The contribution of the European Space Agency to the ALOS PRISM / AVNIR-2 commissioning phase

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Abstract— **The Advanced Land Observing Satellite (ALOS) was launched on Jan 24th, 2006 by a Japan Aerospace Exploration Agency (JAXA) H-IIA launcher. It carries three remote sensing instruments: Advanced Visible and Near Infrared Radiometer type-2 (AVNIR-2), Panchromatic Remote-sensing Instrument for Stereo Mapping (PRISM) and Phased Array Type L-band Synthetic Aperture Radar (PALSAR). Within the framework of European ALOS Data European Node (ADEN), European Space Research INstitute (ESRIN) as part of European Space Agency (ESA), teamed up with JAXA for contributing to ALOS commissioning phase plan. This paper summarizes the strategy that ESA adopted to define and implement a data verification plan for mission operated by foreign nation, classified as so called ESA Third Party Missions (TPM). The verification of ALOS optical data from PRISM / AVNIR-2 instruments activities had begun four months after satellite launch on March 2007.GAEL Consultant (French company) has supported ESA / ESRIN for designing and executing the plan. A team of principal investigator's has been put together to provide technical expertise. This paper includes a description of the verification plan and summarizes the methodologies that were used for radiometric, geometric and image quality assessment. Preliminary results indicate that the radiometric calibration of the AVNIR-2 sensor agrees with Landsat 5 (L5) Thematic Mapper and the MEdium Resolution Imaging Spectrometer (MERIS) calibration to within 10%. The geometry accuracy of PRISM and AVNIR-2 product remains within specifications but some recommendations are provided to improve the quality of product. The preliminary results from the PRISM image quality assessment through computation of PRISM Modulation Transfer Function (MTF) raised few questions toward jpeg compression that degrades image.**

Keywords-component; Commissioning phase, calibration, data verification, radiometry, geometry, image quality

I. Introduction

The Advanced Land Observing Satellite (ALOS) spacecraft was launched on Jan 24th, 2006 onboard a Japan Aerospace Exploration Agency (JAXA) H-IIA launcher for an operational lifetime of 3 years in a near-polar, Sun-synchronous orbit, at a mean altitude of 691 km. Its payload consists of two optical and one radar sensors. The Advanced Visible and Near Infrared Radiometer type-2 (AVNIR-2), and the Panchromatic Remote-sensing Instrument for Stereo Mapping (PRISM) are the both optical sensors. The coverage and distribution of ALOS data is done through the implantation of the ALOS Data European Node (ADEN) concept. The acquisitions performed globally are classified in four regions: Asia, Europe and Africa, America, Australia and Oceania. Each Data Node is responsible for the provision of level-1 data to the users within the geographical zone covered by the Node. In that framework, the European Space Agency (ESA) is managing the European Node. The ALOS foreign mission is supported as a "Third Party Mission" (TPM); ESA uses its multi-mission ground systems of existing national and industrial facilities and expertise to acquire, process and distribute data.

In that context the ESA is participating to the JAXA CALibration/VALidation Science Team (CVST). During the commissioning phase the quality of ALOS data is verified in order to get the approval for operating ALOS as a TPM mission and to report to JAXA on the product quality.

The AVNIR-2 multi spectral sensor operates in four spectral bands in the Visible and Near Infrared (VNIR) bands, with 10 meter spatial resolution and a ground swath of 70 km at nadir. The PRISM panchromatic sensor offers a ground sampling distance of 2.5-meter for a ground swath that depends on the number of camera views involved in the observation; 35 km if data from the three views are recorded (in triplet mode) and 70 km if only one view is operating. The PRISM has three independent optical systems for nadir, forward and backward looking to achieve along-track stereoscopy [1]. This design forms a good basis for extracting highly accurate digital elevation model (DEM). This paper describes the verification plan and proposes a compilation of results collected during the data verification period.

