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Multidate Quality Assessment of Alsat-1 Satellite's Imager

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Abstract. Control of image quality of an earth observation satellite must be permanently carried out during all orbit life. To achieve this, reference images of three types of targets were taken into consideration, by Alsat-1 (First Algerian launched Satellite) between early 2004 and late 2006: The first target is a homogeneous white region (clear snow) of the Antarctica and above the Arctic regions. The second target is a dark region taken by night over the Pacific Ocean in order to emphasize variations of dark noise, The third target is a clear area along the Rail Road Valley (Nevada, United States) in which radiation is measured on the ground and simultaneously to get the absolute calibration of on board instruments.

The purpose of this paper is to assess the variation of the camera quality over a three years period of Alsat-1 operations, by analyzing the images reference taken in the period stated above. We also analyzed the channel light sensitivity (green, red and infrared) through a radiometric estimation, pixel by pixel of two images for a typical homogeneous site (scenes with a uniform background radiation) at two distinguished periods of time, while maintaining the same setting. This radiometric evaluation concerns two types of targets only (dark target and bright target). To this aim, we used a variety of assessment methods, all based on mathematical and algorithmic tools. They includes objective assessment such as PSNR (sigle de Peak Signal to Noise Ratio), entropy, AMBE (Absolute Mean Brightness Error-AMBE), etc.., and much more other subjective methods, such as visual analysis,use of statistical indicator, etc...

Keywords: *Alsat-1, Satellite images, radiometric quality, CCD sensor, SLIM-6-, Dark noise.*

Résumé. Le contrôle de la qualité des images pour un satellite d'observation de la terre doit se faire pendant toute sa duré de vie en orbite, à cet effet, des images de référence ont été prises par Alsat-1 entre le début 2004 et la fin 2006. Elles ont été prises pour trois types des cibles: La première cible est une région enneigée homogène claire (blanche) au dessus de l'Antarctique (en automne/hiver) et au dessus de l'Arctique (au printemps/été). La deuxième est une région sombre prise de nuit au dessus de l'océan pacifique pour mettre en évidence les variations du bruit d'obscurité, La troisième est une région claire du Nevada (USA) appelée Rail Road Vallée dont la radiation est mesurée au sol pendant l'acquisition de l'image par le satellite et ceci pour ajuster le calibrage absolue des instruments embarqués. L'objectif de ce travail est d'évaluer la variation de la qualité de la caméra SLIM-6 durant une période de trois ans de fonctionnement d'Alsat-1 en analysant les images obtenues par l'observation des cibles de référence prises entre le début 2004 et la fin 2006.

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Nous avons aussi analysé la sensibilité lumineuse pour chaque canal (vert, rouge et infra-rouge), en faisant une comparaison de l'évaluation radiométrique, pixel à pixel, entre deux images des sites homogènes (scènes avec un rayonnement de fond uniforme) en deux dates différentes avec les mêmes conditions de prise de vue. Cette évaluation radiométrique a été faite sur deux types des cibles (noires et lumineuses). A cet effet, on a utilisé plusieurs méthodes d'évaluation basé sur des outils mathématique et algorithmique. En peut cite des méthodes d'évaluation objective (PSNR, Entropie, AMBE) ainsi que d'autre méthodes d'évaluation subjective (analyse visuel, utilisation des indicateur statistique).

Mots clés: *Alsat-1, image satellitaire, télédétection, la qualité radiométrique, capteur CCD, SLIM-6-, bruit d'obscurité).*

1. Introduction

ALSAT-1 is the first Algerian satellite put into orbit. It was launched November 2002, 28th at 6:07 GMT into a 700 KM sun-synchronous orbit. Alsat-1 payload is a multispectral imager [1,2], with two banks of 3 channels. Each channel is equipped with a CCD sensor and an optical convergent associated electronic circuit [3].

