Radiometric Responses of the Multispectral Imager SLIM 6 for Dark and Bright Target

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Abstract— **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 (SLIM-6) is a multispectral imager, with two banks of 3 channels. Each is equipped with a CCD sensor and an optical convergent associated electronic circuit.**

The image quality of ALSAT-1 depends on the quality of imager and design. For the control, we must 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 defects on raw reference images.

The aim of our study was to analyze the sensitivity of each channel, using reference images (scenes with a uniform background radiation): images taken at night, images over the ocean, or images of snowy areas; were taken by Alsat-1 between early 2004 and late 2006.

In this purpose we used several assessment methods based on mathematical and algorithmic tools. These includes objective assessment and many of subjective method (visual analysis, use of statistical indicator).

Key-Words— Slim-6, Alsat-1, Satellite Image, Radiometric Quality, CCD Sensor.

I. Introduction

CONTROL of image quality of alsat-1 satellite must be permanently carried out during all orbit life. a set of radiometric measurements of the imager of ALSAT-1 (SILM-6) performed before the satellite launch and during the beginning of its life in orbit, by analyzing the first reference images. Then, this analysis should be periodic to detect changes in the radiometric quality of the camera.

For this purpose, reference images of three types of target were taken by Alsat-1 between early 2004 and late 2006:

- The first target is an homogeneous region white (clear snow) of Antarctica (in fall/ winter) and above the Arctic region (spring / summer).
- The second target is a dark region taken by night over the Pacific Ocean to demonstrate the variations of dark noise.
- The third target is a clear area of Rail Road Valley (Nevada United States) and of where the radiation is measured on the ground at the same time to get the absolute calibration of on board instruments.

II. Slim-6 (Alsat-1 imager)

SLIM-6 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. 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].

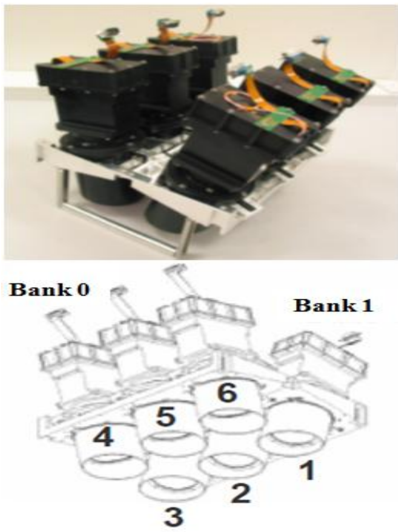

Fig. 1. Alsat-1 Imager (SLIM-6)

Each channel is equipped with a CCD sensor KLI-10203 and an optical convergent associated electronic circuit.

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) [2].

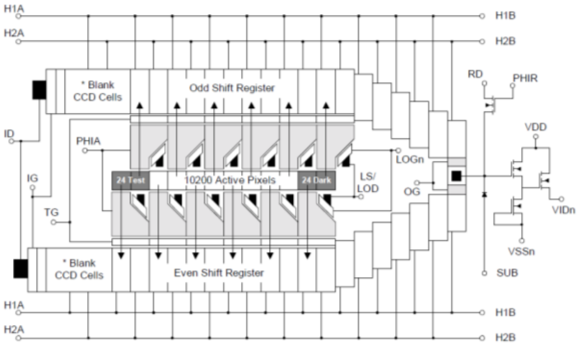

Fig. 1. Internal schematic of KLI 10203

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].

III. Images Used

The radiometric analysis requires two types of target:

A. Dark targets: a dark region taken by night over the Pacific Ocean

TABLE I. 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		

B. Bright targets: an homogeneous region white (clear snow) of Antarctica and above the Arctic region.

TABLE II. 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 «Antarctic»				
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

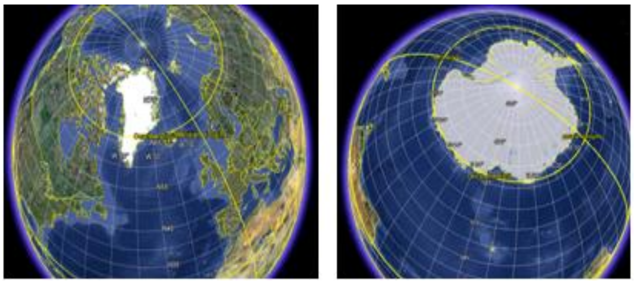

Fig. 2. geographical location of the Greenland and Antarctic area.

