9) ground control points. The results are in metre unit.

GCP No	5	5	9	9
Model	DGR	PPM-2	DGR	PPM-2
RMSExy	2.34	2.58	2.2	2.3
RMSEz	1.05	2,36	1.03	2.35

table 10 - Accuracy results from exterior and interior orientation procedures.

With the DGR model, the RMSE values in planimetry are at sub pixel level (below 2.5 m) with five GCPs. The use of nine GCPs do not improve results. The accuracy in height (RMSEz) from DGR model is about 1 m with five GCPs and the use of nine GCPs do not improve accuracy. With PPM-2 model results, orientation procedure using five GCPs provides accuracy in height on the order of 2.3 m. The use of nine GCPs do not improve the accuracy.

External and internal orientation parameters have been used to generate the DSM depicted with fig. 9.

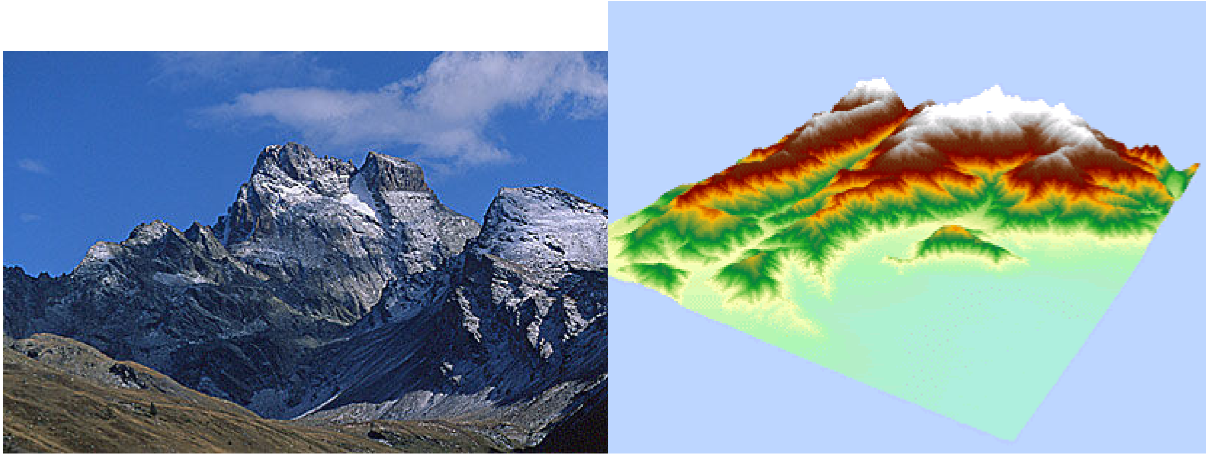


fig. 9 - DSM Piemonte (Italy), generated by ETH..

<u>Test field</u>

Site (7.3°E, 44.5°N) is located at edge of Mt Viso, a natural frontier between France (Queyras) and Italy (Piemont). The site displays mountainous landscape (forest, bare soil), agricultural fields over flat area, and small urban areas. The elevation ranges from 40 meter to 3841 meter.

Two GPS campaigns have been funded by ESA over Piemont test field. The first one has been operated by GAEL Consultant and has occurred in September 06' during which about 23 GCPs have been collected. The present report is based on these first measurements.

The second one has been done conjointly with GAEL Consultant and ETH Zurich. About 20 measurements have been collected and they are using for results consolidation before data surface model generation. Results will be published in the next document version.

3.2 Verification of PRISM DSM

Purpose of the verification exercise was to evaluate the z accuracy of generated PRISM DSM.

<u>Method</u>

The analysis has been performed using reference altitudes retrieved on one hand from ground control point recorded with Differential GPS and on the other hand from a SPOT 5 HRS DSM.

This both reference dataset are used independently and the z-accuracy obtained is compared. The statistical computation is based on altitude class defined as follow:

- class 1 < 400 m,
- 400 <Class 2 <800 m;
- 800 <class3<100 m,
- 100 < class 4.

