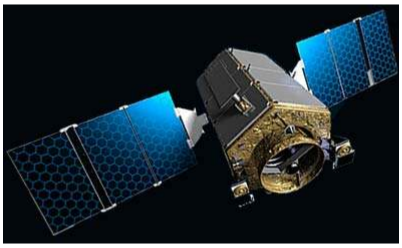
New Third Party Mission, Quality Assessment

Kompsat-2 Mission



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1 INTRODUCTION

1.1 Purpose of this document

In the frame of ESRIN Contract No 19565/06/I-OL, purpose of this study is the achievement of an expertise on the fourth Third Party Missiosn to be assessed; KOMPSAT-2 (K-2) mission.

This document is comparing K-2 mission following the standard nomenclature for remote sensing optical mission description defined previously. Then it follows a preliminary product inspection is proposed and remarks on the format, the image quality and the geometry are formulated.

1.2 Document overview

- Chapter 1 Introduces the document and the references. This is the current chapter;
- Chapter 2 Mission profile, describe and compare the K-2 mission with the existing ones,
- Chapter 3 Product quality assessment, geometric and image quality.

1.3 Applicable documents

A-1 *New Third Party Missions: quality assessment*
ESRIN Contract N°: 19565/I-OL
May 3rd, 2006
ESA-ESRIN

1.4 Reference documents

This section describes the related documents and applied conventions to be considered within the present document.

R-1 *GAEL-P232-DOC-001.002* *A new third party quality assessment*
Template document: DMC Mission profile
May 03rd, 2006
GAEL Consultant

R-2 KOMPSAT-2 Users Manual
September, 1st, 2007
Korea Aerospace Research Institution.

R-3 *GAEL-P232-DOC-004.001* *Processing level standardization*
September, 1st, 2007
GAEL Consultant.

R-4 NUC algorithm of KOMPSAT-2 in on-board relative radiometric calibration
J. H. Song, S. Y. Park, D. C. Seo, D. H. Lee, H. S. Lim
Korea Aerospace Research Institution.

R-5 KOMPSAT-2 Orbit Determination using GPS Signals
D.W. Chung, S. R. Lee, S. J. Lee
The 2004 International Symposium on GNSS/GPS, 2004.

1.5 Abbreviations and Acronyms

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

The list is written in alphabetic order.

ANSI	American National Standards Institute
ASPRS	American Society for Photogrammetry and Remote Sensing
BLMIT	Beijing Landview Mapping Information Technology Company Ltd
BNSC	British National Space Center
CCD	Charge Couple Device
CMOS	European Cooperation for Space Standardization
CMT	China Mapping Telescope
CNTS	Centre National des Techniques Spatiales (Algeria)
COBAN	Colk Bantil Kamera (Turkish), Multiband camera
ESA	European Space Agency
ESIS	Extended Swath Imaging System
GCP	Ground Control Point
GPS	Global Positioning System
GSD	Ground Spatial Distance
KARI	Korean Aerospace Research Institute
KOMPSAT	KOrean Multi Purpose SATellite
NASRDA	National Space Research and Development Agency (Nigeria)
NIR	Near InfraRed
S/C	Spacecraft
TBD	To Be Defined
WWW	World Wide Web

1.6 Definitions

This chapter provides the definition of all common terms used within the project. Special attention has been paid to adopt definitions from international standards as ISO, ANSI or ECSS.

The list is written in alphabetic order.

Term	Definition
CCD Camera	Charge coupled device (CCD) cameras contain light-sensitive silicon chips that detect electrons excited by incoming light. They also contain micro circuitry that transfers a detected signal along a row of discrete picture elements or pixels, scanning the image very rapidly. CCD cameras use two-dimensional CCD arrays with many thousand of pixels

CMOS	Complementary metal oxide semiconductor (CMOS) image sensors operate at lower voltages than CCDs, reducing power consumption for portable applications. Analog and digital processing functions can be integrated readily onto the CMOS chip, reducing system package size and overall cost
Dynamic range	The dynamic range of a sensor system is determined by the ratio of the maximum observable energy (Qmax) and the minimum of the still useful energy (noise level Qmin) it is defined in decibels (dB) as 10log(Qmax/Qmin). All radiant energy <Qmin vanishes into noise, while the energy above Qmax disappears into saturation of the detector.
Duty Cycle	Fraction of orbital period in which a sensor is actually operational, determined by the overall power limitations of the payload.
Focal plane Array	Focal plane arrays (FPA) are detectors which have more than one row of detectors and one line of detectors together.
IFOV	The IFOV is the angular cone of visibility of the sensor and determines the area on the Earth surface.
LEO (Low Earth Orbit)	The term LEO is used un Earth Observation as well as for communication satellite constellations. These are usually circular or near circular at altitudes less than 200 km above Earth's surface. The orbital period in the altitude range of 300-2000 km varies between 90 and 120 minutes. The visibility period of the satellite over the horizon may varies for an observer (ground station) may vary from about 5 up to 20 minutes.
Radiometric resolution	Radiometric resolution refers to the resolving power of a system in wavelength and energy. The limiting factor for radiometric resolution is the signal to noise ratio of the instrument receiver. Considering the effects of varying illumination, the radiometric dynamic range of a sensor is determined by the maximum radiance value that sensor can experience for a given band. Measurements are converted into a number of discrete digital levels in a process also referred to as 'quantization'.
Spatial or geometric resolution	Spatial resolution refers to the area on the ground that an imaging system can distinguish. It is measured as the size of a pixel on the ground, when the image is displayed at full resolution (*CCRS Tutorial, 2004*). Spatial resolution is a function of geometry (scale) between sensor and target for the instant of measurement.
Spectral resolution	The spectral resolution of the sensor represents the capability of the sensor to distinguish fine wavelength interval and is described by the number of band their wavelength ranges. High spectral resolution is achieved by narrow bandwidths, which collectively, are likely to provide a more accurate spectral signature for discrete observation than broad bandwidths.
Temporal resolution	Temporal resolution is closely related to revisit period, which refers to the interval of time needed by a satellite for one entire orbit. Absolute temporal resolution is the interval time between two successive acquisitions of exactly the same area.
Signal to Noise Ratio	The ratio of the level of information bearing signal power to the level of signal power. The maximum SNR of a device is called the 'dynamic range'. In general, the higher the signal value is and the better the signal quality for recognition and detection.
Magnetometers	Measuring the known magnetic fields components

2 MISSION PROFILE

2.1 Mission description,

Background

KOMPSAT-2 (Korean Multi Purpose Satellite) also known as Arirang 2 EO, is a South Korean (KARI) remote sensing craft that was launched by a Rokot rocket (a modified ICBM, SS-19) from Plesetsk at 07:05 UT on 28 July 2006. The 798 kg craft carries imaging systems to yield high-resolution, multispectral images of Earth's surface.

Paik Hong Yul, director of KARI's Satellite Operation and Application Centre said the Kompsat-2 program cost is about $200 million[1].

The project development has been done in **close cooperation with EADS ASTRIUM** (platform integration) and **ELOP** Electro Optics Industries Ltd (payload).

Spot image is the exclusive distributor of data from KOMPSAT-2 with KOREA. , except for customer in Korea, the united states and the Middle East[2].

History of KARI has begun with the KITSAT series of micro satellite (1 to 4) and KOMPSAT-1. After KOMPSAT-2, it is planned to continue the series with KOMPSAT-3,4,5. In addition, KARI has developed COMS-1 and more than 10 satellites are in the pipeline for the next decade.

1999 December 21 – **KOMPSAT-1** - *Launch Site*: Vandenberg. *Launch Vehicle*: US-Built Taurus Rocket *Mass*: 510 kg. *Altitude 685 km*. *Inclination*: 98.13 deg. *Period*: 98.46 min.

2006 July 26 – **KOMPSAT-2** - *Launch Site*: Plesetsk. *Launch Vehicle*: Rockot Rocket *Mass*: 800 kg. *Altitude 713 km*. *Inclination*: 98.10 deg. *Period*: 98.46 min.

Orbit

Kompsat-2 orbit type is SSO (Sun Synchronous Orbit). As the K-1 one; the orbit of L-2 is ascending.