II. VERIFICATION PLAN DESCRIPTION

The plan has been organized according to three major milestones,; quick assessment, in depth assessment and calibration / validation such as depicted in (Figure 1.) and has been defined as close as possible to the one of JAXA science team schedule. The first stage was dedicated to quick assessment of products. It purpose was to provide qualitative results; to validate assessment tool, to demonstrate ALOS mission operates nominally and to check processing chain installed at ESA ground stations. The second stage has been oriented towards in-depth control of geo location and geometry, stereoscopic capability and image quality. The last stage has focused on radiometric calibration activities and on the follow up of processing chain improvements.

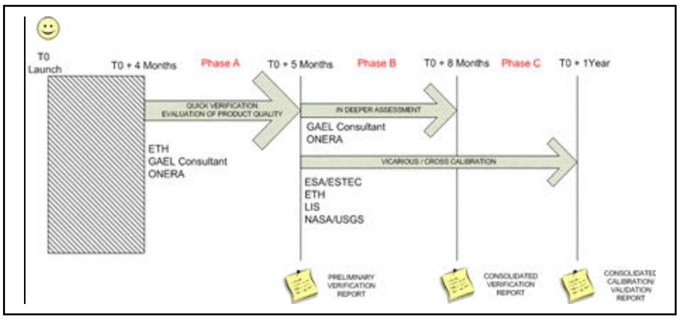

Figure 1. Scheduling of verification plan.

The ESA / ALOS science team gathered a wide panel of skilled actors, experts in the fields of radiometry (ESA, ULCO, and USGS), geometry (ETH, and GAEL Consultant) and image quality (ONERA). During this period, a major concern of ESA has been to ensure an efficient data distribution, to facilitate the sharing of reference equipments and methods. A set of tools has been proposed to support investigators in reading and inspecting ALOS products: the ALOS Expert Tool [1] and the BEAM VISAT toolbox [2].

III. RADIOMETRIC CALIBRATION

Assessments on the radiometric calibration of AVNIR-2 has been carried out through analysis of band to band calibration stability and inter calibration exercises between AVNIR-2 sensor and other Earth observation sensors; PRISM, Landsat-5 Thematic Mapper (TM), and MEdium Resolution Imaging Spectrometer (MERIS). A major part of methodology and results are explained in [2]. This section is a synthesis on radiometric calibration methods and results. Methodologies have been applied to AVNIR-2 dataset acquired over the western Libyan desert site (28.9°N / 23.75°E). Libya site is considered to be an invariant target that is stable and uniform with time. Dataset sample includes more than 20 products observed from mid May 2006 to December 2006.

A. AVNIR –2 Band to band calibration and radiometric calibration stability

A coarse evaluation of interband calibration and Top Of Atmosphere (TOA) reflectance based on time series analysis provide a first appreciation on the calibration stability. When excluding ratio between band 1 and band4, the band ratio remains stable and does not exceed 5% (Figure 2.). Regarding TOA reflectance time series, if one consider the first measurement as reference, the deviation observe for the next measurement remains also within 5% for band number 2, 3, 4 (Figure 3.). Because atmospheric component affects more seriously the band 1 measurements, the conclusion for band 1 are more difficult to establish.

