ORTHO PRODUCT TESTING
KOMPSAT-2 KARI / K2PS
ACCURACY COMPARISON

1 INTRODUCTION

This work is done in the frame of the K2PS / KARI processing software comparison. The second stage of the study was focused on the anomaly closure analysis and the testing of a couple of 'ortho' products generated by the both processing software.

1.1 Test data

The analysis has been conducted using the following working dataset

Scene name	Code	KARI	K2PS PTLS	AUX_PROCESSED_SW_VER	Processing Date
MSC_080701100409_10285_01281325	128-1325	X		CAP 1.0.080508.01	2008-07-04
MSC_080701100409_10285_01281325	128-1325		X	v1.00.00.0002 (= v1.00.00.0005)	2008-07-03

table 1 - Products to be analysed

The Kompsat-2 level 1R Panchromatic imagery processed into Spot DIMAP format has been used as input of the processing.

1.2 The reference equipment

The ortho validation exercise required accurate reference dataset; the following ones has been used

- GPS points measurements from Spot Image provided for this analysis,
- DEM from reference 3D spot image product.

1.2.1 GPS points

The accuracy of the ground control points measured using GPS techniques are given to be within 30 cm.. Points coordinates are expressed into different cartographic system; WG84, UTM31, L93,L2E. The conversion between the various DATUM reference is given as well.

The GCP derived from the GPS measurements are however somehow difficult to identify into the image space for at least two reasons that sometimes are correlated.

- The GPS points definitions,
- The quality of the image.

Such as depicted with the figure just here after, the GCP point id KTS08-38 (fig.2 A-B), the geometry of each of the two little flower beds smear within the image and so that is not well defined. In addition, the white part between these 2 object don't show a good contrast. In consequence; the 2 directions and there intersection can't be determined accurately.

In the case of GPS point id KTS08-39 (fig.2 C-D), the problem of location determination is due to a strong aliasing which affect the boundaries of the sport field, more likely because a terrain slop aside the sport field is not well documented.

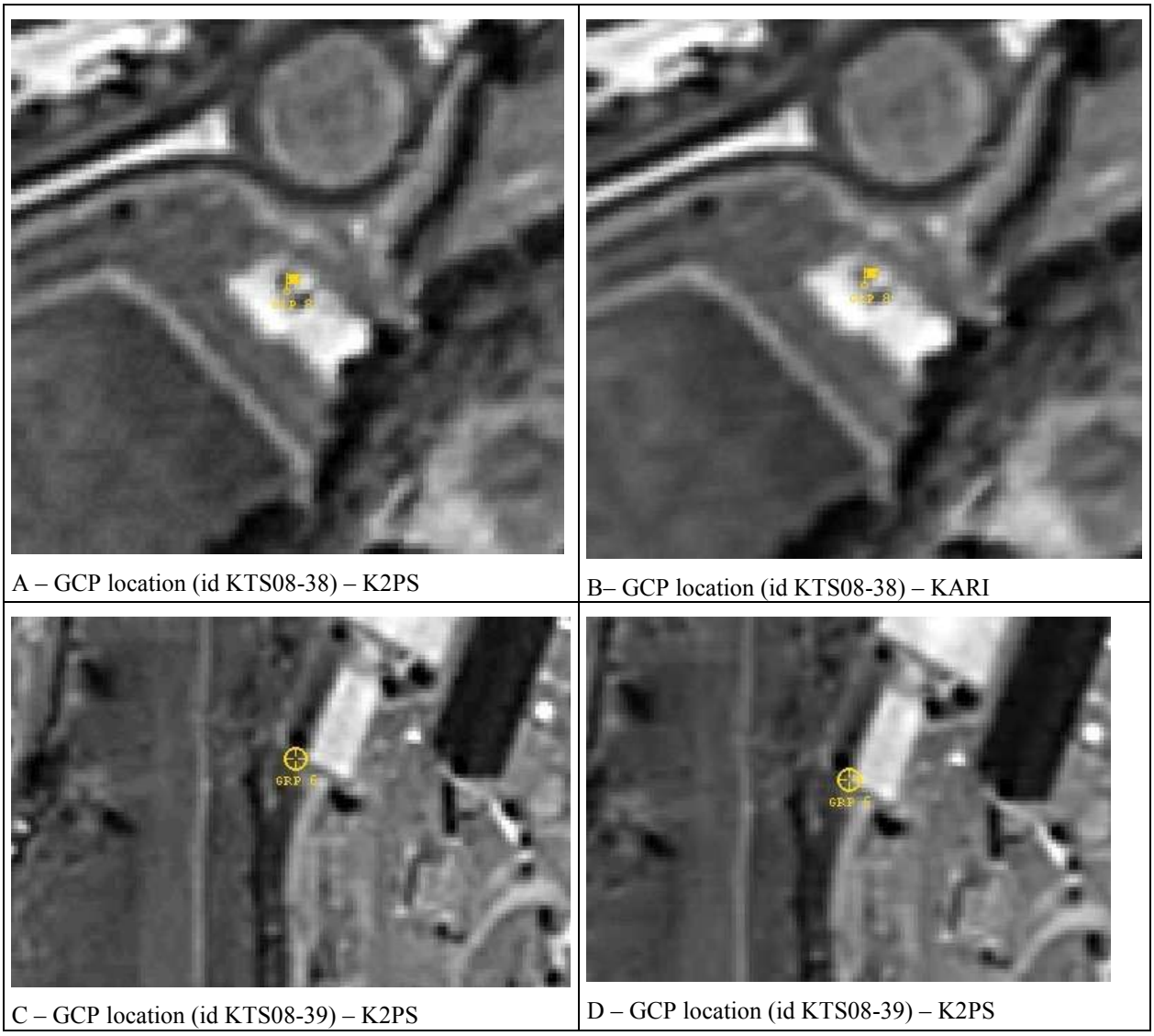
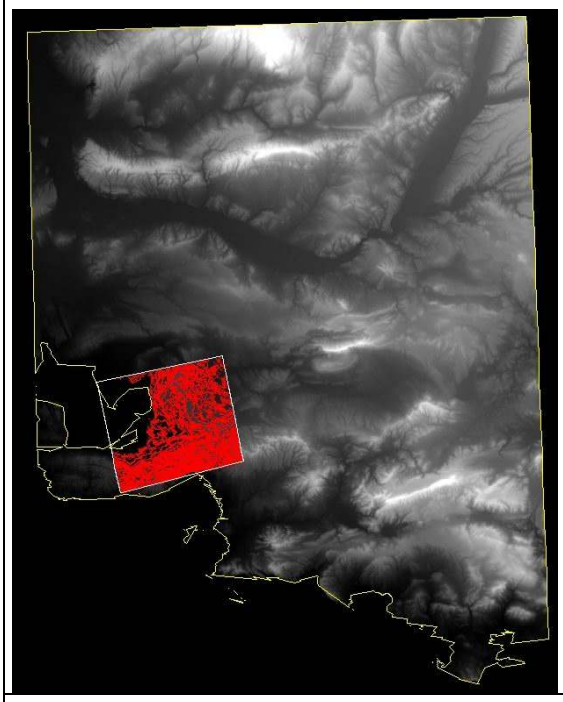