The image quality of ALSAT-1 depends on the quality of imager and design. For the control, a set of radiometric measurements of the imager are performed before the satellite launch [4] and during the beginning of its life in orbit, by analyzing the first reference images. Then you have to detect and analyze changes in the radiometric quality of the camera caused by aging instruments and satellite. This analysis should be periodic to locate the smallest defects on raw images. In order to evaluate the variation in the quality of the camera SLIM-6 in flight, it analyzes the images obtained from the reference targets taken.

The aim of our study was to analyze the sensitivity of each channel, by comparing pixel by pixel of two images for a typical homogeneous sites (scenes with a uniform background radiance) acquired on two different dates at two distinguished periods of time, while maintaining the same setting.

2. Payload description

The Alsat-1 payload is a multispectral camera which works in a push-broom mode (forward scan is provided by the spacecraft motion). It is in fact a couple of two imagers (of three channels each) which work separately or both together.

Fig. 1. Alsat-1 Image.

This adds flexibility to program images (satellite operations). For each spectral band (green, red, near-infrared), two channels (from both banks) provide a 600 km swath with (5% overlap between them) at 32 meters ground sampling distance in three spectral bands [1,2].

Each channel is in fact an independent camera and contains a complete optic-system plus a PCB supporting the sensor & linked to the main PCB board in the stack (one main board per bank) thanks to a flexi-rigid PCB cable.

- Optics: The lens is a Schneider Apo-Componon HM 150mm FL (aperture f/4). It’s a flight proven lens (flown onboard Tsinghua-1 satellite in 2000). This commercial lens has been subject to a set of test prior to use.
- Filters: They are high quality dichroïc filters in the optical assembly provided by BARR Associates Inc.. Due to the mission requirement, the spectral band is red [523-605nm], Green [629-690nm] and Near Infrared [774-900nm]. The spectral characteristics are identical to the Landsat ETM+ bands (2, 3 and 4).
- Sensor: It is a KLI-10203 linear CCD sensor, designed for color scanning applications. This is an RGB, 3 channels, 10k pixels. Due to the mission requirements, this COTS element was requested from Kodak without the RGB organic dye filters (applied to the light sensitive areas) but with a multilayer AR coated cover glass [1,5].

The KLI-10203 is tri-linear array designed for high-resolution color scanning applications. Each device contains 3 rows of 10200 photoelements, consisting of high performance "pinned diodes" for improved sensitivity, lower noise and the elimination of lag. Each channel has two (02) shift registers, one for even pixels and the other for odd pixels (Figure 2). In the case of Alsat-1, the organization of the pixels is adopted as follows: (20 Dark reference pixels + 10 000 active pixel + 4 Dark reference pixels) [1, 2, 6].

3. Evaluation methods and tools

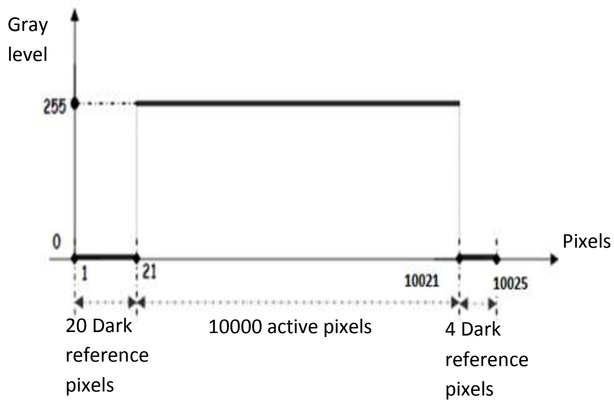

Fig. 2. Ideal Radiometric response of the camera for Alsat-1.

To the flight evaluation of the imager Alsat-1, we compare the radiometric responses for each detector array (banc0, banc1) for each sensor (green, red and NIR bands) to characterize their response to both dark (this is to highlight the variations of dark noise) and bright targets obtained at different dates.