The orbital parameter are the following ones[3];

i = 98.127 (orbital inclination)

e = 0.0 (eccentricity of circular orbit)

h = 685.13 km (altitude of orbit)

a = 7063.275 km (orbital semi-major axis)

rep = 409 orbits (repetition rate of orbital cycle)

p = 5907.72 s (period of orbit (seconds))

s = 13.6 km (effective swath)

Revisit time

The **revisit cycle is specified to be within three days**, which is extremely low. The roll of nadir is of about 56 degrees in the both directions whereas the off pointing in pitch direction reach 30 degrees. In comparing with K-1, we observe that the improvements have been concentrated on the agility in across track direction (45 degrees for K-1).

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[1] http://www.space.com/spacenews/archive04/kompsatarch_121304.html

[2] http://www.spotimage.fr/web/en/1383-kompsat-2-data-distribution.php

[3] Kompsat-2 User Manual, September 1, 2007, KARI

On comparing with operational in-flight segments, the off nadir capability of K-2 is the best one. Only the future Pleiades constellation mission will offer a greater off nadir capability (60 degrees).

With 409 orbits per circle and a cycle of a 98.49 min duration, **the K-2 repeat cycle is about 28 days**. It is below the Landsat one 16 days and above the ALOS / PRISM one 45 days.

Lifetime

K-2 is built for 3 years of operational life.

2.2 Platform

AstroSat 500 bus

The Kompsat-2 satellite bus is an AstroSat 500 model developed by KARI (EADS, only ground segment)

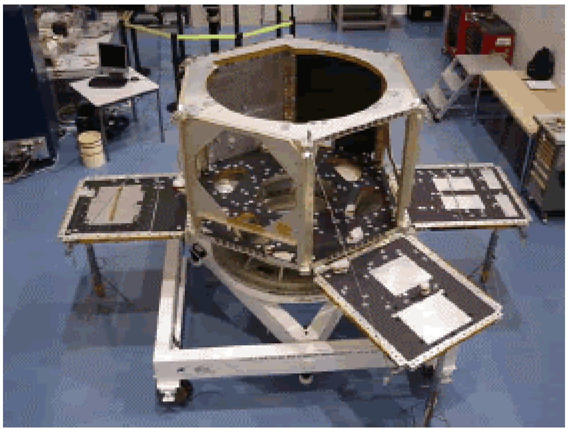


fig. 1 - Astrosat 500 - hexagonal type[4].

The attitude control system is three axis stabilized with zero momentum bias. The orbit determination and control is performed using star tracker.

2.3 Payload description

Elop (Electro-Optics Industries Ltd) is the payload developer for the Israeli government's Ofeq series of spy satellites and other domestic and export programs.

The company's unclassified space work includes the cameras for ImageSat International's Eros commercial imaging satellites and an ultraviolet astronomy payload planned for a late-2005 launch aboard India's GSAT-4 satellite.

MSC on board K-2 satellite

The Multi-spectral Space Camera (MSC) payload is a joint development of KARI and Elop.

"Elop has provided us with full integration of the multispectral camera and all supporting systems, so that when it gets to Korea, all we have to do is physically attach it to the main bus and complete final integration testing with the satellite," (KARI – 2007).

[4] http://www.latecis.fr/fra/elements/pdf/ref/espace/Structure_satellite_Astrosat_500.pdf

Spectral range

MSC have been designed to provide four multi multi-spectral bands covering the visible part of the electromagnetic spectrum regions (blue, green, red and near infrared) as ETM+ band number 1, 2, 3 4 is doing. In addition, MSC provides a panchromatic band.

Channel	PAN	MS1	MS2	MS3	MS4
Spectral Range (nm)	500 ~900	450 ~520	520 ~600	630 ~690	760 ~900

table 1 - Spectral range of Kompsat-2 MSC.

The figure just here intend to compare together instrument spectral ranges of various missions / instrument.

We note that MSC characteristics are very close to those of Ikonos and Landsat ETM+ missions.

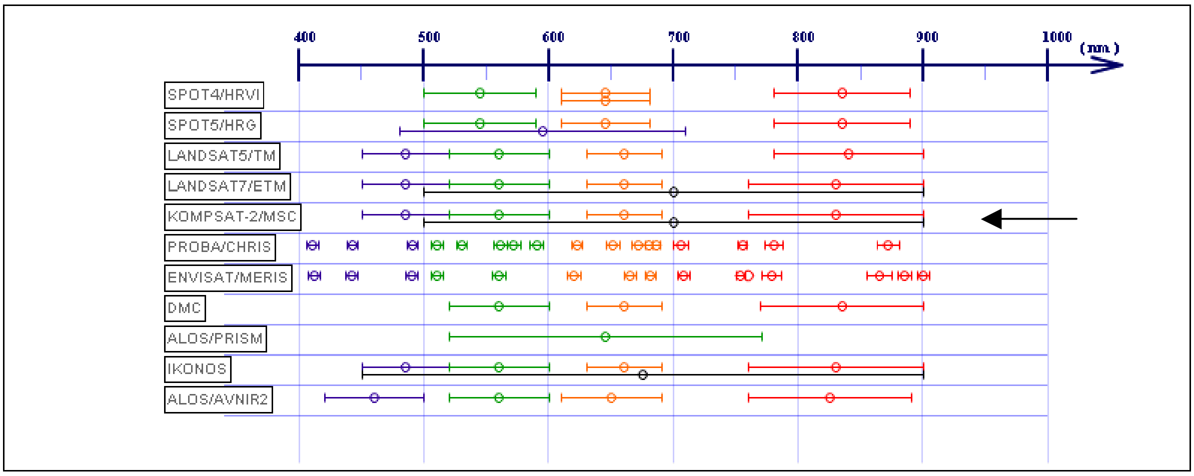


fig. 2 K-2 Spectral band wavelengths compared with those of 'equivalent' EO sensor.

Spatial resolution

The MSC instrument get capabilities to record panchromatic images at a 1 metre resolution and multi spectral images at a 4 metre ground resolution with a data quantization of 10 bits.

One (1) metre 'color' products are proposed by SpotImage as well. The producer used a multiresolution framework for merging the multispectral images with the higher resolution panchromatic band.

The MSC PAN image is reconstructed from 6 separate PAN image data channels, 6 CCD arrays including with 2528 detectors.

On the other hand, the MS image is reconstructed using two separate MS image data channels; two CCD arrays with 3792 dsetector.

Optic system is characterized by a very long focal length (9000 mm) on the order of IKONOS-2 / OSA (10000 mm).

Spectral band	GSD (m)	Focal (mm)
K-2 / MSC MS	4	2000
K-2 / MSC PAN	1	9000

table 2 - Ground sampling distance and focal of Kompsat-2 MSC.

The GSD is varying along with the off track pointing angle. For K-2, a 1-metre GSD for image observed at Nadir is achieved. The GSD is up to 2.5 metre when pointing angle is about 40 degrees. The figure jut hereafter fig. 6 depicts for three high resolution mission the variation in GSD according the off track angle.

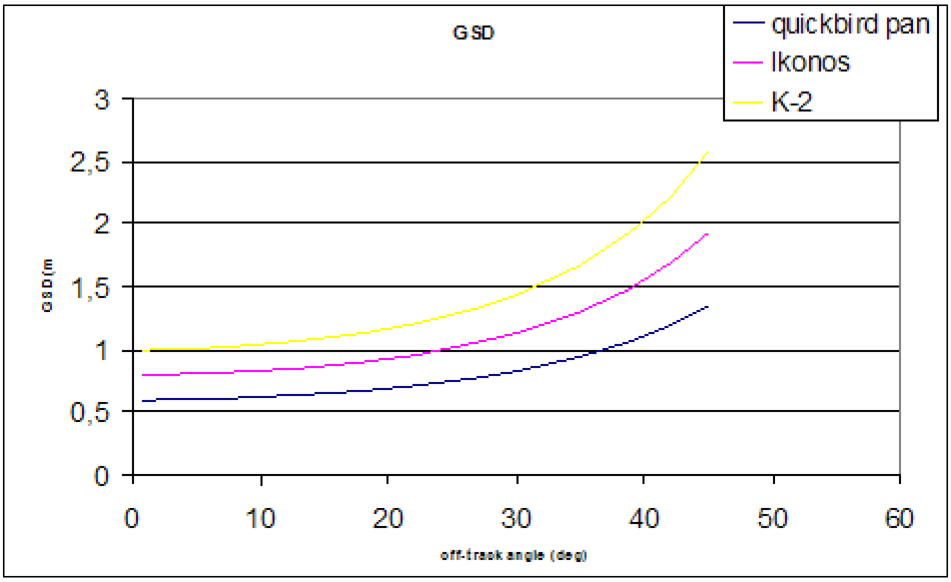


fig. 3 - GSD of K-2 MSC; Ikonos, Quickbird PAN instruments along with to the off-track pointing angle.