fig. 1 - Illustration of Ground Control Point location into the K-2 PAN image space

1.3 DSM



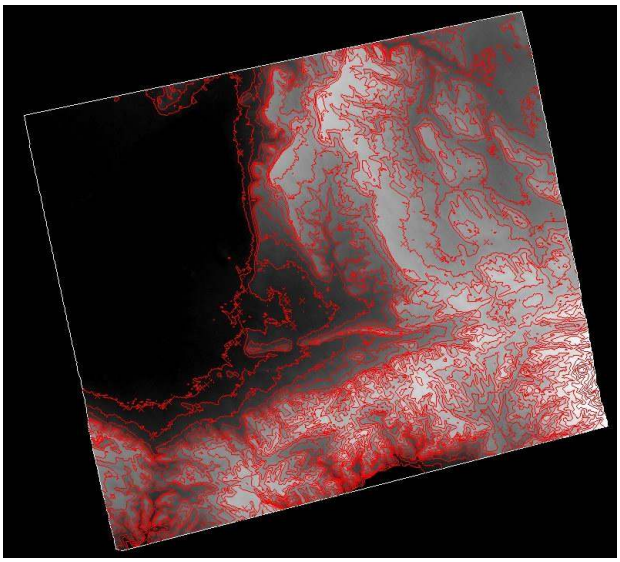


fig. 2 - DSM Spot image.

STASTICTICS ON THE DEM (EGM96)	
IMAGE PIXELS	= 346795 (60.85%)
BACKGROUND PIXELS	= 223115 (39.15%)
BACKGROUND VALUE	= 0
MINIMUM	= 1
MAXIMUM	= 452
LEFT BOUND 2%	= 1
RIGHT BOUND 2%	= 279
MEAN	= 133.769
VARIANCE	= 6597.175
STANDARD DEVIATION	= 81.223
RMS	= 156.497
MEDIAN VALUE	= 143.000
HISTOGRAM MAXIMUM INDEX	= 1

2 METHODOLOGY

The geometric model used along with this study is based on RFM. Auxiliary files give the RPC coefficients. The geometric model enable to predict the location of a point into the image space from geographic coordinates and elevation above ellipsoid (Forward Method)/

2.1 Select ground reference points and ground control points

Eight points (green circle, figure below) used for the geo referencing have been selected. The other part of the sample, (Nine points, red circle, figure below) has been used for the quality check of the ortho-rectified image.