Results

A first visual inspection of altitude curves computed on the both DSM (PRISM and SPOT), highlights that the both altitude curves perfectly match. fig. 10. illustrates that more details are provided with altitude curves computed from PRISM DSM than when using the SPOT one.

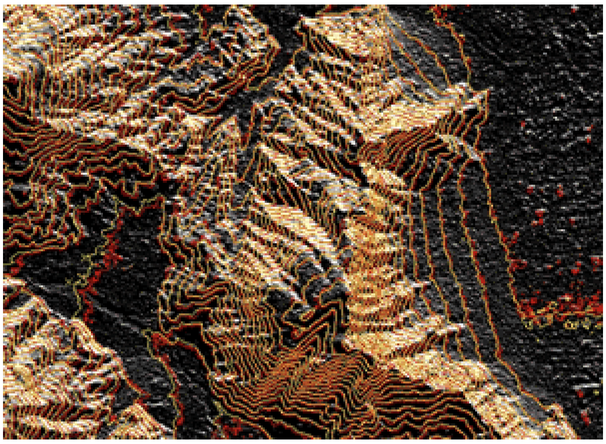


fig. 10 - DSM Piemonte (Italy) in background, altitude curves, PRISM (red), SPOT (yellow).

An overview of results is provided with table 11 and table 12. The z-accuracy is varying according to altitude class. We discarded results obtained with altitude class number 4. For a flat terrain relief , we observed that the first approach provides an accuracy of about 1.5 m. The second comparison confirms that DSM accuracy of PRISM remains within specification. Because SPOT DSM is of lower resolution, results do not reflect the real accuracy of PRISM DSM (3.6 m for altitude class 1)

	Altitude Class		
Données	1	2	3
Moyenne Delta-GPS-ETH	-0,83	-0,906331438	-8,85
Ecartype Delta-GPS-ETH	1,242801495	1,656057706	10,71991915
Min Delta-GPS-ETH	-2,2	-2,7	-24,6
Max Delta-GPS-ETH	1,7	3,471	-0,6
RMS	1,49447501	1,88784634	13,90104912

table 11 - PRISM DSM verification with GPS measurement as reference.

	Altitude Class			
Données	1	2	3	4
Moyenne Delta-SPOT-ETH	-0,908333333	-1,65695	-7,82375	-5,5526
Ecartype Delta-SPOT-ETH2	3,462095065	5,206658727	2,266569563	10,44844753
Min Delta-SPOT-ETH3	-8,015	-11,302	-10,59	-23,099
Max Delta-SPOT-ETH4	2,953	12,733	-5,646	3,854
RMS	3,579269714	5,463952636	8,14545282	11,83221968

table 12 - PRISM DSM verification with SPOT3D product ent as reference.

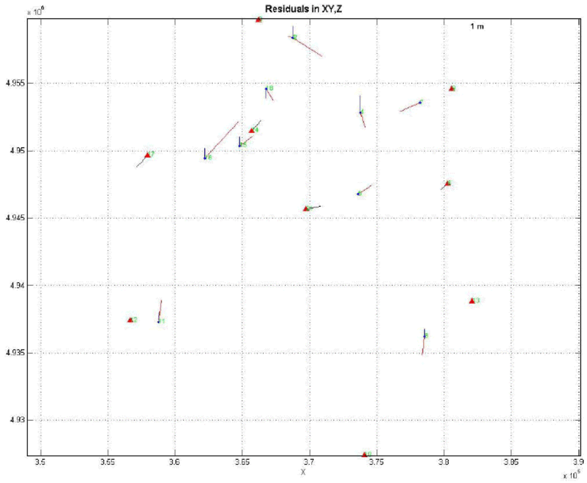


fig. 11 - Planimetry and height residuals distribution in object space.