The Landsat product scene footprint is 185x185 km, in comparison with the PRISM one 35x35 km and the Kompsat-2 MSC one 15x15 km.

fig. 4 - Landsat TM scenes overlaid with ALOS PRISM and K-2 / MSC footprints.

Fields of use

The MSC one meter resolution panchromatic band is distributed to be used in the frame of cartographic project for detailed mapping (1:5000) and photo interpretation (1:2000)[5].

The swath width of the multi spectral product and the related ground sampling distance (4 m) is not very well suited for vegetation monitoring.

Obviously, the multi spectral data brings value added to the panchromatic data for data fusion product and classification.

Small area primarily located in the city for which we need to perform urban mapping activity (planning, modeling) and update Geographical information System database. In addition to the high resolution, the agility of the satellite makes it operational in the frame defense and security programs; disaster emergency, military equipment survey, conflict …

2.4 Operation

Pointing capability

Items	Value / Comment
Swath width	15 km
Off-pointing capability in pitch direction	+- 30 deg
Roll of nadir capability	+- 56 deg (max) ±30° (normal)
Yaw steering maneuver with TDI (32 levels)	Yes
Stereo Image	Using AT and AC pass
Compatibility with the daily revisit	Yes by roll off nadir (degraded GSD)

table 3 - Pointing capability items.

Duty Cycle

A maximum of 20% per orbit (R-2).

Storage capability

The KGS has RF communications links with the satellite at S-band (uplink and downlink) and X-band (downlink only). Data transmission rate Kompsat-2 320 Mbits and the data transmission is 600 Gb per day. In addition, the on board storage –128 Gbytes outside ground station coverage. The storage capability is the same as the one of IRS P6, QUICKBIRD (BGIS 2000).

Mission constraints

Sun Incidence angle Kompsat-2, SIA should not exceed 34 degrees for protecting the optical model of the MSC.

[5] Advertising Spot Image, April 2008

2.5 K-2 Product

Organization of product format

Image of K-2 products are processed into GeoTiff format and the dataset format is compliant with the Spot DIMAP format specification.

An extract of the metadata file available within the product format is provided in Appendix at the end of the document. The format structure is very well explained in [R-2]. Information provided with the format give to user the whole of required information to perform additional processing.

We will notice that the value of the modulation transfer function at Nyquist frequenct estimated on board is written within the product format in addition to the focal length. It is not usually done.

Processing level

The processing level are well defined into the Kompsat User Handbook document R-2. Based on their definition, the table just hereafter proposed a comparison with standard applied for other EO products. The fusion product level is considered as a value added product and is associated to the internal product level 9.

Internal level	Definition	SPOT5	ALOS PRISM / AVNIR-2	K-2
1	Raw data with aux	0A	1A	**1A**
2	Radiometric corrected	1A	1B1	**1R**
3	Ilevel2 + Geometric corrected from systematic error	1B	1B2R	**1G**
4	Ilevel3 + Standard registration to a geographic map without GCPs	2A	1B2G	**Nav**
5	Ilevel3 + Standard registration to a geographic map with GCPs	2B	Nav	**Nav**
6	Ilevel4 + Correction of parallaxe using DSM		1B2D (Optionnal)	**Nav**
7	Ilevel5 + Correction of parallaxe using DSM	3	Nav	**Nav**
8	Atsmopheric correction	Nav	Nav	**Nav**
9	Fusion (pan sharpened using the panchromactic and multi spect images)	Nav	Nav	**x**

table 4 - K-2 product processing level, the comparison with other EO Products.[6]

[6] Nav in the table for Not Available

3 THE ASSESSMENT OF PRODUCT QUALITY

3.1 Synthesis

The assessment has been based on Kompsat-2 dataset observed over La Crau (5114) and Toulouse (4340) in France, with a respective observation date (July,13 2007 and May, 05, 2007).
Standard end-user products (level 1b2) have been delivered to GAEL by SPOT IMAGE and ESA. The dataset from observation over La Crau have been processed two times with software version 'SPSv0.8' in September, 21, 2007 and 'CAP 1.0.071207.001' in January, 07, 2008.
To get the same dataset but processed with different processing version has been the opportunity to perform intensive product comparison to better understand the improvements between the both processing chain versions.
We intended to mainly focus on the geometric and image quality of products. The absolute radiometric calibration part has not been assessed. We gathered the whole of material required to perform a cross comparison between K-2 MSC and ALOS AVNIR-2. The rescaling gain and offset enabling to convert calibrated digital number to radiance values are not yet provided within product format. The results of radiometric calibration campaign are more likely still analyzed before updating processing parameters.
This assessment part is encompassed the early and in-depth studies. Results looks mainly consistent along with the processing chain evolution. In general, the product specifications are in accordance with those written into [7] .
However, it is important to alert ESA on the following aspects.
Some image artifacts have been observed, this is not an anomalies and this not due to instrument or processing chain malfunction. Their magnitude does not impact greatly on the image quality. The actual correction level applied during the processing (on board and on ground) is sufficient to propose to the user products 'free' from the following artifacts:

1. Inter-camera limit ('butting zone'),
2. Recurrent noise,
3. Detector to detector mis-calibration,

These artifact can be observed with an expert eyes but do not impact in certain extent on the usability of the product. The flight and ground operator usually monitor and control these artifacts.
One anomaly more likely due to the geometric model and Rational Polynomial Coefficient (RPCs) generation has been detected. The magnitude of the displacements observed into the image is important (up to 15 pixels). Some non-linear distortions are observed into the image. These distortions are not present in the dataset processed with previous software version. Everything let us think that an anomaly has occurred during the generation of the RPCs.. The full description of the problem is proposed within the present document.
In addition, thanks to note that the geo location results from ground control points located over contaminated image parts because of distortions have been discarded from the final results .
The last part of the document is dedicated to the image quality. We observed, specifically when checking the panchromatic images; that the pan sharpening filtering applied during product generation, modifies, locally, the understanding of the image data and so that impact on the image interpretability. The associated smoothing process looks too strong as well and so that, the textural information is lost.
The panchromatic images from high resolution sensor are mainly used for the urban mapping and the extraction of the image edges. So, one can think that the preservation of the textural content has not been put in priority during the design.
The application of Modulation Transfer Function Compensation may lead to more satisfactory results. According to the product specification, we understand that an MTF estimate is performed routinely on board. Practically, contact and discussion with SpotImage staff let us think that a such parameter is not use for product processing.

[7] K-2 Image Quality Status, January 2008 – SISA & KARI, K2-PE-K2-02-SI V1.3.

3.2 Geometric accuracy

Note

orbit determination

Orbit determination is an important to acquire the information for ground antenna tracking and image processing. In the case of using one ground station at a world, same as the case of KOMPSAT series, GPS based orbit determination is one of good solutions. To enhance the quality of GPS based orbit determination, precise orbit determination technique using double differenced GPS data is used at KOMPSAT-2. The difference between NASA GSFC Precise Orbit Ephemeris and precise orbit determination results using TEC are radial 6.9 cm RMS, along track 19.4 cm RMS, and cross track 6.9 cm RMS.

RPC

Rational Polynomial Coefficients (RPC) for the KOMPSAT-2 MSC sensor is generated from the resulted KOMPSAT-2 DSM (Direct Sensor Modeling) using the Rational Function Model (RFM). coefficients of the RFM are called Rational Polynomial Coefficients (RPC). In general, distortions caused by optical projection can be represented by ratios of first order polynomials, while corrections such as earth curvature, atmospheric refraction, and lens distortion etc., can be well approximated by second order polynomials. Some other unknown distortions with high order components can be modelled using a RFM with third order polynomials.

We will see that the distortions put in evidence in fig. 7 . are more likely due to a third order polynomial transformations (‘unknown parameters’).