3.1. Subjective Quality Assessment

Recommended in the literature, the visual analysis of the images is needed to verify and evaluate the results and quality differences. The visual analysis is subjective as the judgment of a person on the qualitative result image will depend on knowledge, expectations and application.

3.2. Objective Quality Metrics:

- Entropy: it allows assessing the wealth of informative image. It is defined from the occurrence probability of a value relative to the entire image [7].

$$H(x) = -\sum_i P_i \log_2 (P_i) \qquad (1)$$

- AMBE (absolute mean brightness error) : is calculated from equation below

$$AMBE = | E(X) - E(Y) | \qquad (2)$$

Where E(X) and E(Y) are mean of new and original gray level of image, respectively. Generally, classing number of histogram region affects to AMBE value. The more one is, the less AMBE. Also, suddenly hanging of slope of gray level in image indicates that contrast is either increase or decrease [8].

- MSE and PSNR : Given a reference image I and a test image $\hat{I}$, both of size M×N, the PSNR between I and $\hat{I}$ is defined by

$$PSNR = 10log_{10}\left(\frac{I_{max}^2}{MSE}\right) \qquad (3)$$

$$MSE = \frac{1}{M \times N}\sum_{m=1}^{M}\sum_{n=1}^{N}(I(m,n) - \hat{I}(m,n))^2 \qquad (4)$$

The PSNR value approaches infinity as the MSE approaches zero; this shows that a higher PSNR value provides a higher image quality. At the other end of the scale, a small value of the PSNR implies high numerical differences between images [9].

4. Dark Images

Table.1 Acquisition Details for the Dark Images

image	**Date**	**Time**
DA000264sm	12/12/2004	05:12:15
DA00026csm	23/12/2004	05:32:00
DA0002f5sm	24/06/2005	05:18:22
DA000264pm	12/12/2004	05:12:15
DA00026cpm	23/12/2004	05:32:00
DA0002f5pm	24/06/2005	05:18:22
Integration time : 2048 µs		

To simplify the comparison between these images, we calculated the average radiometric responses of each column of the image and obtained a single line that represents the entire image. We analyze the average detectors radiometric responses for each camera, and then we took the radiometric response of the green channel for both banks (camera 1 and 4), which showed a greater dispersion compared to other channels.

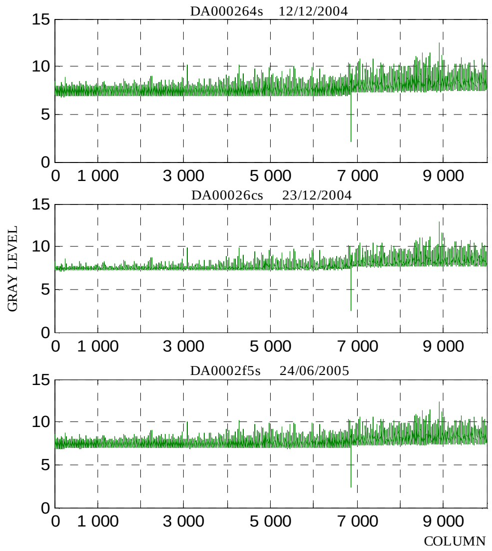

Fig.3. the average detectors radiometric responses (camera 1)

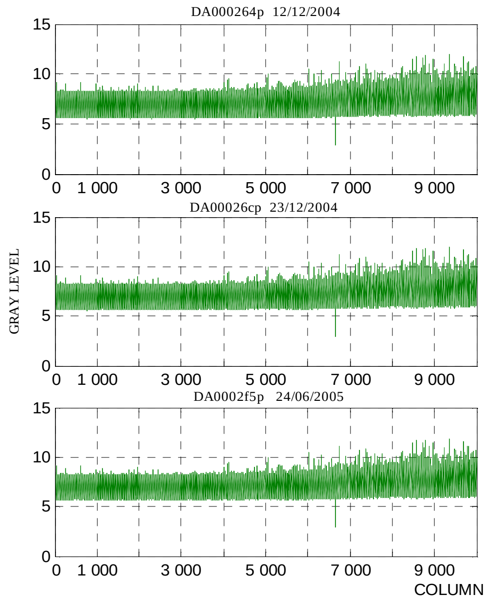

Fig.4. The average detectors radiometric responses (Camera 4)

Figures (4 and 5) show the average detectors responses (in gray level) of the camera 1 and 4 for three images taken at different dates.