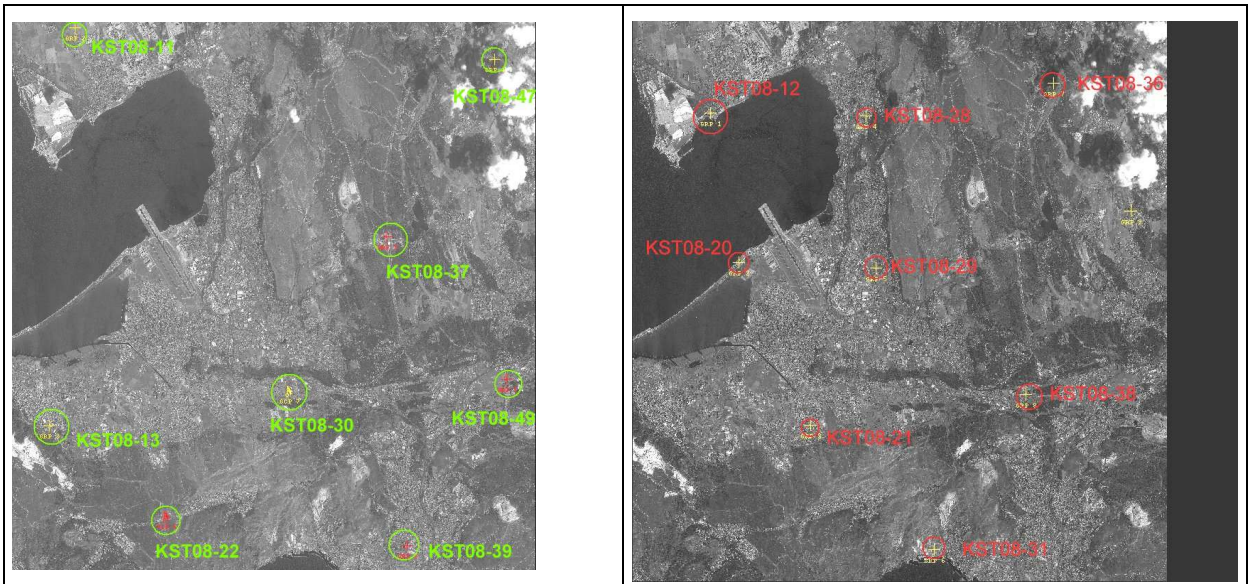


fig. 3 GPS points location in the image – PAN 1R. A) GRP used for orthorectification, B) GCP used for quality control

2.2 Quality control

2.2.1 Check the point definition

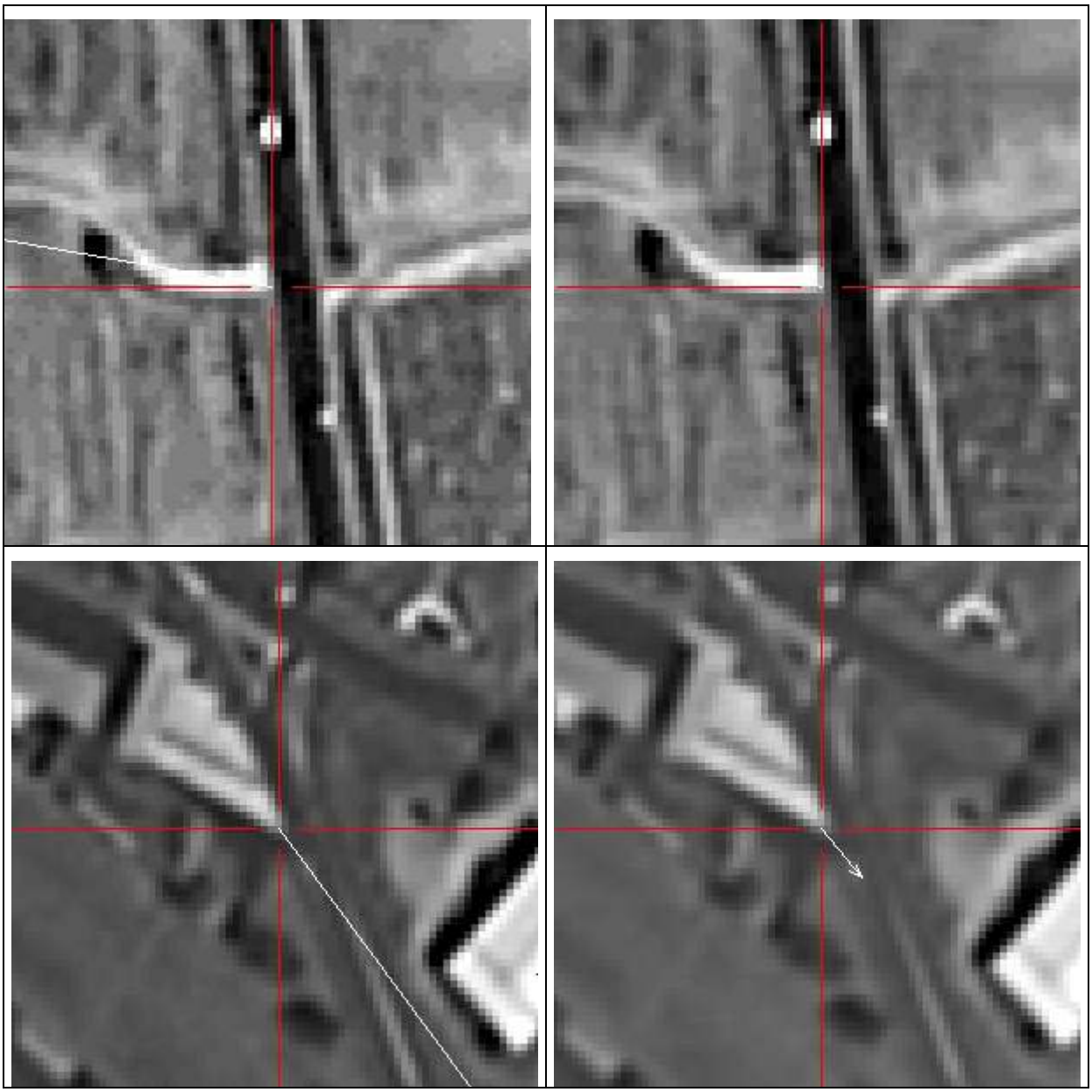
Such as mentioned just here after two points KTS08-22, KTS08-30 have been discarded/