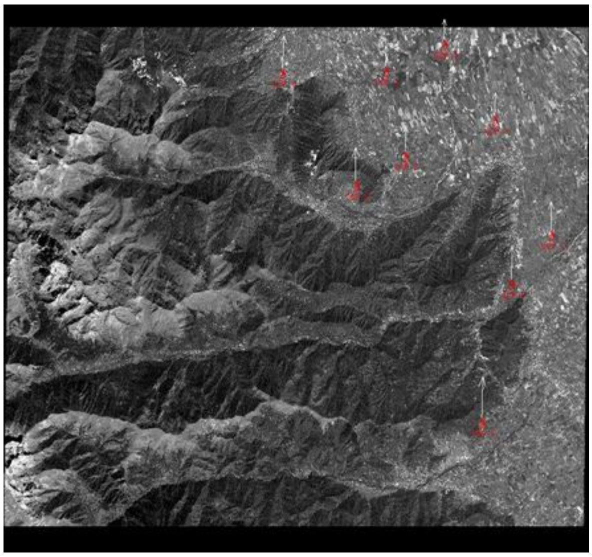


fig. 12 - Piemont site, a part of GRPs collection

4 PRODUCT IMAGE QUALITY

4.1 Modulation transfer function results

Purpose

The objective of this work was to confirm Modulation Transfer Function (MTF) results obtained as output of the previous image quality assessment performed by ONERA team ([RD-6],[RD-8]) . Results were unconsolidated because of saturation that contaminated the input dataset.

Method

The MTF computation developed at GAEL Consultant is based on Point Spread Function (PSF) method. Image data used as input are from natural or artificial target for which sharp transition between dark and bright uniform areas is observed.

The procedure is non parametric. MTF is calculated as the Fourrier Transform (FT) of the estimated PSF derived from the Edge Spread Function (ESF). The MTF results at the Nyquist frequency is reported. The methodology is explained in [RD-10].

The measurements have been performed on artificial target located at Salon de Provence (South of France, lat / lon 43,514 / 5.184). The target looks a draughtboard; its size and surface reflectance properties are well known (table 14).

The target such as view per the three radiometers is not saturated (table 15). The ESF is deduced from a discrete re-alignment procedure based on the sub pixel location of the edge on each line / column (fig. 13).

The re-alignment procedure gives as output a one-dimensional series of measurements that are non-equally spaced. The non parametric approach is adopted because of missing information regarding the detector behavior electronic and optical system characteristics.

The difficulty of such method is the data sample. Interpolation and filtering schemes are set up in order to re build the edge profile with equally spaced data. From the edge profile is computed the point spread function, the Signal to Noise Ratio (SNR) and the Full Width at Half Maximum (FWHM). The SNR and FWHM indicate the quality of the FTM measurements.

A target oriented in across track direction will conduct to the determination of ESF along with image line and so that will lead to the computation of the along track MTF.

Working data

Following ALOS / PRISM dataset sample has been used for sensor model validation. Dataset has been delivered by JAXA to ESA. Study has focused on 1B1 product level (table 14).

Observation date	Processing date	File identifier	Processing sw	Testfields
12-avr-07	24-avr-07	ALPSMB060152780 ALPSMN060152725 ALPSMF060152670	4500307004	La Crau

table 13 - Dataset used for MTF computation.