IV. Objective Quality Metrics

a. Entropy: it allows assessing the wealth of informative image. It is defined from the occurrence probability of a value relative to the entire image[4].

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

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

$$AMBE = | E(X) – E(Y) | \quad (2)$$

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 [5].

c. 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

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

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

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 [6].

V. Radiometric Analysis of the Dark Images

To simplify the analysis of these images, we calculated the mean of each column of the image and obtained a single line that represents the entire image. We analyze the average radiometric responses for each camera.

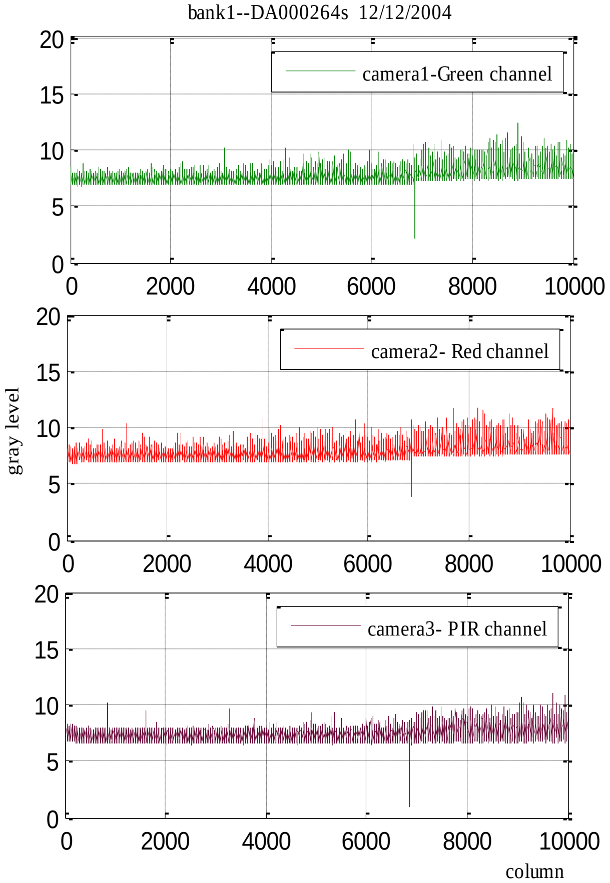

Fig. 3. The average detectors radiometric responses (Camera 1, 2 and 3-- bank1– image DA000264s)