- The results, for each camera, of the three images taken at different dates provided the same level of information, and confirmed a low variability between them.
- Peaks coincide in location and amplitude confirmed that: the photosite 6864 of the camera 1and photosite 6640 of the camera 4 have a reduced radiometric sensitivity. the photosite 8902 has a higher radiometric sensitivity than the other.
- Small step (visible in the responses of the even pixels) similar location in all images (pixel 6840 in Figure 3 and pixel 6640 in Figure 4).

- The variations of the gray levels of the camera 4 are in the inside of a wider range, related to the increase of the gap between the responses of even and odd pixels, and this due to the channel separation for odd and even pixels in the internal architecture of the sensor.
- The decrease of gray levels related at the decrease in the charge moved from one register to another for the right during the transfer operation.

5. Snow Scene

Table.2 Acquisition details for images

Image « *greenland* »	date	Time	Solar Angle (°)	Observation
DA000208s	07/07/04	10:27:58	27,76	Cloudy (75%)
DA0002e7s	12/06/05	10:21:52	28,81	clair
DA000208p	07/07/04	10:27:58	27,76	Cloudy (50%)
DA0002e7p	12/06/05	10:21:52	28,81	clair
DA0001dap	03/06/04	10:25:47	27,9	Cloudy
DA0001ebp	16/06/04	10:23:47	28,57	clair
DA00021bp	20/07/04	10:25:52	25,64	Cloudy (50%)
Image «*Antarctique*»				
DA000286s	17/01/05	11:37:56	14,53	Cloudy (50%)
DA000270s	27/12/04	11:35:41	16,69	clair
DA000286p	17/01/05	11:37:56	14,53	Cloudy (30%)
DA000270p	27/12/04	11:35:41	16,69	clair

We noted from the table that most of the images are cloudy, Knowing which were taken with the same shooting conditions, so it is difficult for us to compare. To solve this problem, we tried to make the most out of clear windows to the comparison.

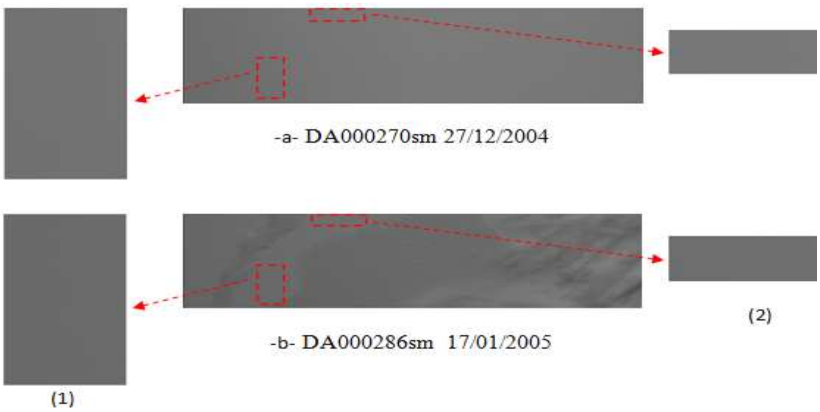

Fig.5. Images of Antarctica and selected windows (camera-1).