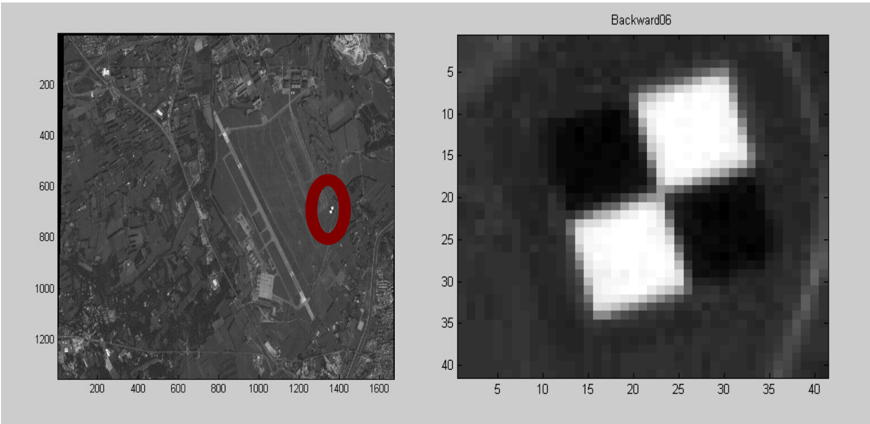


table 14 - Salon airport and MTF target.

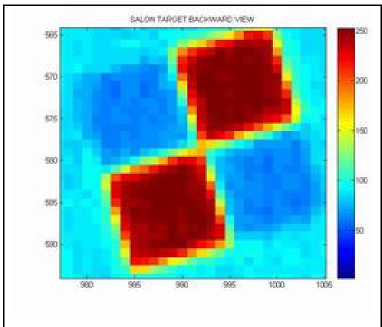
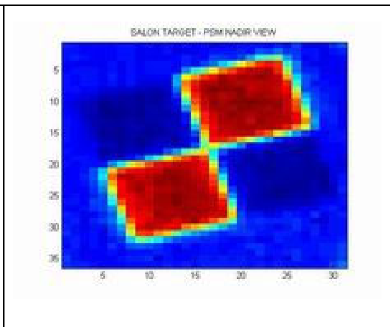
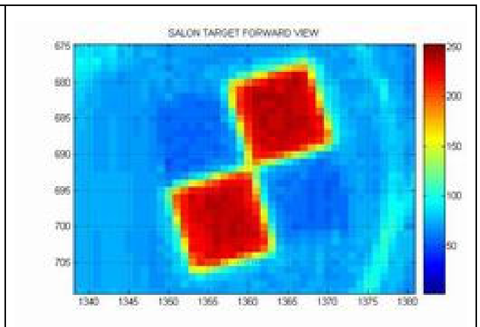
		
Backward view	Nadir View	Forward view

table 15 - MTF target observed with the three PRISM views.

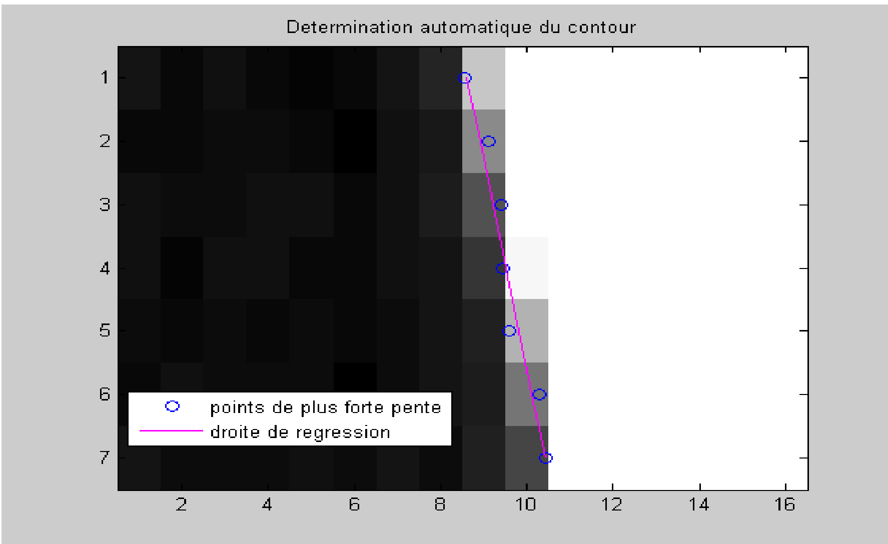


fig. 13 - sub pixel location of the edge location and interpolation.