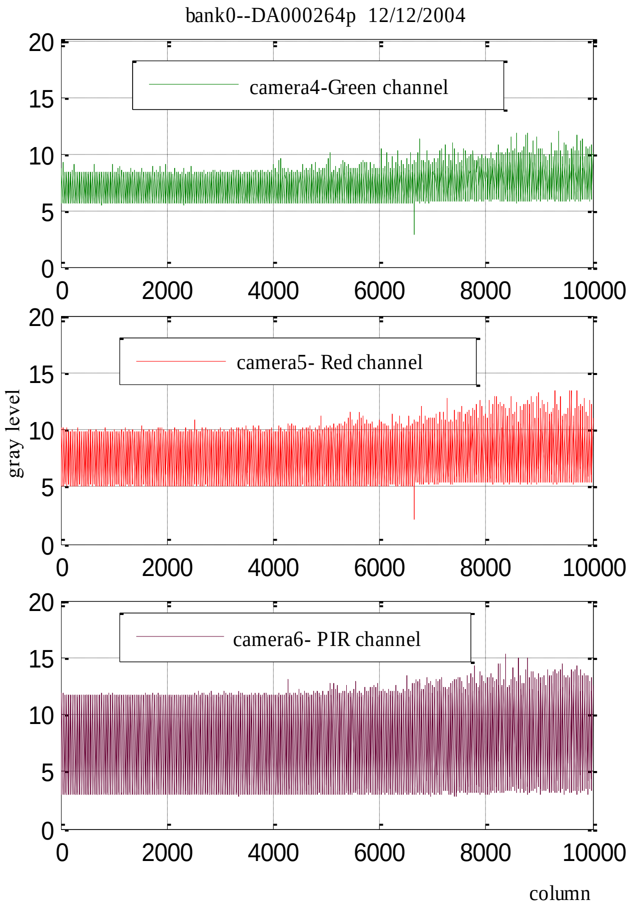

Fig. 4. The average detectors radiometric responses (Camera 4, 5 and 6 –bank0– image DA000264p)

Figures (3 and 4) show the average detectors responses (in gray level) of six cameras of the two banks for tow images DA000264s and DA000264p.

- The results, for each bank of cameras, of the tow images taken provided the same level of information.
- Peaks coincide in location and amplitude confirmed that: the photosite 6864 of the cameras of bank1 and photosite 6640 of the cameras of bank0 have a reduced radiometric sensitivity. the photosite 8902oh the cameras of bank1 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, 5, and 6 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.

VI. Radiometric Analysis of the Bright Images

Among the selected images from Antarctica and Greenland, we analyzed the image DA000270sm, DA000270p and DA0002e7s size 10000 × 2500 captured by the cameras of the bank-1- and bank 0 (cameras 1, 2, 3,4, 5 and 6).

Fig. 5. Reference image DA000270sm of the Antarctic taken by the camera 1 on 27/12/2004 bank1

Fig. 6. Reference image DA000270sp of the Antarctic taken by the camera 4 on 27/12/2004 bank0

Fig. 7. Reference image DA0002e7s of the Antarctic taken by the camera1 on 12/06/2005 bank1

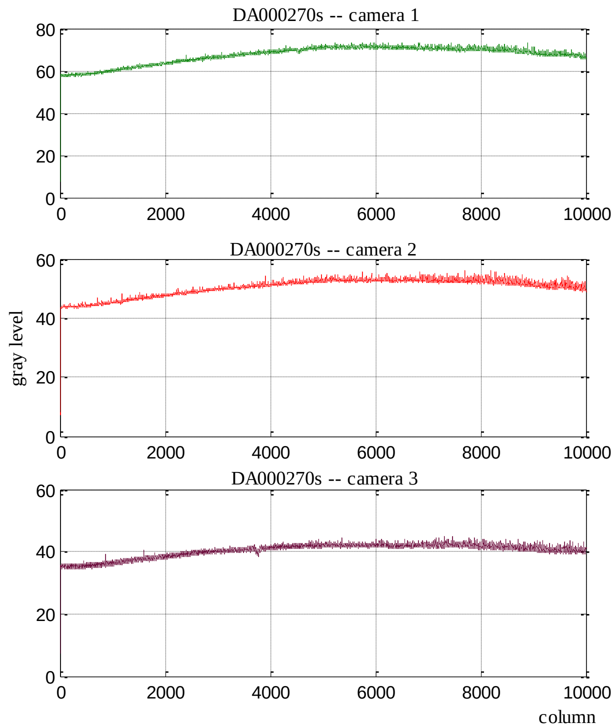

Fig. 8. The average detectors radiometric responses (DA000270s - 27/12/04)