Table.3 statistical indicators for both windows (images of the Antarctic-bank-1)

First window (600x1000)						
Image		**Mean**	**Standard Deviation**	**H**	**AMBE**	**PSNR**
Green band	DA000270s	63.0685	1.4363	2.5683	7.9041	29.9911
	DA000286s	55.1644	1.2852	2.4055		
Red band	DA000270s	47.3963	1.1206	2.2051	5.5545	32.9774
	DA000286s	41.8419	1.0457	2.1023		
NIR band	DA000270s	38.2267	1.3279	2.4493	4.5580	34.4825
	DA000286s	33.6687	1.2644	2.3766		
2nd window (1000x300)						
Green band	DA000270s	68.8044	1.4742	2.6065	9.1685	28.7497
	DA000286s	59.6359	1.3234	2.4493		
Red band	DA000270s	51.2700	1.1334	2.223	6.3100	31.9263
	DA000286s	44.9601	1.0532	2.1141		
NIR band	DA000270s	41.2110	1.2872	2.4033	5.2794	33.3182
	DA000286s	35.9316	1.2689	2.3807		

Table (3) shows the values of quantitative analysis of selected windows. For each channel, we see that all values are close, and all the gray levels are clustered around the mean value; Values of the standard deviation confirm this result.

The small differences in the standard deviation and entropy show a small variability between multidate images. The AMBE values indicate for the three channels a small degradation of the brightness of the image. PSNR values are between 28 and 34.5, which means that all the windows are closer at the quality.

In the following study, we analyzed the radiometric medium responses of the camera 1, 2 and 3 for both windows.

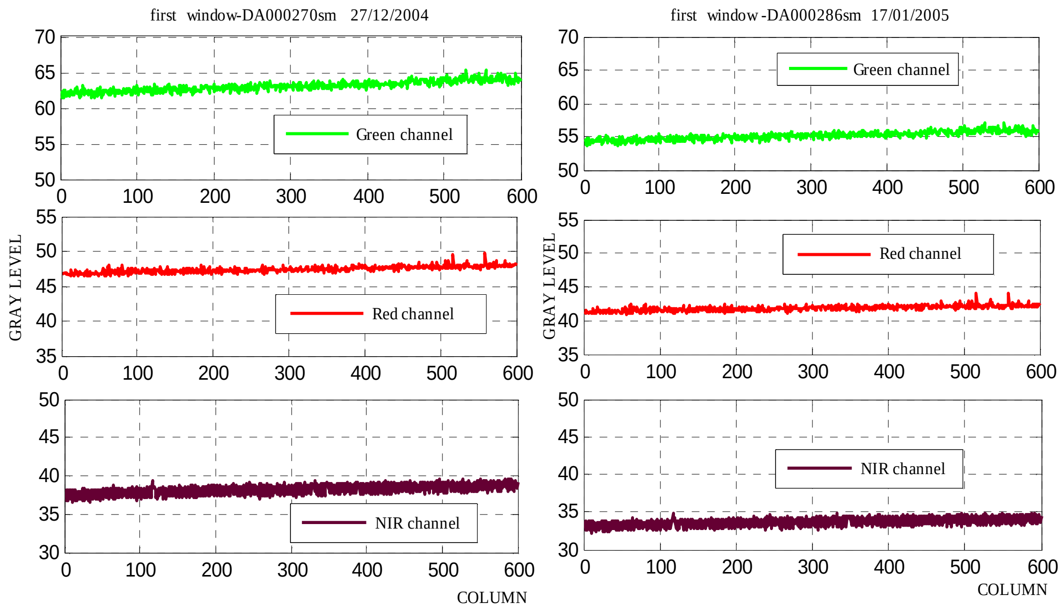

Fig.6. average detectors radiometric responses (Images of Antarctica- first window)