<u>Results</u>

The MTF at nyquist frequency has been computed in the both along/across tack directions and for the three PRISM views. Results are listed in table just here after (table 16).

	MTF Along Track(y) at Nyquist	MTF Across Track(x) at Nyquist	SNRy	SNRx	FWHM y (lines)	FWHM x (pixels)
BACK	0,07	0,20049	54,1906	80,227	1,8	1,3
NADIR	0,079	0,13804	13,7185	85,0553	1,7	1,45
FORWARD	0,11006	0,11777	102	20,781	1,5	1,5
NADIR Corrected	0,075	0,13972	13,8174	33,3067	1,7	1,35

table 16 - MTF, SNR and FWHL results.

As a first approach, we tried to fit a parametric model to the edge profile such as commonly done in the community. No suitable model has been found, the residual errors were always exceed our matching criteria defined using L2 norm. **The linearity of the sensor is difficult to be modeled with a parametric approach.**

The non-parametric approach looks to provide satisfactory results

- the MTF results for Backward view are similar to the ones obtained by ONERA team on an older product,
- the SNR level for backward view indicate that we can consider the measurement as reliable.
- The across track results are always better than the along track ones.

On the other hand, we observe that

- the MTF in along and across track direction is not stable along with radiometers,
- the SNR level in line direction reach 13 for nadir view which is extremely low,
- the SNR level in pixel direction reach 20 for forward view which is also extremely low,

The odd/even mis-calibration and jpeg compression increase the noise level and disturb the linearity of the detector response.

These artifacts make the MTF computation very sensitive to the choice of the window and our interpolation process maybe less efficient. The methodology will be played back using much more configurations.

We applied to image data from NADIR view, cosmetic algorithms proposed by a member of the ALOS calibration/validation science team. **The MTF has been computed on the resulting image (NADIR Corrected). We observe that MTF is not increased significantly and remains very close to results obtained with the original NADIR view.**

The FWHM in pixel direction decreases due to sharpening (table 16), in parallel the SNR remains low and decrease for the pixel direction. Some hypothesis may be formulated; the smoothing process does not remove and even reinforce the jpeg compression patterns.

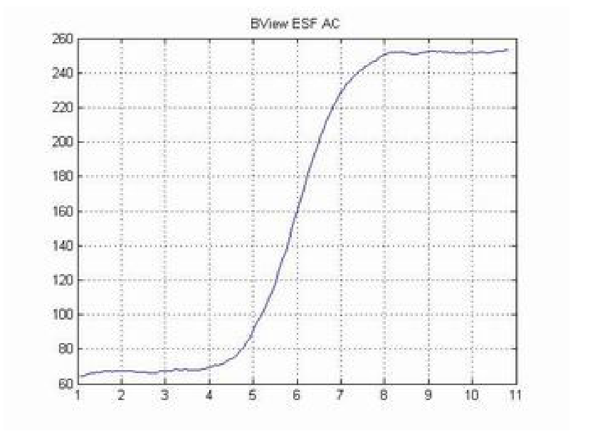
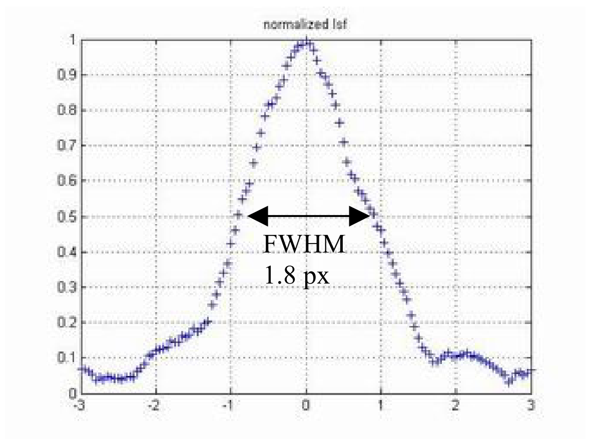
	
AL BACK VIEW - ESF	AL BACK VIEW - PSF

table 17 - Along track BACKWARD VIEW – ESF / PSF.