Early results, product processed without RPCs

dataset

The product geo location assessment for the early investigation purposes have been performed on dataset received and processed in October 2007 *(.MSC_070521102314_04340_00981326M1P20G_1R*). All details regarding the MSC PAN dataset is given in [A.1], [A.2].

Methodology

Early assessment tasks encompassed the following studies;

- The product Geo location ,
- The Multispectral registration,
- The co registration between the panchromatic and multispectral band.

The reference data used for the product id 4340 was an IKONOS data. Its geometric was within specification, and has been used extensively at GAEL. Its accuracy is within specifications for given a coarse estimate of the K-2 product accuracy.

The methodology is semi-automatic, and is based on visual identification of several couples of Ground Control points. For comparison with IKONOS data proposes, the data has been into a common geographic grid using metadata information provided with the header data.

Results

At the import of the product , we observed that product processed with SPSV0.8 software version does not an ‘the Rational Polynomial Coefficients (RPC) file compliant the mostly used conventions.

The product geo location

	Multi Spectral	Panchromactic	Panchromactic 1 grp
Mean X (Easting)	-4.004	-10.513	2.816
Mean Y(Northing)	35.292	37.644	-2.016
Mean	36.788	39.432	5.624
RMS Error X (Easting)	10.663	11.785	5.260
RMS Error Y(Northing)	35.4000	37.736	3.997
RMS Error	36.971	39.534	6.606

table 5 - Geo location error (metre unit) , product Id 4340.

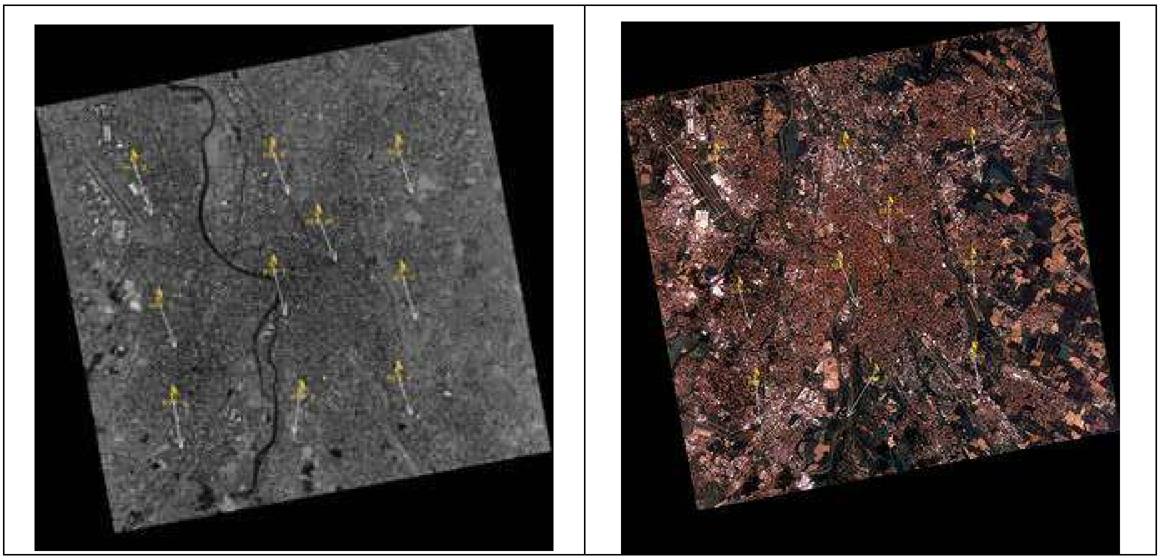


table 6 - Error Vector fields x 50, product Id 4340.

Co registration Multispectral / Panchromatic

The multispectral is used as working image and the panchromatic as the reference one. provided with the header data.

	Multi Spectral / Panchromatic
Mean X (Easting)	-4.526
Mean Y(Northing)	-1.076
Mean	5.025
RMS Error X (Easting)	4.874
RMS Error Y(Northing)	2.169
RMS Error	5.335

table 7 - Co-registration Multi Spectral / Panchromatic (metre unit) , product Id 4340.

Multispectral registration

With a image GSD of 4 metre, the multi-spectral registration is below the pixel. The registration of band 4 with the other bands looks less accurate. The magnitude of mis registration is more important according to the easting direction.

	band1		band2		band3		band4	
	x	y	x	y	x	y	x	y
band1	x	x	x	x	x	x	x	x
band2	2,09	1,19	x	x	x	x	x	x
band3	2,61	1,56	2,92	1,41	x	x	x	x
band4	3,44	1,12	3,52	1,07	3,06	2,08	x	x

table 8 - Multi Spectral registration (metre unit) , product Id 4340.

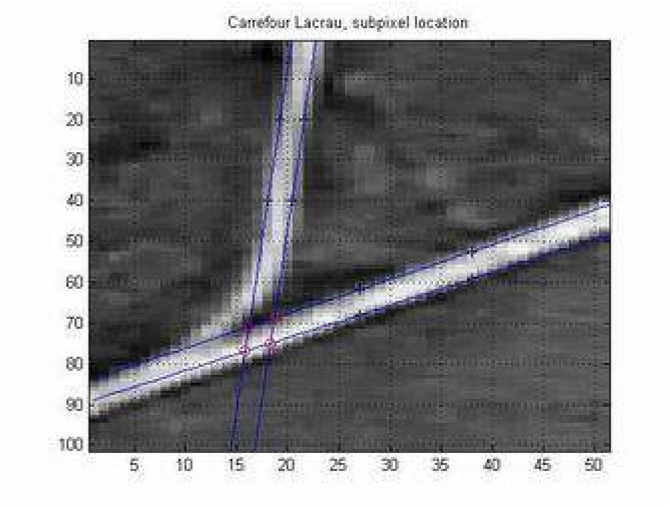
In depth investigation; product processed with RPCs

dataset

The product geo location assessment for the early investigation purposes have been performed on dataset received and processed in January 2008 *(MSC_070713100624_05114_01251326M2P16B_1R*). All details regarding the MSC PAN dataset is given in [A.3].
For this dataset we focused on the evaluation of geometry quality of dataset output from KOMPSAT-2 MSC PAN instrument.
The dataset embeds an RPC file that can be used for prediction of the pixel geo location.
The reference data are based on set of Ground Control Points derived from Global Positioning System (GPS) measurement and consolidated using Differential GPS. The accuracy reaches is below 50 centimetres.

Methodology

The use of GCPs derived from GPS measurement has required a different strategy for the control procedure (when comparing with the one explained previously).
In a fist iteration, the GCP are identified manually, the GCP location in the image space is adjusted using sub pixel approach. The sub pixel location is defined as the intersection between two directions. The directions are extracted from image data using sub-pixel estimated of the point for which the slope is the most important. The location in the image space is estimated at a 0.005 step.



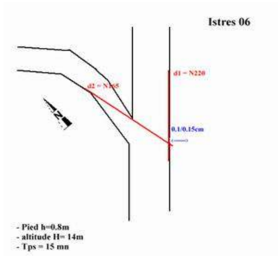


table 9 - GCP derived from GPS measurement, related representation and sub-pixel approach.

The pixel location is predicted using polynomial functions based on RPC file embedded within the product. We assessed the accuracy of this predictions. It is important to note that in this case, we do not put the image data into a geographic grid, such as done previously for the early investigation.

Results

The product geo location

Such as listed just here after; even if the geometry is different, the product geo location results are surprisingly close to those obtained during the early verification phase.

The RMS error reaches 40 metres without ground control point. When ground control point is added to refine the RPC model, the accuracy is of about 6.5 metres.

	Pan	Pan with 1 gcp
Mean X	-33.459	-2.655
Mean Y	22.829	-1.183
Mean	40.672	5.370
RMS Error X	33.657	4.596
RMS Error Y	23.234	4.596
RMS Error	40.898	6.581

table 10 - Geo location error (metre unit) , product Id 5114.