2.2.2 Georeferencing

The GCP is located rigorously at a same location within the both imageries (KARI / K2PS) according to its definition.

At this first stage, the set of GCPs is used to refine the geometric model of the 1R image. In this case GCP is so called Ground Reference Point.

GCP Image Chip - K2PS PAN Image	GCP Image Chip – KARI PAN Image



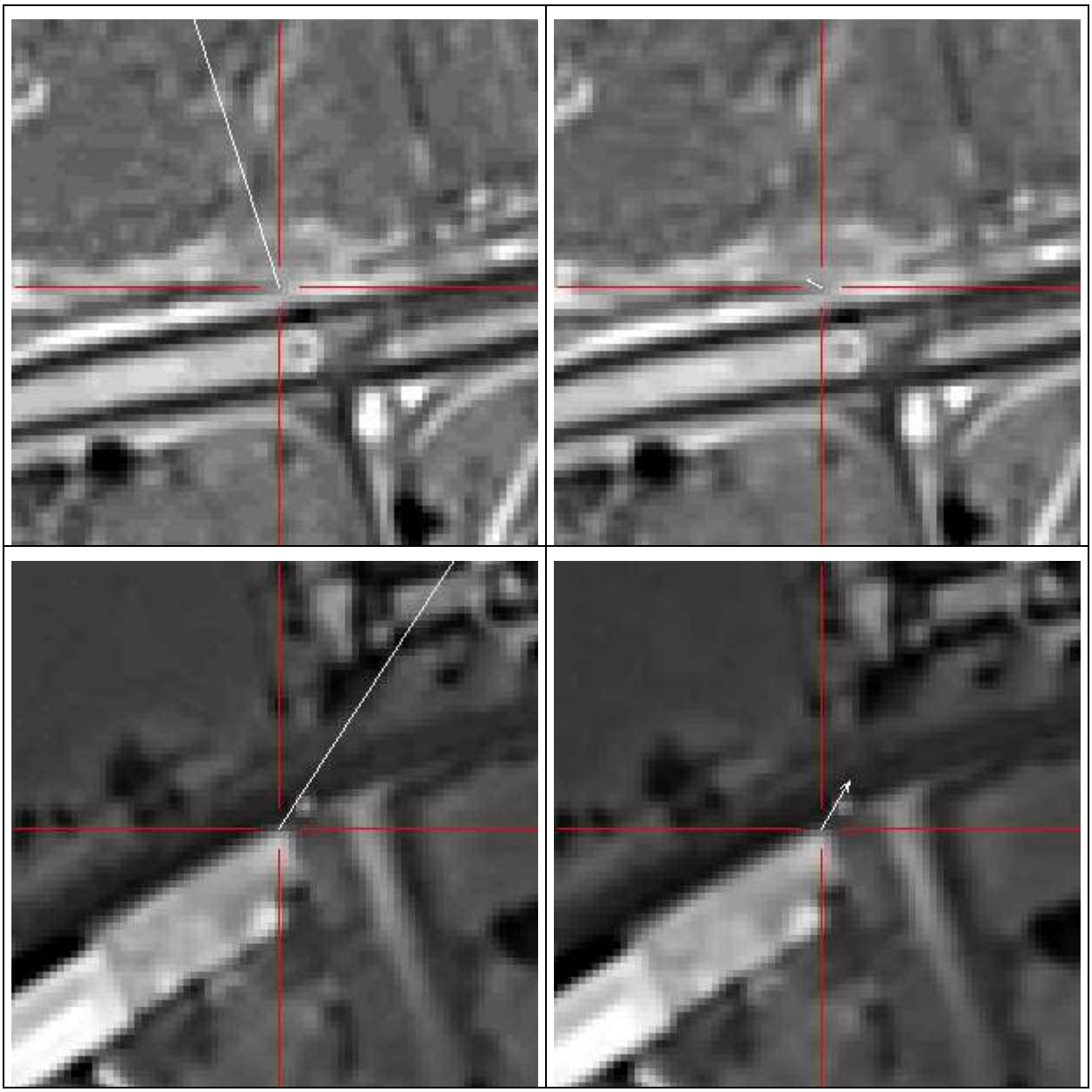


table 2 - GRP location within the both imagery.