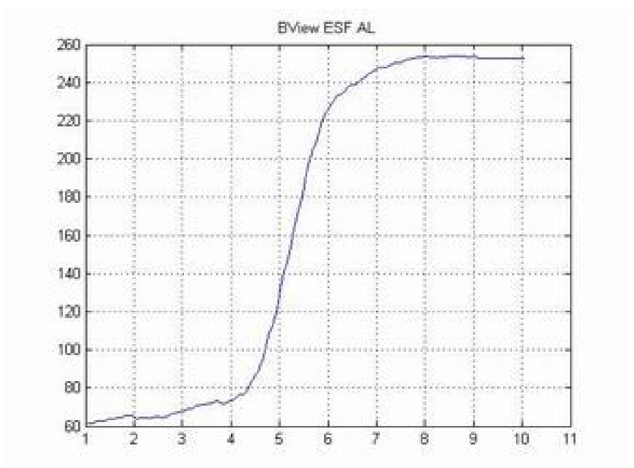
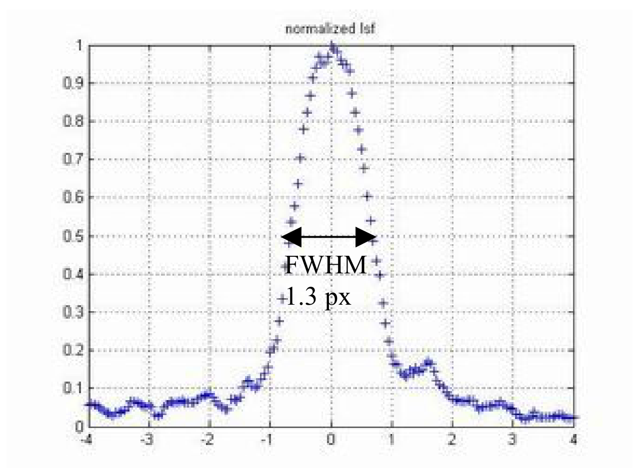
	
AC BACK VIEW - ESF	AC BACK VIEW - PSF

table 18 -Across track BACKWARD VIEW – ESF / PSF.

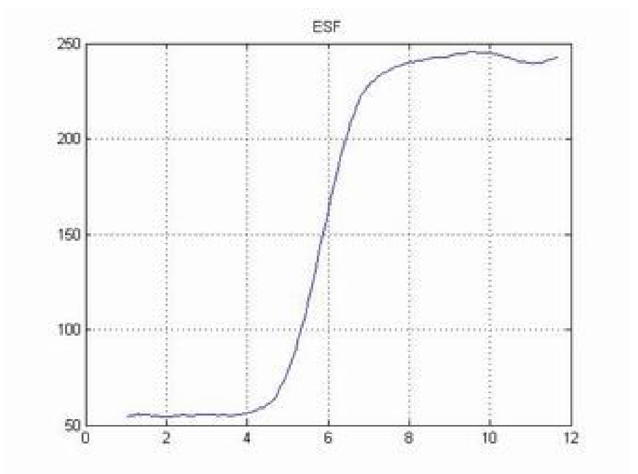
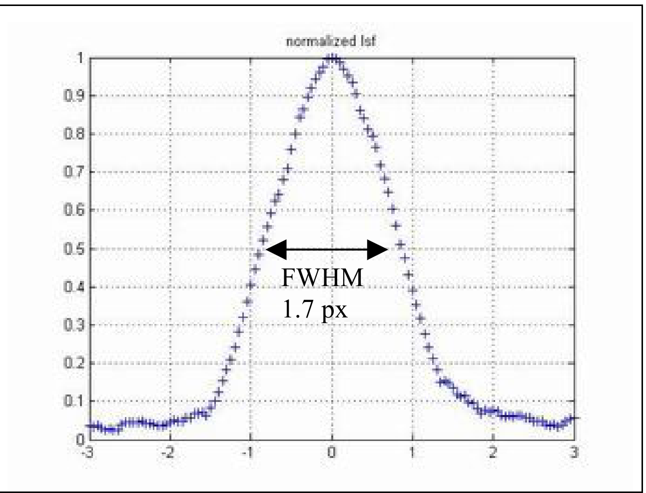
	