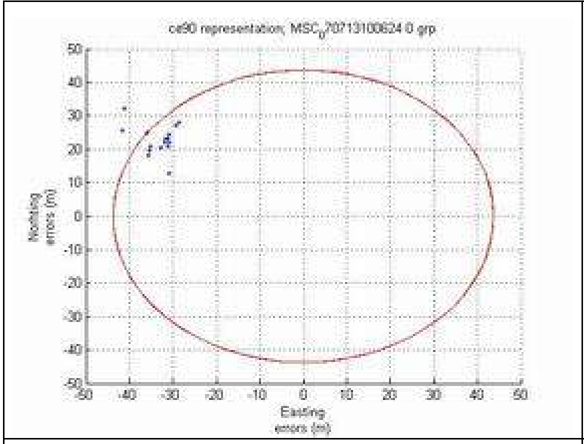
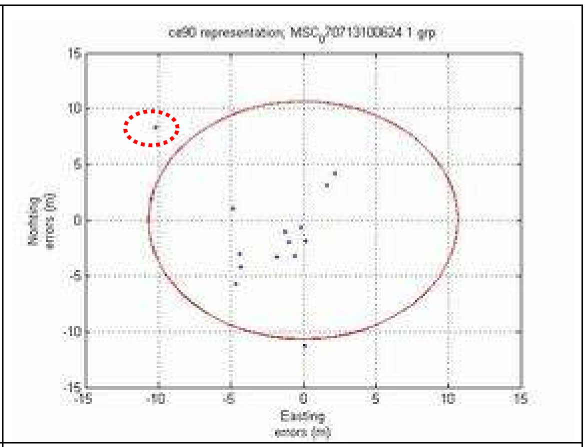
	
With no GCP, RMS@ CE 90 = 43.69 metres	With one (1) GCP, RMS@ CE 90 = 10.632 metres

table 11 - CE90 plot, product Id 5114.

When comparing, with the old product addressed in early investigation stage, we may expect a better accuracy because we used RPC file. Inconsistent results on GCPs location (table 11) let us think that it may be well suited to investigate more in depth the internal image geometry. The analysis of disparities magnifies some anomalies detailed in the next document part.

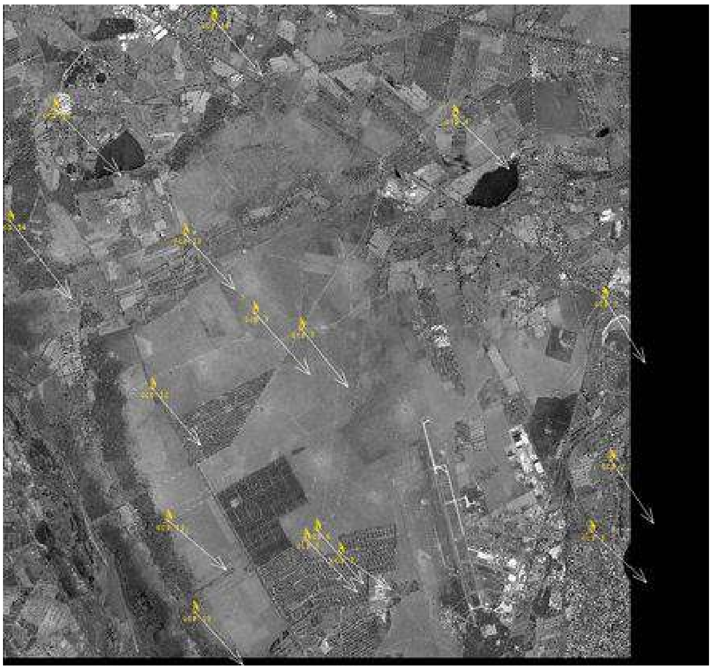


fig. 5 - PanChromatic image overlaid with error Vector Fields (x100), without ground reference point to set the model.

fig. 6 - PanChromatic image overlaid with error Vector Fields (x100), with one ground reference point to set the model.

3.3 Image Quality

Product comparison

The comparison of image data between a couple of dataset processed with a different software version leads to observation on data quality and its improvement.

Dataset used for the product comparison is the '5114' series [A.2] and focused on data from MSC panchromatic data. The first product has been processed on September 21, 2007 with software number SPSV0.8. The last one has been processed on January, 7 2008 with software number CAP 1.0.071207.001.

The major modification relies on the improvement of image quality and refinement of geometric model in order to generate Rational Polynomial Coefficients for a better product location that account for terrain relief.

The following image artifacts have been detected. Their magnitudes are not so strong except for the image local incoherence (up to 15 pixels), refer to table 12.

1. Inter-camera limit ('butting zone'), (1),
2. Local incoherence (2),
3. Recurrent noise (3),
4. Detector to detector mis-calibration

The two first items affects the quality of the image geometry. The last ones are due to radiometric calibration.

The dataset comparison has been done on pixel per pixel basis and performed through the analysis of disparities. Results are illustrated with table 12, table 13 and .

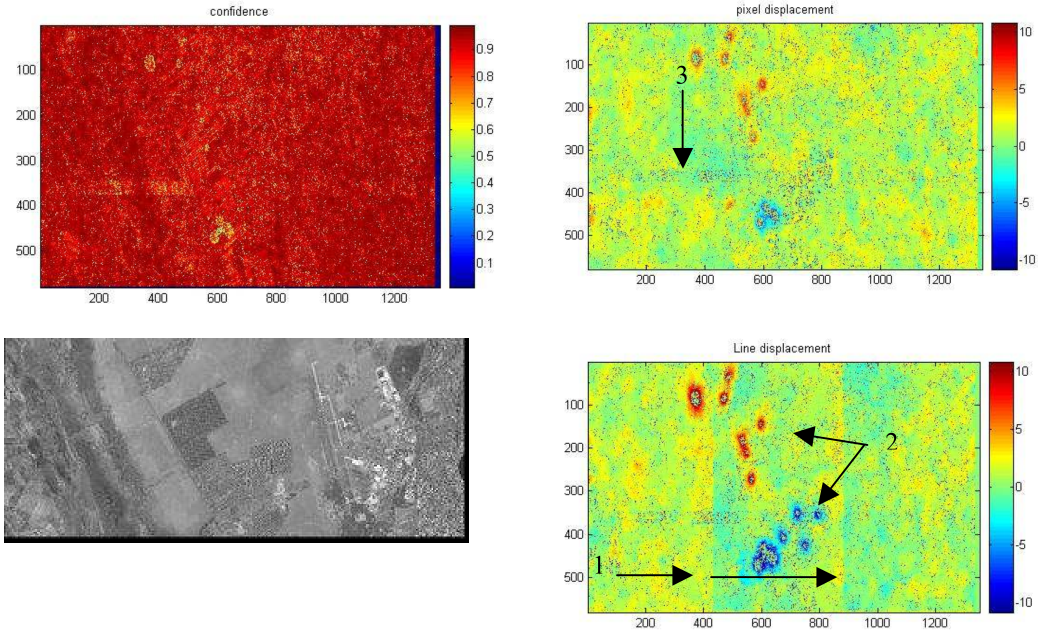


table 12 - Disparity analysis (raw results).

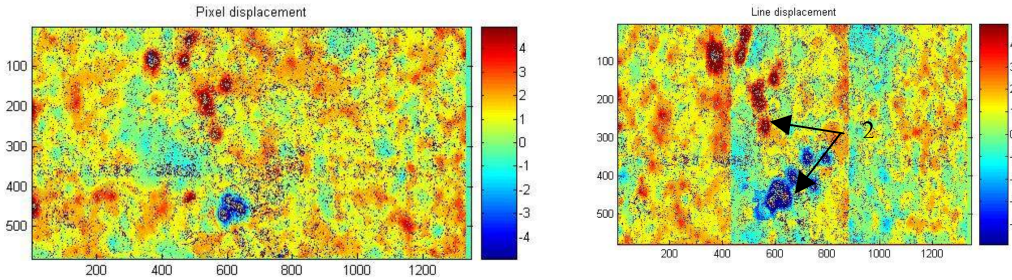


table 13 - Disparity analysis (bounded results).