	KARI	K2PS
GRP Number	8	8
Average elevation above ellipsoid (m)	171	171

X error: mean	-1.175	-1.173
Y error : mean	-0.190	-0.206
XY error : mean	5.821	5.059
X (Easting) error: Stddev.	3.862	2.803
Y(Northing) error : Stddev	5.374	5.154
RMS Error (m)	**6.618**	**5.867**
CE 90 (m)	**10**	**8.9**

table 3 Georeferencing quality report results – PAN Level 1R product (8 GRPs)

The following snapshots (fig. 3 and fig.4) present the error vectors for each KARI and K2PS-PTLS 1R product

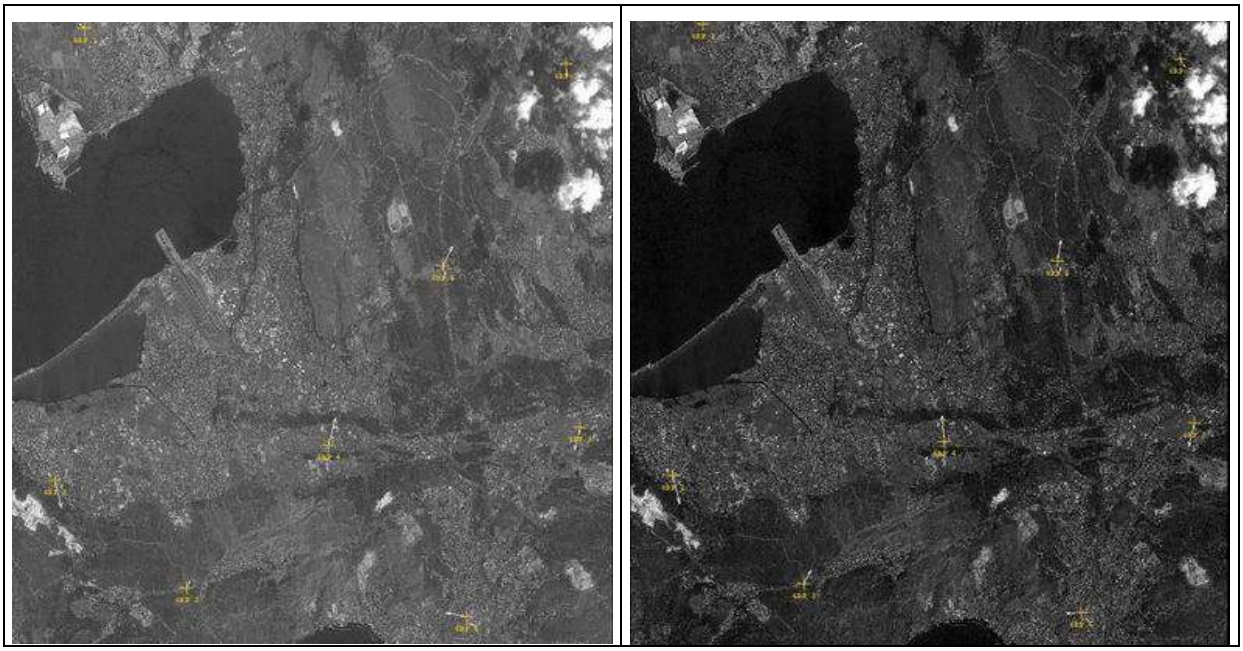


fig. 4 Error vectors (x200) KARI PAN(left) – K2PS-PTLS PAN (right) with 8 grp.

After consecutives attempts, we were not able to reach the same level of accuracy for the both KARI and K2PS product.

In investigating the inner geometry of the both 1R imageries, setting the KARI product as refrerence, one can observe the following results, such as depicted with figure just here after.