AL NADIR VIEW - ESF	AL NADIR VIEW - PSF

table 19 - Along track NADIR VIEW – ESF / PSF.

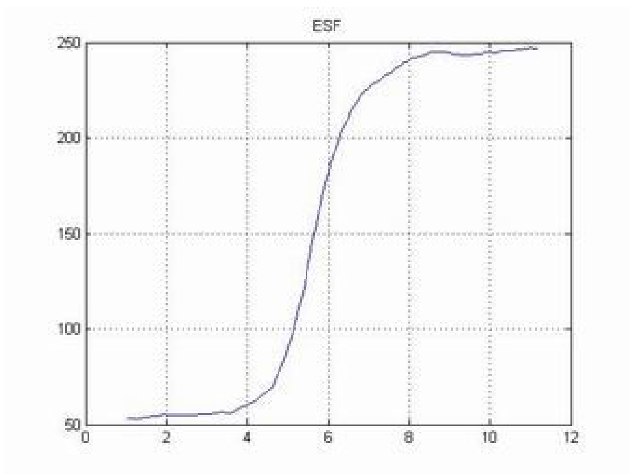
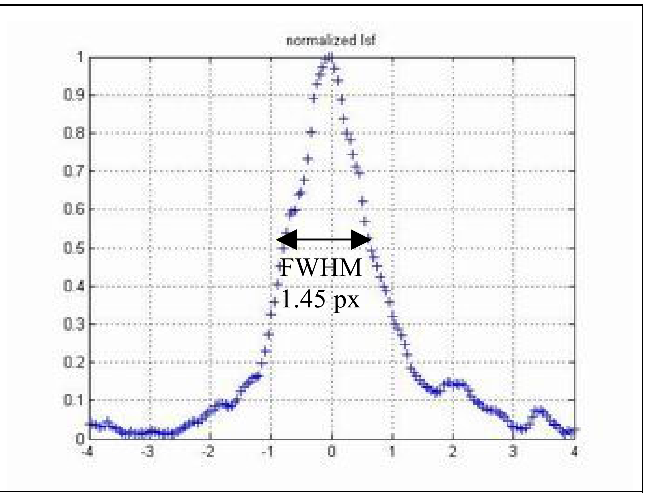
	
AC NADIR VIEW - ESF	AC NADIR VIEW - OSF

table 20 – Across track NADIR VIEW – ESF / PSF.