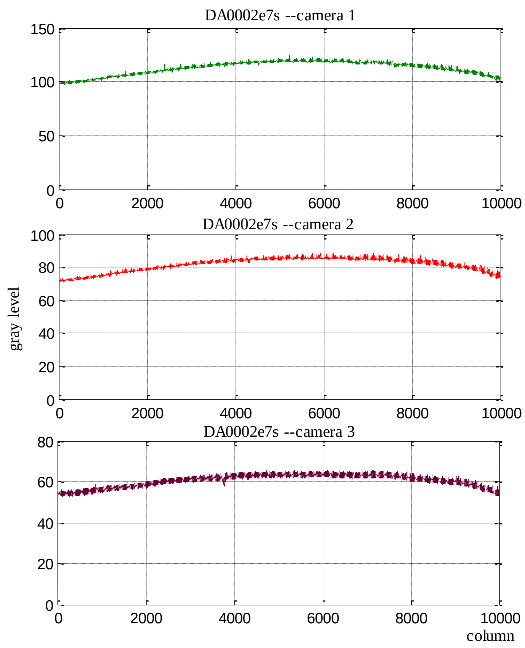

Fig. 9. The average detectors radiometric responses (DA000270s - 12/06/05)

Figures (8 and 9) show the average detectors responses (in gray level) of the camera 1, 2 and 3 for two images taken at different dates. Every curve has larger dispersions and asymmetric appearance. We have also noticed a flattening edge this anomaly is related to the phenomenon of vignetting is due to the optics.

A slight decrease in sensitivity appears suddenly, affecting 48 pixels. It is limited between 4522 and 4570 columns in the response of camera 1 (Green channel). Appearance of another decreased sensitivity to three grayscale limited between 3722 and 3810 columns in the response of camera 3 (PIR channel). “This anomaly of decreased sensitivity appears in the first test results imager Alsat-1-, and may be associated with the presence of dust or impurity on the optic or on the CCD detector. [3]"

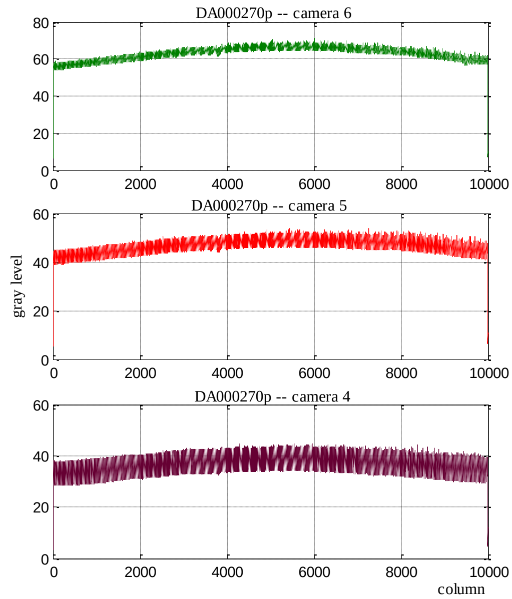

Fig. 10. The average detectors radiometric responses (DA000270p- 27/12/04)

Figure (10) shows the average detectors responses (in gray level) of the camera 4, 5 and 6 for the images DA000270pm in three spectral bands (green, red, NIR). From this figure we see:

- The general shape of the three curves is symmetrical and centered with respect to the CCD.
- Flattening the edges. This anomaly is related to the phenomenon of vignetting is due to the optics.
- the presence of a dark band along of 44 columns in response camera-4.
- 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).

A. objective assessment

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 bright targets obtained at different dates.

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.

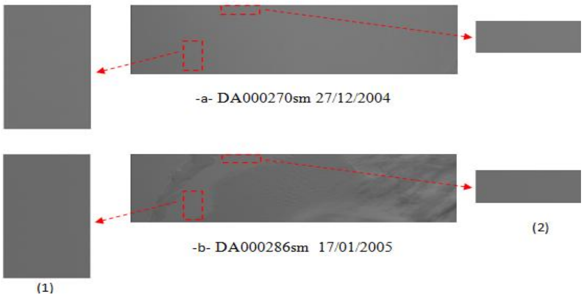

Fig. 11. Images of Antarctica and selected windows (camera-1).

TABLE III. 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.