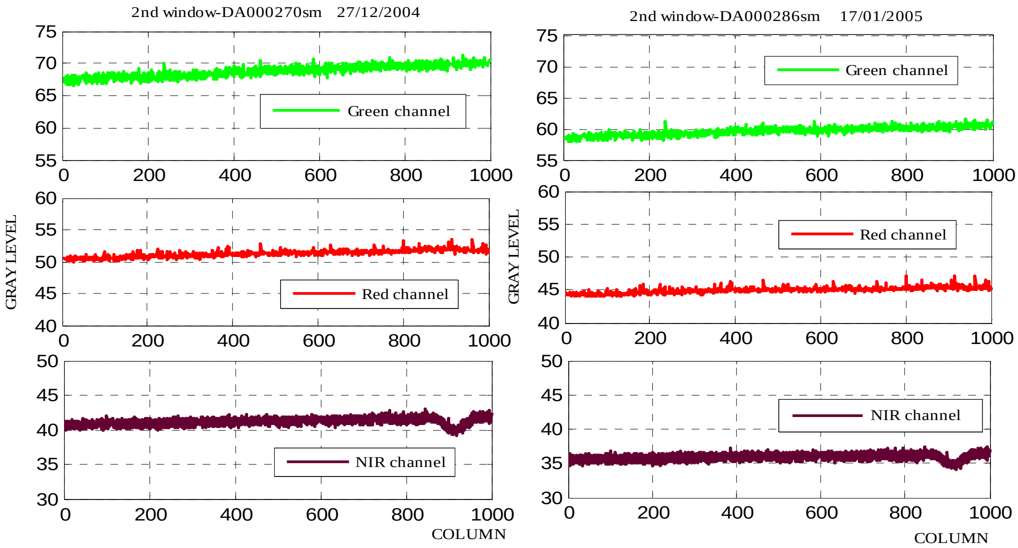

Fig.7. The average radiometric responses (Images of Antarctica- 2nd window)

The analysis of the average radiometric responses (Fig. 7 and 8) confirms the previous results. For each channel, all the gray levels are clustered around the mean value. And degradation of the brightness of the image between the two windows which was taken on 27/12/2004 and the other was taken on 17/01/2005; we noticed from the shooting information, a difference of two degree solar angle (14.53 ° for DA000270sm image and 16.69°for DA000286sm image), and from the literature, when the variation of the solar angle is less than 6 ° the influence on the brightness of the image is very low. So in this case the degradation of the brightness is not related to this variation.

In the general shape of all the curves we have noticed a growing radiometric response, this anomaly related to the optical effect.

Then we did the same work for windows extracted from images of Greenland.

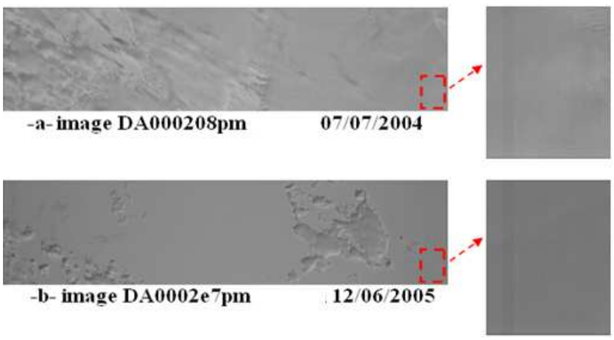

Fig.8. Images of Greenland and selected windows.

Table.4 statistical indicators for both windows (images of the Greenland-bank-0)

Window (550x900)					AMBE	PSNR
Image		**Mean**	**Standard Deviation**	**H**	**AMBE**	**PSNR**
Green band	DA000208p	102.7083	2.9579	3.1914	6.2117	31.4660
	DA0002e7p	96.4966	3.3718	3.6923		
Red band	DA000208p	74.4098	3.5340	3.5144	4.6221	33.8786
	DA0002e7p	69.7877	3.6380	3.8537		
NIR band	DA000208p	53.9993	4.7016	3.4789	2.7214	37.7398
	DA0002e7p	51.2779	4.7109	3.7974		

We noted that:

For each channel, all the values of the statistical indicators are close. AMBE values indicate a small degradation of the brightness between the two images. The near infrared channel showed a small dispersion compared to other channels.

Then we analyzed the radiometric medium responses of the camera 4, 5 and 6 for the two windows.