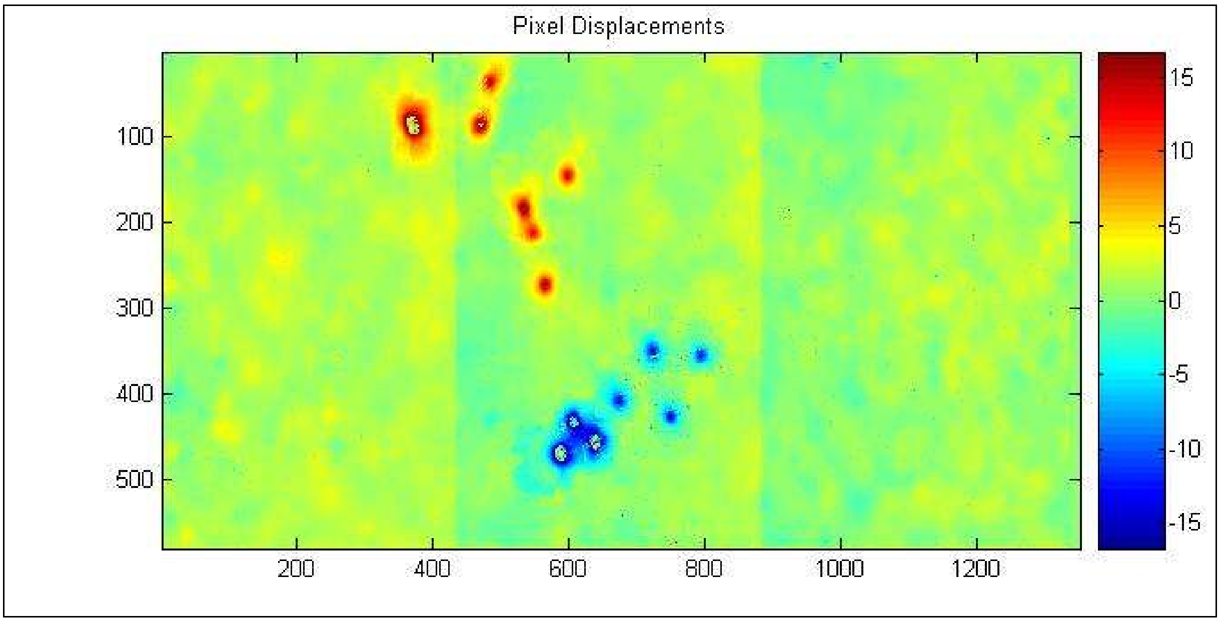


fig. 7 - Disparities analysis, pixel displacements.

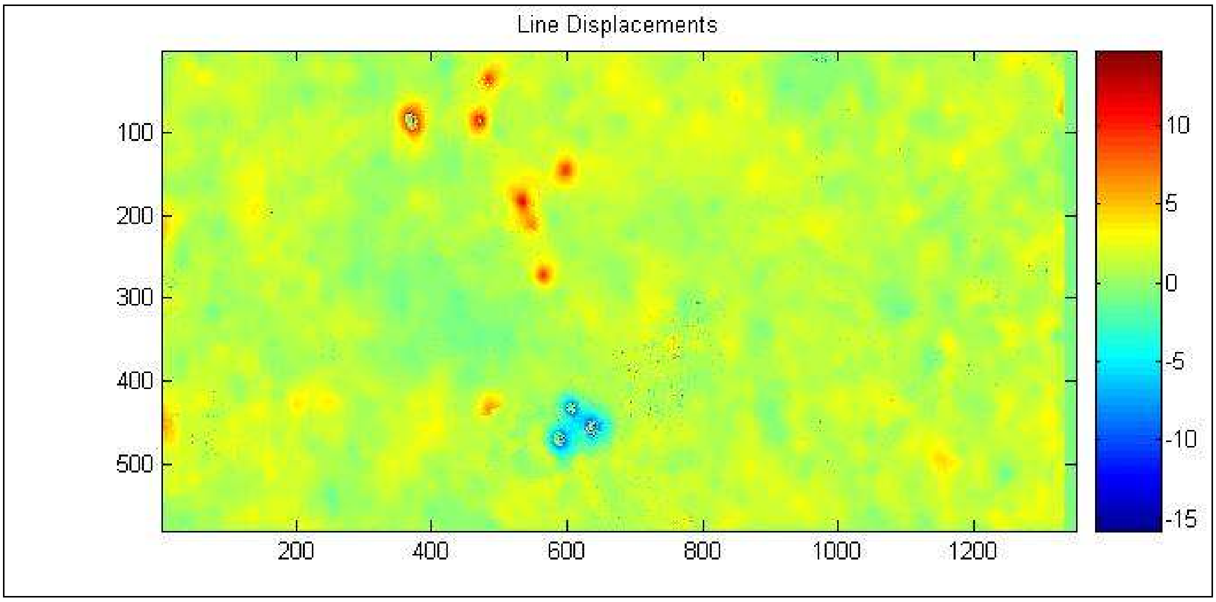
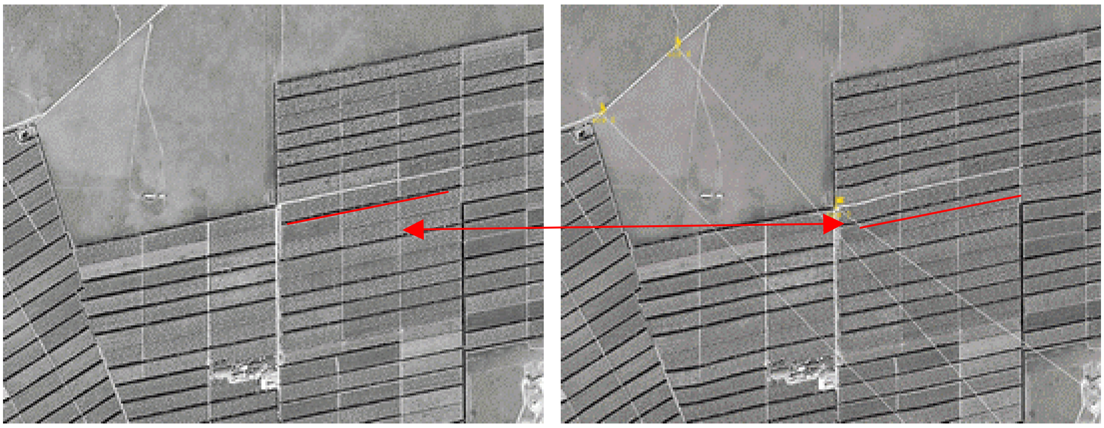


fig. 8 - Disparities analysis, line displacements.

Local incoherence

Some local incoherence of the image are spread all over the scene observed. Their magnitude is varying between –10 and 10 pixels (table 12) and remain between –4 and 4 pixels for a major part of pixels (table 13).
It has not been observed when checking the product processed by the past, this is a new problem. Probably due to RPCs, this question should be investigated.



Old processing version (without RPCs) | The last processing version (without RPCs)

table 14 - Illustration of the image distortion.

Inter-camera limit

It is a part of non-uniformity noise level correction. The non-uniformity noise level of KOMPSAT-2 imagery is corrected with an algorithm details into the following document ([R-4]). "*Relative radiometric calibration is necessary to account for the detector-to-detector non-uniformity in this raw imagery. Nonuniformity correction (NUC) is that the process of performing on-board relative correction of gain and offset for each pixel to improve data compressibility and to reduce banding and streaking from aggregation or re-sampling in the imagery.*"

KOMPSAT-2 has six panchromatic bands whose order is PAN1, PAN2, PAN4, PAN3, PAN5, PAN6. There are two butting zones (full signal zone and overlap zone) in the panchromatic band between CCD 2 and 4 and between CCDS 3 and 5.

The artifact is still present on product processed with the last software version.

The magnitude of this artifact has been reduced in the frame of the non uniformity correction. The problem is difficult to be observed when looking image data.

Generally, the purpose of panchromatic data is the urban mapping and extraction of ground features. We applied to the image segmentation algorithm to appreciate the impact of the artifact on results of such algorithms (fig. 9).

fig. 9 - Intercamera limit visible (CCD2-CCD4) when applying edge detection.

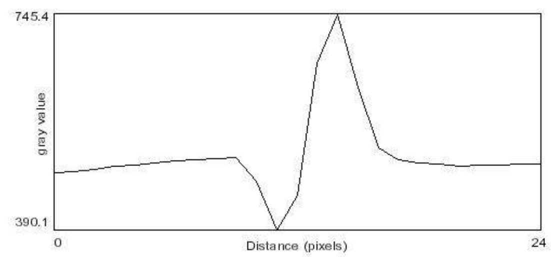
Recurrent noise

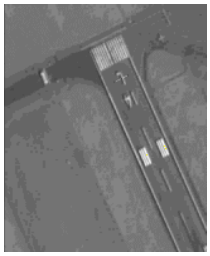
This noise appears periodically and contaminated all data from the image record (all ccds). Its width is about 400 lines. On the 5114 product, we observed these artifact two times, at two different location of the image. This artifact is not visible when looking at image data. Its magnitude is reduced with the image filtering applied.