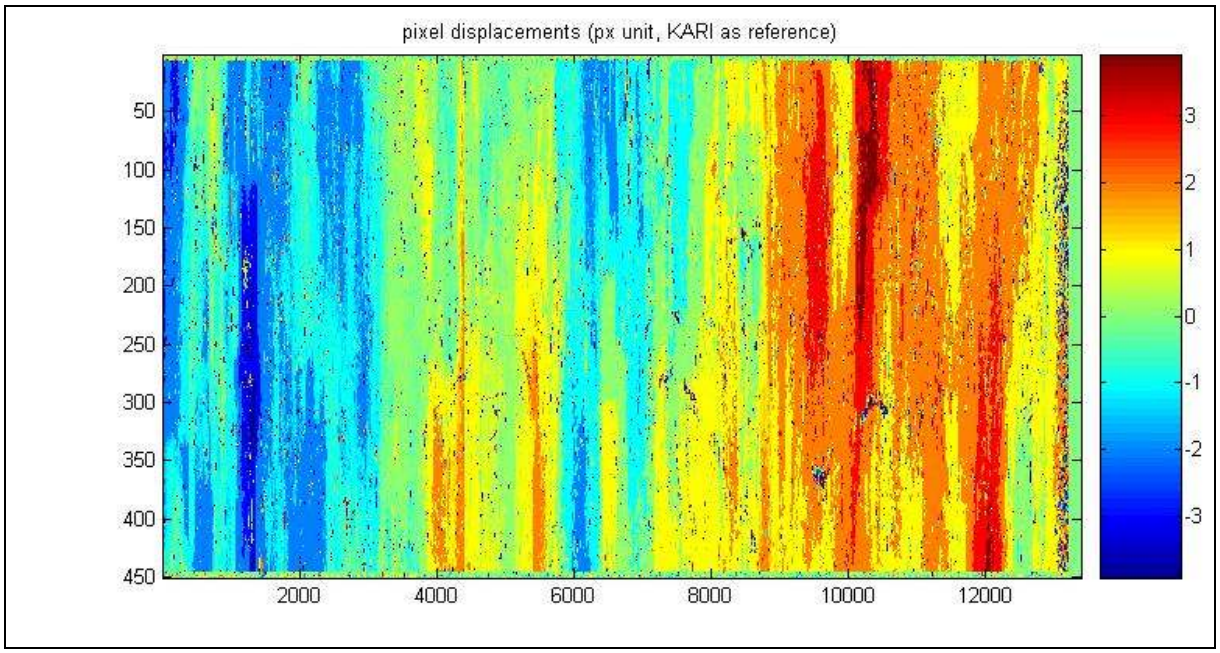


fig. 5 - Pixel displacements.

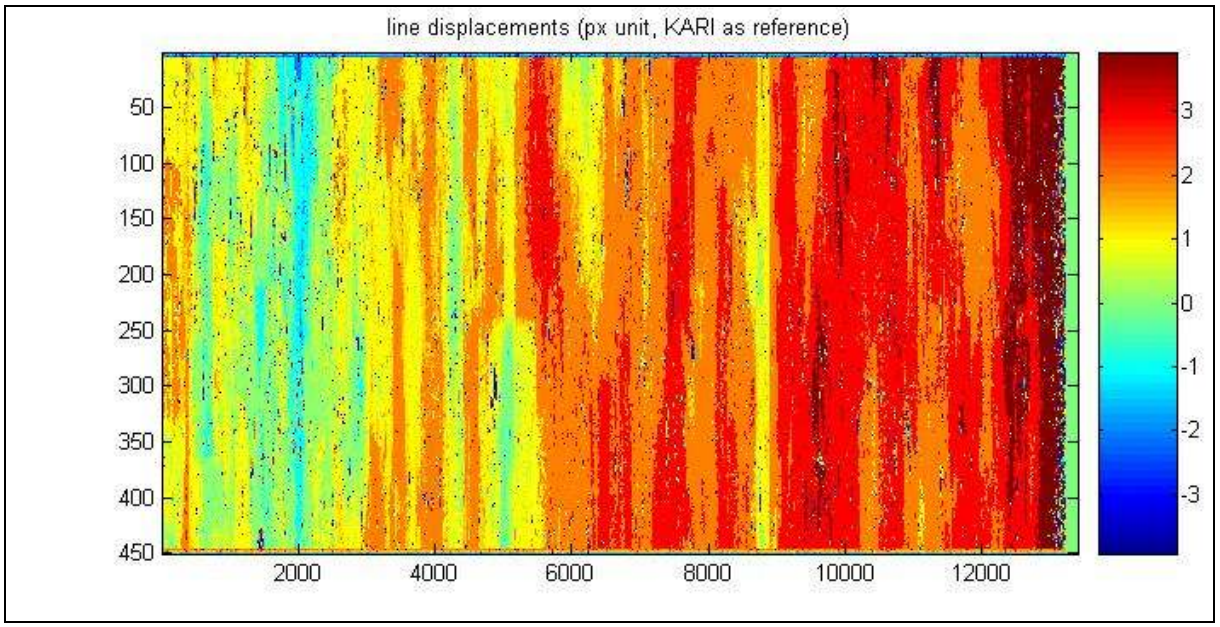


fig. 6 - Line displacements.

This procedure has been used previously at the first validation stage. When comparing results, we observed that the deviation between the both imageries has increased. The butting zone are clearly visible.

For a same location in the object space, the deviation can be up to 3.5 pixels for line or pixel direction. The butting zones are still clearly visible when checking the disparities results in pixel or line direction.