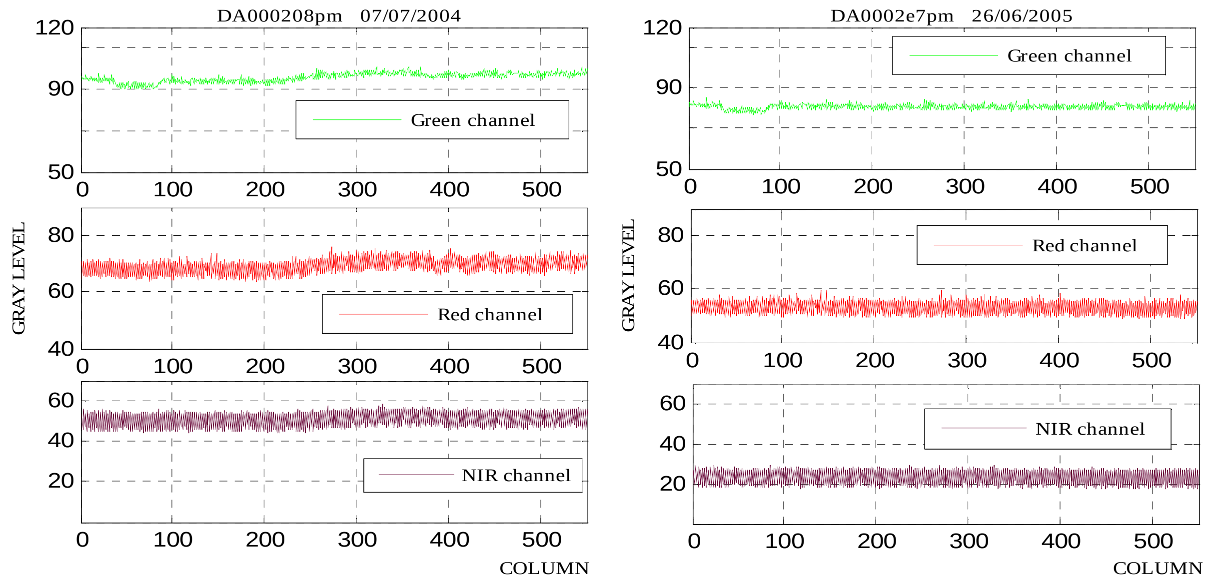

Fig.9. The average radiometric responses (Images of Greenland)

Given the results, we note that the general shape of the curves appear stable for two windows, with a small difference in brightness between the two windows which was taken on 07/07/2004 and the other to was taken on 12/06/2005.

We also noticed, for the red channels and near infrared, variations of gray levels is the interior of an interval larger than green channel and other channels of the bank 1, and this anomaly related to the increase of the difference between odd and even pixels in the bank(0).

We did the same work for multiple windows extracted from the selected images to confirm the previous results.

We have also noticed a decrease in sensitivity along certain columns to four cameras. This anomaly can be associated to the difference in sensitivity of photosites, or for the presence of dust or task at the optical CCD sensor:

- Cameras-1 (green): 4522 to 4570 photosite.
- Camera-2 (red): 1140 to1200 photosite.
- Camera-3 (near infrared): 3722 to3810 photosite.
- Camera-4 (green): 9479 to 9523 photosite.

6. Conclusion

This work has presented and interpreted results of multidate assessments of Alsat-1 Satellite's Imager. We have analyzed the sensitivity of each channel using the first test images taken before the satellite launch, and 141 reference images taken during the beginning of its life in orbit. It shows a stable quality of the imager during three years of operation. Some anomalies remain apparently linked in part to the design of the imager, and secondly, the elements making up each part of channel (camera). All results showed a decrease in sensitivity along certain columns to four cameras, which are: camera 1(green channel), 2(red channel); 3(NIR channel) and 4(green channel). We also noted the appearance of a small difference in brightness between multidate images. This clearly indicates a low variability between these images that may be due to aging of camera. This remains a hypothesis because the number of images is not sufficient to validate.

7. Reference

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