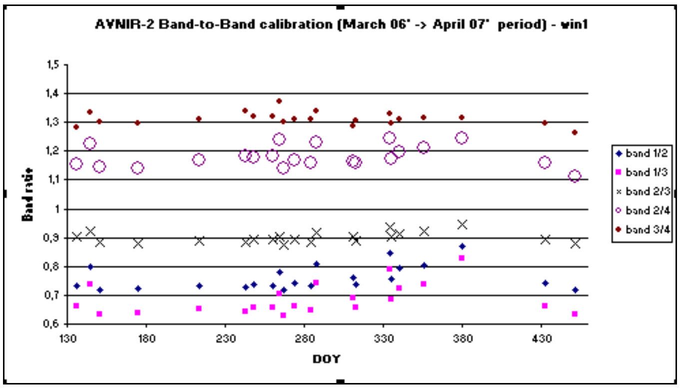

Figure 2. - AVNIR-2 multi date band to band ratio series over one Year

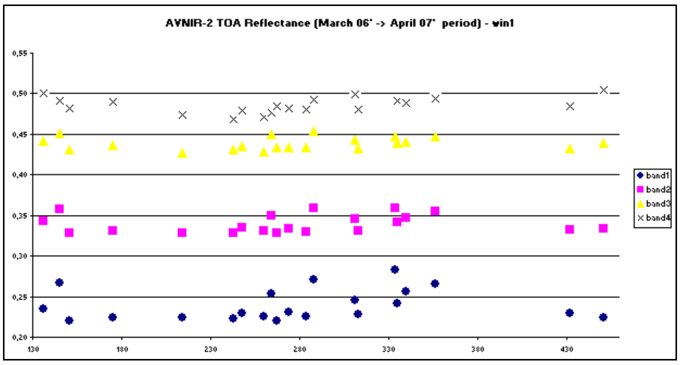

Figure 3. AVNIR-2 TOA reflectance time series over one Year.

This method does not account for influence of atmosphere and Bidirectional Reflectance Distribution Function (BRDF) but remain suitable in the first stages of verification period.

B. AVNIR-2 data vs. Landsat 5 Thematic Mapper data

The comparison of nearly simultaneous TOA reflectances over areas observed by the AVNIR-2 and TM sensors have been compared. The cloud-free L5 TM scene acquired on May 15, 2006 (9:10:12 AM) has been selected and compared to an AVNIR-2 scene acquired a day later on May 16, 2006 (8:47:16 AM). The average relative differences in reflectance obtained from the comparison are shown in TABLE I. In band 1, the average percentage difference is -6.55%; in band 2, 1.24%; and in band 4, -4.99%.

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[1] ALOS Expert tool (ALEX) is a subset of telimago application available at http://www.gael.fr/telimago

[2] BEAM VISAT available at http://www.brockmann-consult.de/beam/

C. *Intercomparison 2: AVNIR-2 datas vs. Simulated AVNIR-2 data using AATSR, A-MODIS, POLDER-3 and MERIS data*

The inter comparison of AVNIR-2 measurements and the simulated ones using multi sensor data set observations, namely, POLDER-3, Aqua MODIS (A-MODIS), AATSR and MERIS [3] has been performed. Processing based on radiometric rescaling to the MERIS reference sensor results into a radiometrically homogeneous dataset. The error budget of the methodology is estimated to be about 5 %. AVNIR-2 appears to be 7.0 %, 1.1 %, 2.5 % (saturated band) and 3.5 % below the radiometric scale of MERIS in respectively band 1, 2, 3 and 4 (TABLE I. . Band 1 is out of the error budget.

D. *Intercomparison 3:AVNIR-2 data vs. Simulated AVNIR-2 data using MERIS data*

AVNIR-2 data has been simulated using MERIS data. The methodology is based in the identification of the linear relationship between the TOA reflectance and the scattering angle. The linear fit of the simulated AVNIR-2 data with scattering angle provides linear BRDF models associated to each AVNIR-2 spectral band. AVNIR-2 data are then reconstructed and compared with simulated values. After correction of effects due to water vapor absorption occurring in band 4, we observe that magnitude of difference between AVNIR-2 data and simulated ones using MERIS are the following ones: ones -4.6 %, -1.4%, -5.9% and -10.3 % respectively for band 1, 2 , 3, and 4; as shown in TABLE I.

E. *Conclusions*

	Inter comparison1	Inter comparison 2	Inter comparison 3
Band 1	-6.55%	-7%	-4.6%
Band 2	1.24%	-1.1%	-1.4%
Band 3	Saturation	Saturation	Saturation
Band 4	-4.99%	-3.5%	-10.3%

TABLE I. SYNTHESIS OF RADIOMETRIC CALIBRATION RESULTS.