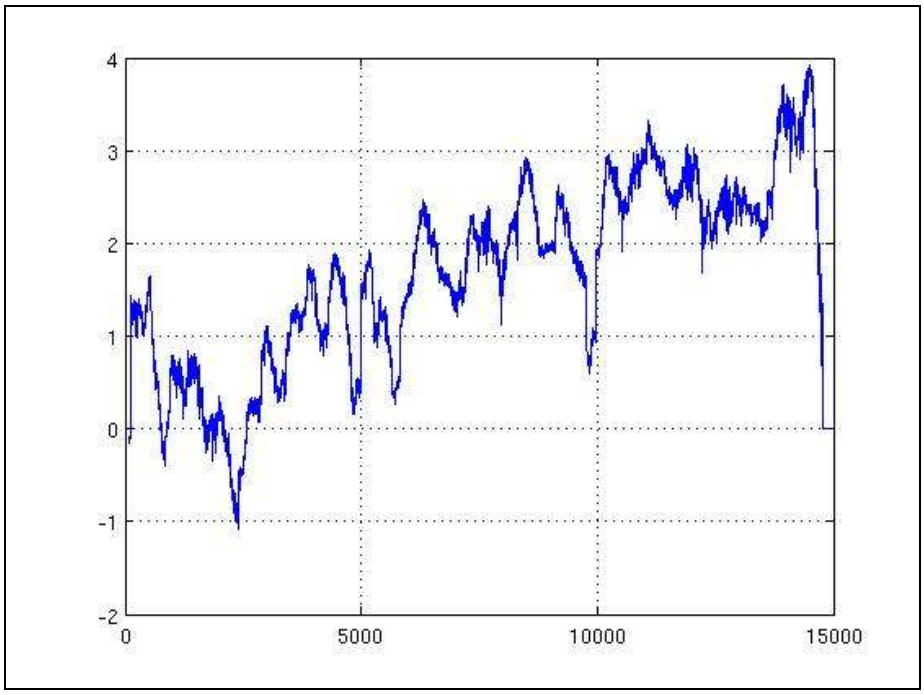


fig. 7 - Pixel displacements (image pixel location).

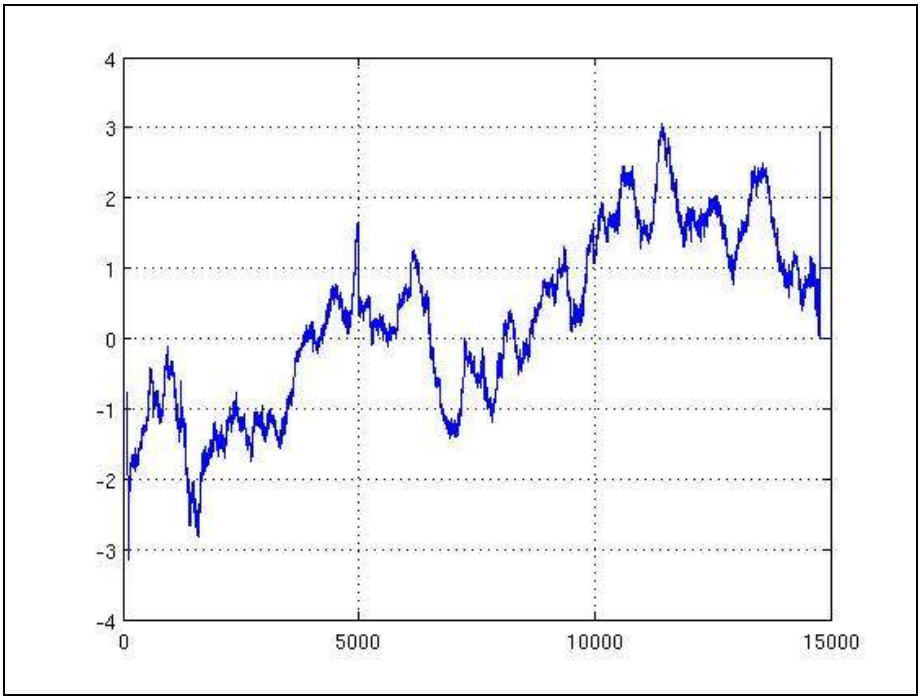


fig. 8 - line displacements (image pixel location).

3 ORTHORECTIFICATION RESULTS AND COMPARISON

3.1 Results

In order to validate the accuracy of the geometric model and appreciate the trends, the both 1R imageries are orthorectified using 1,2,3,4, and 8 GRPs.

The geometric control has been done using the second independent GCP set, such as explained previously.

	KARI	K2PS
GCP Number	8	8
Average elevation (Z)	107,88	107,88
X (Easting) error: mean	-0.474	-0.95
Y(Northing) error : mean	-6.207	-4.938
XY error : mean	6.501	5.582
X (Easting) error: Stddev.	2.012	2.788
Y(Northing) error : Stddev	6.908	5.912
RMS Error (m)	**7.195**	**6.536**
CE 90 (m)	**10.918**	**9.9184**

table 4 –geometric quality results of orthorectified Image with all grp..

Using the 8 GRPs available, one can notice that the CE90 measurement performed on the K2PS products provides more satisfactory results reaching 9.91 m. The difference with the KARI product is on the order of 1 m.

When looking at the evolution of the accuracy along with the number of GRPs used to set the model, one can observe that the K2PS model looks to be improved with the GRP number where as the situation is degrading for the KARI one.