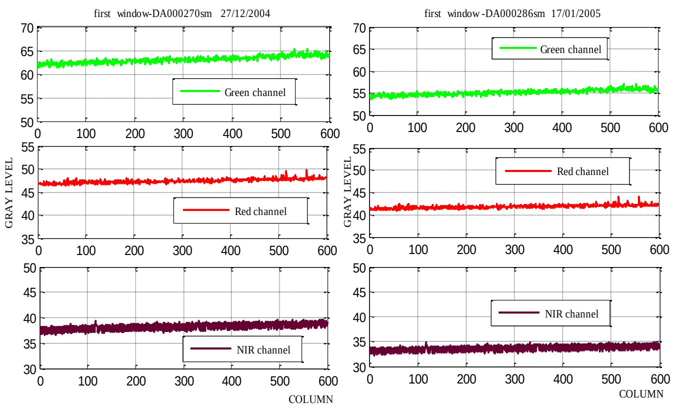

Fig. 12. The average detectors radiometric responses (Images of Antarctica- first window)

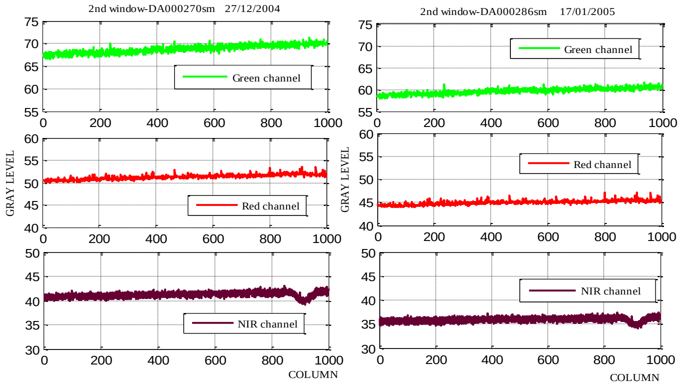

Fig. 13. The average radiometric responses (Images of Antarctica- 2nd window)

The analysis of the average radiometric responses (Fig. 12 and 13) 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.

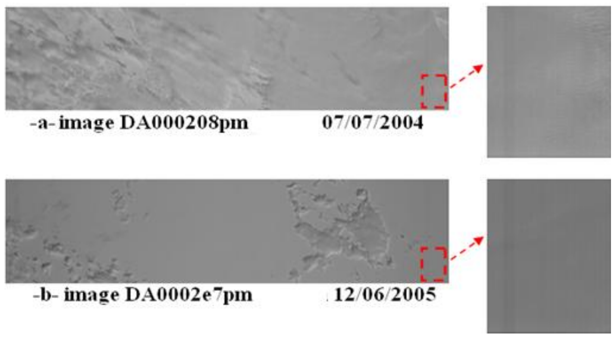

Fig. 14. Images of Greenland and selected windows.

TABLE IV. STATISTICAL INDICATORS FOR BOTH WINDOWS (IMAGES OF THE GREENLAND-BANK-0)

Window (550x900)						
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.

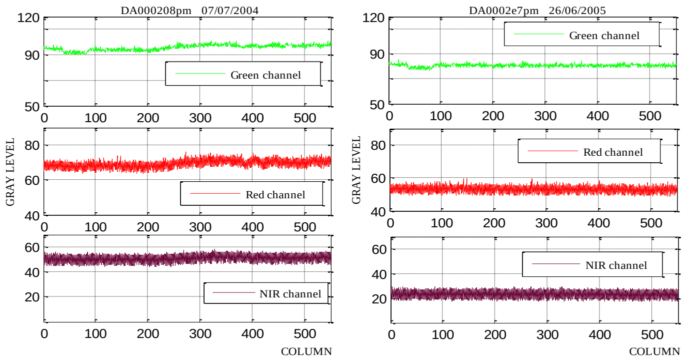

Fig. 15. The average radiometric responses (Images of Greenland)

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.

VII. Conclusion

This work has presented and interpreted results of multidate radiometric analysis of the reference image were taken by Alsat-1 between early 2004 and late 2006. It shows a good quality of the reference image during this period. Some anomalies remain apparently linked in part to the design of the imager, and secondly, the elements making up each part of channel (camera).

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