The different approaches notice saturation occurring in AVNIR-2 band3 which make difficult to fully appreciate radiometric calibration. Band ratio method and intercomparison 2 seems to indicate that a degradation occurs in band 1 and 2. This results are still to be confirmed with longer time series.

IV. GEOMETRIC CALIBRATION

A. *AVNIR-2 Band to band registration*

Band to band registration results demonstrate that accuracy remains within 0.4 and 0.5 pixels for band 1, 2, 3. Some inconsistencies (between 0.5 and 1 pixel) are observed when band 4 is involved into computation. The impact of cubic convolution on band to band registration accuracy should not be neglected.

B. *Absolute geo location accuracy*

AVNIR-2/PRISM image model is defined according to polynomial coefficients embedded within product format and stored into the leader file. This model is planimetric and does not account for altitude; geo location values are predicted at ellipsoid level. The methodology is defined in [4].

1) *AVNIR-2, multi-date analysis*

The geo location accuracy assessment for multi-date dataset observed over La Crau site France (43.513°N,4.875°E),and processed on September 15, 2006 has been performed. The accuracy tends to improve along with time to be now within 1000 m (RMS). The geo location shift occurs mainly along with the pixel direction from 200 m up to 1000 m (RMS). Its magnitude is strongly related to acquisition date and pointing angle. On the other hand, the correlation between pointing angle and line displacement reach 0.85, a change in sensor alignment parameters may lead to improve significantly the geo location accuracy.

2) *AVNIR-2, verification of internal geometry*

Using previous dataset, when polynomial model is refined and terrain relief is accounted, results lead to hypothesis on internal geometry.

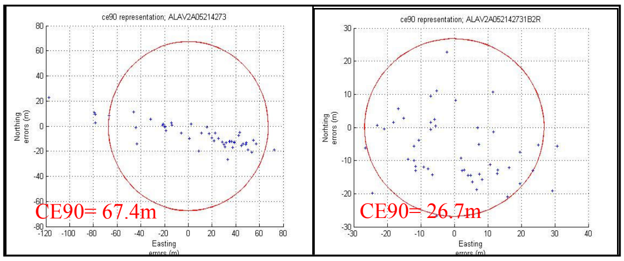

Figure 4. AVNIR-2, product geo-location (CE90), data corrected from the biais (left) andd data corrected from terrain relief effect (right).

With dataset corrected from across and along track shifts product geo-location, is about 67.4 meter CE90 - Circular Error at 90 %, Figure 4. When correcting displacements from terrain relief effect, geo location accuracy reaches 18m (RMS) and 26.70m (CE90). The co-registration between every couple of AVNIR-2 bands had been checked. The registration accuracy remains mainly within half a pixel, except between band 2 and 4 (0.8 pixel in line direction)

3) *PRISM product geo location*

The geo location control of PRISM products at the beginning of the commissioning phase magnifies a persistent bias up to 11 km. Important Along Track (AT) and Across Track errors were observed. The various processing chain updates with for instance correction of 1s time delay (also seen on AVNIR-2 product) and across track misalignment improved significantly the geo location accuracy. The assessment of geo location for a part of product dataset processed in April 2007 indicates that the accuracy remains below 20.7 m, 25.6 m and 73 m RMS for respectively image from Nadir; Backward and Forward cameras. When setting one reference point, for accounting of translation; the geolocation accuracy reaches 7.5 m (RMS).

The relative geo location accuracy of PRISM 1b2 image views (Backward/Nadir, Forward/Nadir), projected into cartographic grid using polynomial transformation without ground reference point, is estimated to be within 10 meters (Ground Control Points (GCPs) are located at ellipsoid level).