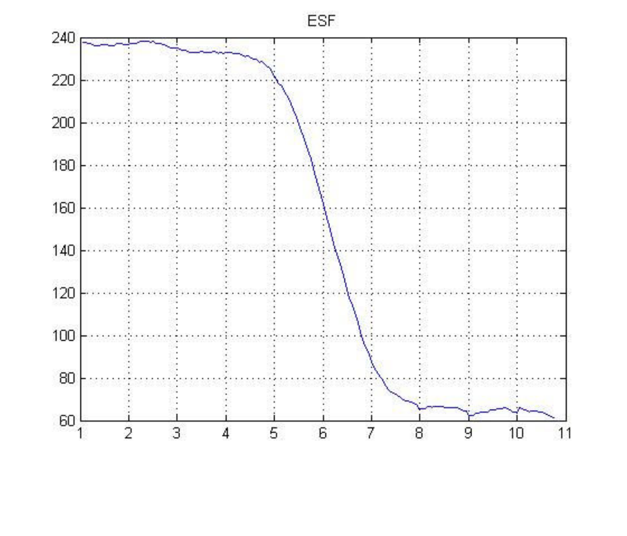
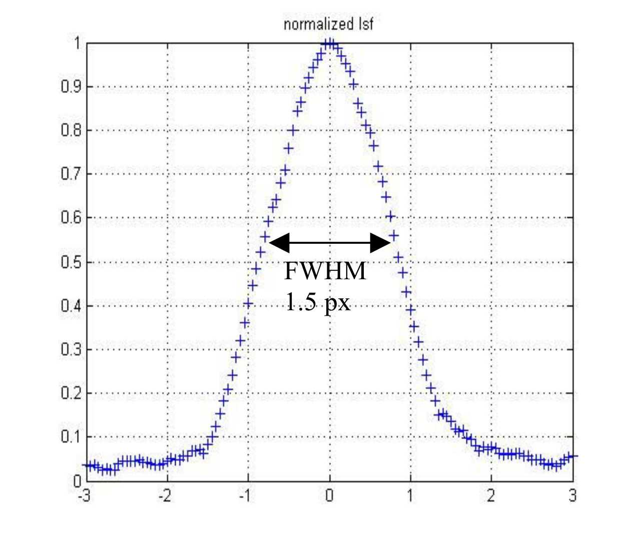
<table>
<tr><td>
</td><td>
</td></tr>
<tr><td>AL FORWARD VIEW - ESF</td><td>AL FORWARD VIEW - PSF</td></tr>
</table>

table 21 - Along track FORWARD VIEW – ESF / PSF.

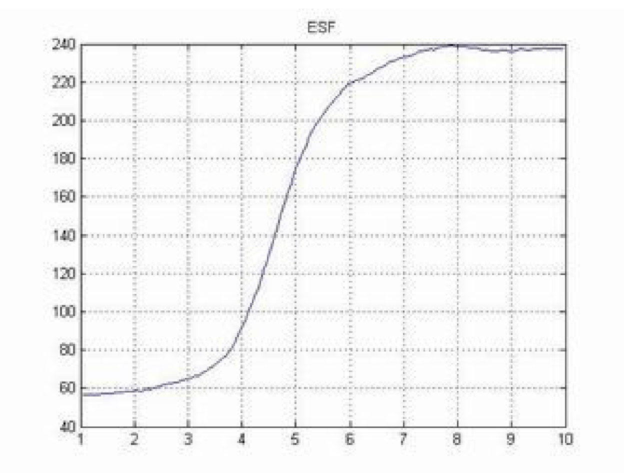
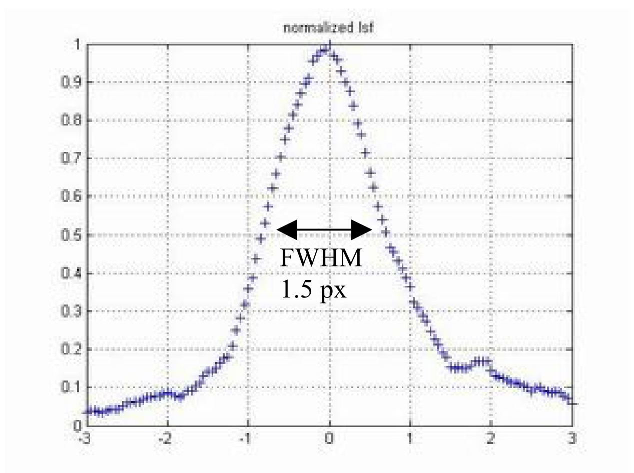
<table>
<tr><td>
</td><td>
</td></tr>
<tr><td>AC FORWARD VIEW - ESF</td><td>AC FORWARD VIEW - PSF</td></tr>
</table>

table 22 - Across track FORWARD VIEW – ESF / PSF.