The artifact is not observe anymore for product processed with the last software version.

Pan sharpening

A sharpening filter is applied to image from MSC PAN in order to enhance the contrast. These filters make the image edge more 'steeper' and remove noise over smooth area. The filter parameters maybe to strong and introduce artifact. That can become a problem for specific applications.





White line boundaries appear to be shadowed.

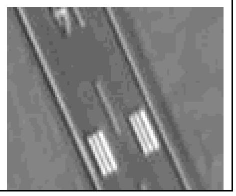


fig. 10 - Edge profile with MSC PAN image

Some similar problem are experienced with other sensors. The reason are mainly due to the edge sharpening filter, most probably the 'LoG'. This processing can be done even online, during imaging.

With The pan-sharpening filtering, image areas considered as uniform are smoothed and image texture is significantly. The following tables proposed a comparison between a subpart of IKONOS and KOMPSAT-2 panchromatic images (table 15).

The IKONOS data is 8-bit encoded with an image GSD of 0.8 metre whereas the MSC data is 16-bit encoded with an image GSD of about 1.1 metre.

When looking at IKONOS data, we observed that texture content is preserved (white line over the grass, of the stadium (right panel). This is not the case for MSC data, the texture have been lost during the processing and no detail can be observed.

The both observations; 'shadowing effect' and 'over smoothing' may raised some interrogations about the quality of the filtering and the lost of information.

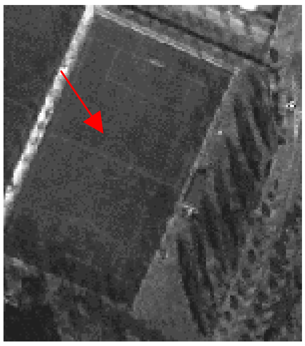


table 15 - Image comparison between panchromatic images from IKONOS (upper) and KOMPSAT-2 MSC.

APPENDIX A PRODUCT METADATA

A.1 MSC_070521102314_04340_00981326M1P20G_1R

INST_LAST_NUC_DATE 20061216

INST_LAST_GEO_DATE 20070831

INST_COMPRESSION_FLAG FALSE

INST_COMPRESSION_RATIO_OF_MS 0 0 0 0

INST_TDI_GAIN_OF_MS 3 4 1 3

INST_ELEC_GAIN_OF_MS 0 0 0 0

INST_ELEC_OFFSET_OF_MS 0 0 0 0

INST_BAND_DISPLAY G

INST_BAND_WIDTH 80

INST_MS_CCD_ALIGNMENT -0.0247100 -0.0226269 0.0240400 -0.0222851

INST_MS_FOCAL_LENGTH 2.25467733

INST_CCD_MODE MS_Primary

CAL_MTF_OF_MS 1150016629 1123072235 1137262666 1123663080

CAL_RADIANCE_GAINOFFSET_MS 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00

BEGIN_CALGCP_BLOCK

NMR_GCP 0

END_CALGCP_BLOCK

CAL_DEM_FILE NULL

AUX_FILE_NAME MSC_070521102314_04340_00981326M1P20G_1R.tif

AUX_STRIP_ID MSC_070521102314_04340_00981322_1331BP20_1A

AUX_STRIP_BEGIN_END 11855 15729

AUX_IMAGE_LEVEL L1R

AUX_PRODUCT_LEVEL RPC

AUX_CLOUD_STATUS 9

AUX_IMAGE_QUALITY NULL

AUX_IMAGE_BAD_LINES NULL

AUX_IMAGE_BAD_COLS NULL

AUX_SATELLITE_NAME KOMPSAT2

AUX_SATELLITE_SENSOR MSC

AUX_TILT_ANGLE_ROLL_DEG 20.668

AUX_TILT_ ANGLE_PITCH_DEG 0.604

AUX_BITS_PER_PIXEL 16

AUX_SAMPLES_PER_LINE_MS 3750

AUX_LINES_PER_IMAGE_MS 3875

AUX_SCENE_CENTER_XY_PIXEL 1875 1937

AUX_IMAGE_GSD_METER 4.744 4.188

AUX_LINE_SCAN_TIME_USEC 0.0006219887

AUX_IMAGE_SATELLITE_AZIMUTH_DEG -15.875597

AUX_IMAGE_SATELLITE_INCIDENCE_DEG 66.944169

AUX_IMAGE_PAD_POD_FLAG TRUE

AUX_IMAGE_MTF_FLAG FALSE

AUX_PROJECTION_NAME UTM

AUX_PROJECTOIN_PARAMETER UTM:North,31 WGS 84

AUX_PROJECTOIN_ELLIPSOID WGS 84

AUX_RESAMPLING_NAME NONE

AUX_LOCATION_KGRS_KJ 98 1326

AUX_IMAGE_SHIFT_TO_ALONG 3

AUX_IMAGE_ORBIT_NUMBER 4340

AUX_IMAGE_CENTER_LATLONG_DEG 43.60238285 1.44668154

AUX_IMAGE_CENTER_ALTITUDE 683968.913334

AUX_IMAGE_TL_LATLONG_DEG 43.65944176 1.32139841

AUX_IMAGE_TC_LATLONG_DEG 43.67509924 1.42598172

AUX_IMAGE_TR_LATLONG_DEG 43.69092462 1.53167459

AUX_IMAGE_BL_LATLONG_DEG 43.51391894 1.36303714

AUX_IMAGE_BC_LATLONG_DEG 43.52957268 1.46736136

AUX_IMAGE_BR_LATLONG_DEG 43.54537522 1.57279762

AUX_STRIP_ACQ_DATE_UT 20070521

AUX_STRIP_ACQ_START_UT 102316.979414

AUX_STRIP_ACQ_CENTER_UT 102326.479221

AUX_STRIP_ACQ_END_UT 102335.979069

AUX_STRIP_ACQ_DURATION_SEC 18.999656

AUX_IMAGE_L0_PROCESSED_UT **20070921165218.00**

AUX_IMAGE_L1A_PROCESSED_UT 00000000000000.00

AUX_IMAGE_L1R_PROCESSED_UT 20070921110146.00

AUX_IMAGE_MINMAX_OF_MS 0 1100 0 1100 0 1100 0 1100

AUX_RECEIVED_STATION_NAME NULL

AUX_RECEIVED_STATION_LOCATION_LATLONG_DEG 0.00000000 0.00000000

AUX_PROCESSED_STATION_NAME KARI

AUX_PROCESSED_STATION_LOCATION_LATLONG_DEG 36.30000000 36.30000000

AUX_PROCESSED_PRODUCER admin

AUX_PROCESSED_SW_VER SPSv0.8

AUX_REQUESTER_NAME NULL

AUX_REQUESTER_COMPANY NULL

AUX_REQUESTER_DATETIME NULL

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A.2 MSC_070713100624_05114_01251326PP16_1R