C. Stereoscopic capabilities

ETH Zurich Laboratory managed the verification stage dealing with the evaluation of PRISM stereoscopic capability on scene acquired over Piemont site (44.5°N ,7.3°E). ETH methodology and results for calibration validation of PRISM sensor model are more detailed in [5]. TABLE II. listed results of exterior and interior orientation procedures according to sensor model used. The RMSE values in planimetry are at sub pixel level with five GCPs. in height depends on model used. The accuracy are given according to geo referencing model used and with 5 and 9 GCPs for checking.

GCP no *Model*	**RMSExy** *(m)*	**RMSEz** *(m)*
5 DGR	2.34	1.05
5 PPM-2	2.58	2.36
9 DGR	2.22	1.03
9 PPM-2	2.30	2.35

TABLE II. RESULTS FROM EXTERIOR AND INTERIOR ORIENTATION WITH DGR AND PPM-2 MODEL THE DIRECT GEOREFERENCING (DGR) AND THE PIECEWISE POLYNOMIAL MODEL (PPM).

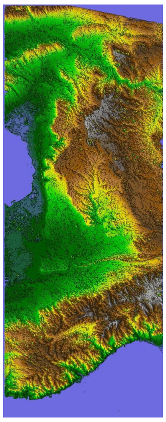

Figure 5. Surface model generated in using a direct method.

V. IMAGE QUALITY EVALUATIONS

A. Visual inspection

The visual inspection of optical data from instruments on board ALOS magnified artifacts mainly occurring on data from PRISM. The compression mode creates blocking artifacts, because pixels from odd and even detectors are compressed separately, it accentuates the effect and makes image sometimes difficult to interpret. Dectector over saturation is also observed with PRISM, neighbored detectors are also saturated and a bright tray is contaminated the whole of image data from the CCD. The last processing software version embed the correction of PRISM stripe noise. The algorithm applied is efficient but introduce more image saturations. Despite image quality artifacts, the image correlation procedure between a couple of PRISM views is working fine and provide satisfactory results in the frame of automatic digital surface model generation (Figure 5.).

B. Modulation Transfer Function (MTF)

The MTF is to evaluate and quantify capability of PRISM / AVNIR-2 instruments to discern ground features. The method implemented is the step edge one for image from PRISM. The AVNIR-2 MTF has then be derived using bi-resolution method [6]. The artificial target (checkerboard) is located at Salon-de-Provence (4.875°E, 43.513°N), it sizes 60 per 60 m. In a first stage, the computation have been performed on two couples of PRISM/AVNIR-2 scenes. The analysis demonstrated that the MTF of AVNIR-2 bands was within specification (>0.25@nyquist). For PRISM instrument, the study magnified that the Cross Track (CT) MTF is stable (>0.20@nyquist) whereas the Along Track (AT) one was changing significantly between the both observations. Moreover, MTF results were not consistent along with PRISM radiometers. In a last stage, for a PRISM dataset observed in April of Year 07', the MTF has been recomputed; the AT MTF value at Nyquist frequency has been confirmed to be about 0.07 for backward and nadir views whereas the CT MTF value at Nyquist reaches about 0.2. The variability of MTF signal to noise ratio, full width at maximum results according to the radiometer is still observed. One may think that the odd/even mis-calibration and jpeg compression increase the noise level and disturb the linearity of the detector response. It results in difficulties to provide reliable model for the MTF estimate.

VI. CONCLUSIONS

We described methods used to implement the ESA verification plan of the ALOS optical data. The ESA ALOS science team has benefited from a large body of research on radiometric calibration, geometric calibration and image quality. A fruitful cooperation and synergy have been created. The study presents early results on PRISM / AVNIR-2 data quality. It forms a good point to exchange with JAXA and to highlight the accuracy ESA users may expect. More data and research are now needed to confirm trend in radiometric and geometric calibration and to characterize image artifacts. This paper demonstrates major improvements have already been accomplished since the launch of ALOS spacecraft.

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