INST_LAST_NUC_DATE 20061216

INST_LAST_GEO_DATE 20070831

INST_COMPRESSION_FLAG TRUE

INST_COMPRESSION_RATIO_OF_PAN 0

INST_TDI_GAIN_OF_PAN 4

INST_ELEC_GAIN_OF_PAN 1 3 2 3 3 2 4 2 7 7 7 9

INST_ELEC_OFFSET_OF_PAN 1 2 0 0 2 0 0 2 1 0 5 0

INST_BAND_DISPLAY PAN

INST_BAND_WIDTH 400

INST_PAN_CCD_ALIGNMENT -0.0988400 -0.0905076 0.0961600 -0.0891404

INST_PAN_FOCAL_LENGTH 9.01870932

INST_CCD_MODE PAN_Redundant

CAL_MTF_OF_PAN 0

CAL_RADIANCE_GAINOFFSET_PAN 1.00 1.00 1.00 1.00

BEGIN_CALGCP_BLOCK

NMR_GCP 0

END_CALGCP_BLOCK

CAL_DEM_FILE NULL

AUX_FILE_NAME MSC_070713100624_05114_01251326PP16_1R.tif

AUX_STRIP_ID MSC_070713100624_05114_01251322_1348BP16_1A

AUX_STRIP_BEGIN_END 53982 69481

AUX_IMAGE_LEVEL L1R

AUX_PRODUCT_LEVEL RPC

AUX_CLOUD_STATUS 0

AUX_IMAGE_QUALITY NULL

AUX_IMAGE_BAD_LINES NULL

AUX_IMAGE_BAD_COLS NULL

AUX_SATELLITE_NAME KOMPSAT2

AUX_SATELLITE_SENSOR MSC

AUX_TILT_ANGLE_ROLL_DEG 16.997

AUX_TILT_ ANGLE_PITCH_DEG 0.474

AUX_BITS_PER_PIXEL 16

AUX_SAMPLES_PER_LINE_PAN 15000

AUX_LINES_PER_IMAGE_PAN 15500

AUX_SCENE_CENTER_XY_PIXEL 7500 7750

AUX_IMAGE_GSD_METER 1.100 1.045

AUX_LINE_SCAN_TIME_USEC 0.0001575893

AUX_IMAGE_SATELLITE_AZIMUTH_DEG -16.439537

AUX_IMAGE_SATELLITE_INCIDENCE_DEG 70.995810

AUX_IMAGE_PAD_POD_FLAG TRUE

AUX_IMAGE_MTF_FLAG TRUE

AUX_PROJECTION_NAME UTM

AUX_PROJECTOIN_PARAMETER UTM:North,31 WGS 84

AUX_PROJECTOIN_ELLIPSOID WGS 84

AUX_RESAMPLING_NAME NONE

AUX_LOCATION_KGRS_KJ 125 1326

AUX_IMAGE_SHIFT_TO_ALONG 0

AUX_IMAGE_ORBIT_NUMBER 5114

AUX_IMAGE_CENTER_LATLONG_DEG 43.56271780 4.86731339

AUX_IMAGE_CENTER_ALTITUDE 705131.881862

AUX_IMAGE_TL_LATLONG_DEG 43.61999601 4.74344571

AUX_IMAGE_TC_LATLONG_DEG 43.63589578 4.84570514

AUX_IMAGE_TR_LATLONG_DEG 43.65191558 4.94886187

AUX_IMAGE_BL_LATLONG_DEG 43.47355428 4.78690283

AUX_IMAGE_BC_LATLONG_DEG 43.48943932 4.88891700

AUX_IMAGE_BR_LATLONG_DEG 43.50544481 4.99182592

AUX_STRIP_ACQ_DATE_UT 20070713

AUX_STRIP_ACQ_START_UT 100627.070709

AUX_STRIP_ACQ_CENTER_UT 100656.570126

AUX_STRIP_ACQ_END_UT 100726.069584

AUX_STRIP_ACQ_DURATION_SEC 58.998875

AUX_IMAGE_L0_PROCESSED_UT 20080107125913.00

AUX_IMAGE_L1A_PROCESSED_UT 00000000000000.00

AUX_IMAGE_L1R_PROCESSED_UT 20080125214523.00

AUX_IMAGE_MINMAX_OF_PAN 0 1100

AUX_RECEIVED_STATION_NAME NULL

AUX_RECEIVED_STATION_LOCATION_LATLONG_DEG 0.00000000 0.00000000

AUX_PROCESSED_STATION_NAME KARI

AUX_PROCESSED_STATION_LOCATION_LATLONG_DEG 36.30000000 36.30000000

AUX_PROCESSED_PRODUCER 5114

AUX_PROCESSED_SW_VER CAP 1.0.071207.001

AUX_REQUESTER_NAME NULL

AUX_REQUESTER_COMPANY NULL

AUX_REQUESTER_DATETIME NULL

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A.3 MSC_070713100624_05114_01251326M2P16B_1R

INST_LAST_NUC_DATE 20061216

INST_LAST_GEO_DATE 20070831

INST_COMPRESSION_FLAG TRUE

INST_COMPRESSION_RATIO_OF_MS 0 0 0 0

INST_TDI_GAIN_OF_MS 3 4 1 3

INST_ELEC_GAIN_OF_MS 0 0 0 0

INST_ELEC_OFFSET_OF_MS 0 0 0 0

INST_BAND_DISPLAY B

INST_BAND_WIDTH 70

INST_MS_CCD_ALIGNMENT -0.0247100 -0.0226269 0.0240400 -0.0222851

INST_MS_FOCAL_LENGTH 2.25467733

INST_CCD_MODE MS_Primary

CAL_MTF_OF_MS -1047013500 0 -1047013500 0

CAL_RADIANCE_GAINOFFSET_MS 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00

BEGIN_CALGCP_BLOCK

NMR_GCP 0

END_CALGCP_BLOCK

CAL_DEM_FILE NULL

AUX_FILE_NAME MSC_070713100624_05114_01251326M2P16B_1R.tif

AUX_STRIP_ID MSC_070713100624_05114_01251322_1348BP16_1A

AUX_STRIP_BEGIN_END 13495 17369

AUX_IMAGE_LEVEL L1R

AUX_PRODUCT_LEVEL RPC

AUX_CLOUD_STATUS 0

AUX_IMAGE_QUALITY NULL

AUX_IMAGE_BAD_LINES NULL

AUX_IMAGE_BAD_COLS NULL

AUX_SATELLITE_NAME KOMPSAT2

AUX_SATELLITE_SENSOR MSC

AUX_TILT_ANGLE_ROLL_DEG 16.997

AUX_TILT_ ANGLE_PITCH_DEG 0.474

AUX_BITS_PER_PIXEL 16

AUX_SAMPLES_PER_LINE_MS 3750

AUX_LINES_PER_IMAGE_MS 3875

AUX_SCENE_CENTER_XY_PIXEL 1875 1937

AUX_IMAGE_GSD_METER 4.605 4.177

AUX_LINE_SCAN_TIME_USEC 0.0006303572

AUX_IMAGE_SATELLITE_AZIMUTH_DEG -16.439537

AUX_IMAGE_SATELLITE_INCIDENCE_DEG 70.995810

AUX_IMAGE_PAD_POD_FLAG TRUE

AUX_IMAGE_MTF_FLAG FALSE

AUX_PROJECTION_NAME UTM

AUX_PROJECTOIN_PARAMETER UTM:North,31 WGS 84

AUX_PROJECTOIN_ELLIPSOID WGS 84

AUX_RESAMPLING_NAME NONE

AUX_LOCATION_KGRS_KJ 125 1326

AUX_IMAGE_SHIFT_TO_ALONG 0

AUX_IMAGE_ORBIT_NUMBER 5114

AUX_IMAGE_CENTER_LATLONG_DEG 43.56271780 4.86731339

AUX_IMAGE_CENTER_ALTITUDE 705131.881862

AUX_IMAGE_TL_LATLONG_DEG 43.61999601 4.74344571

AUX_IMAGE_TC_LATLONG_DEG 43.63589578 4.84570514

AUX_IMAGE_TR_LATLONG_DEG 43.65191558 4.94886187

AUX_IMAGE_BL_LATLONG_DEG 43.47355428 4.78690283

AUX_IMAGE_BC_LATLONG_DEG 43.48943932 4.88891700

AUX_IMAGE_BR_LATLONG_DEG 43.50544481 4.99182592

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AUX_STRIP_ACQ_CENTER_UT 100656.570126

AUX_STRIP_ACQ_END_UT 100726.069584

AUX_STRIP_ACQ_DURATION_SEC 58.998875

AUX_IMAGE_L0_PROCESSED_UT 20080107125913.00

AUX_IMAGE_L1A_PROCESSED_UT 00000000000000.00

AUX_IMAGE_L1R_PROCESSED_UT 20080125214523.00

AUX_IMAGE_MINMAX_OF_MS 0 1100 0 1100 0 1100 0 1100

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AUX_PROCESSED_STATION_NAME KARI

AUX_PROCESSED_STATION_LOCATION_LATLONG_DEG 36.30000000 36.30000000

AUX_PROCESSED_PRODUCER 5114

AUX_PROCESSED_SW_VER CAP 1.0.071207.001

AUX_REQUESTER_NAME NULL

AUX_REQUESTER_COMPANY NULL

AUX_REQUESTER_DATETIME NULL

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