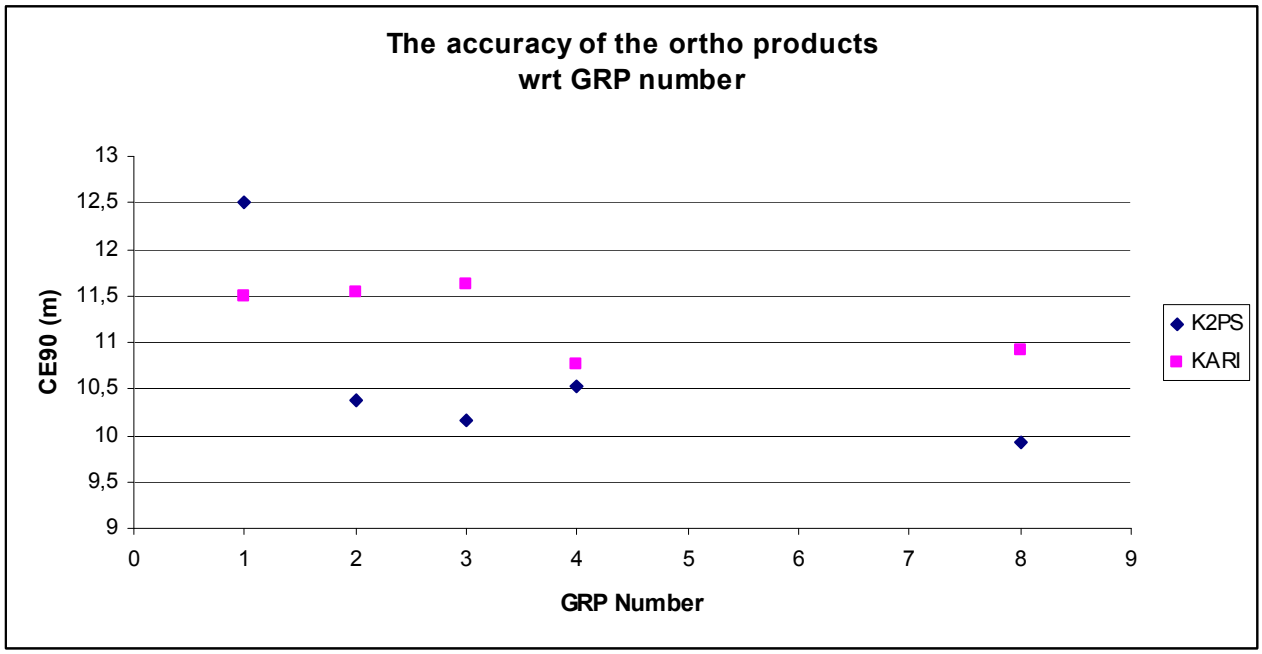


fig. 9 - CE90 results along with grp used for the geo referencing.

The computation with 5,6 and 7 grps may be done to confirm the previous assertion.

The limitation of the method shall be due to the sampling grid of the DEM, 30 m. The definition of the GCP are not as accurate as we may expect for working with the high resolution imagery.

Note one suspicious GCP:

At the beginning, the quality control of the ortho products was based on nine gcps. One can observe that a point is causing problem, more likely to the geometric model. It has been decided to discard this point. The following figures illustrates the outlier point and justify why it has been discarded. The root causes are not understand, probably its location at the image margin (right).

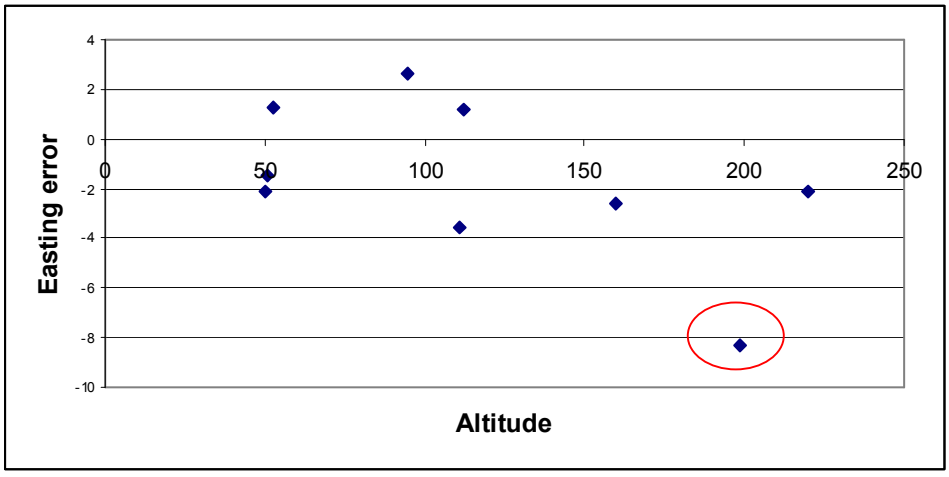


fig. 10 - Inconsistent results, Easting / altitude.

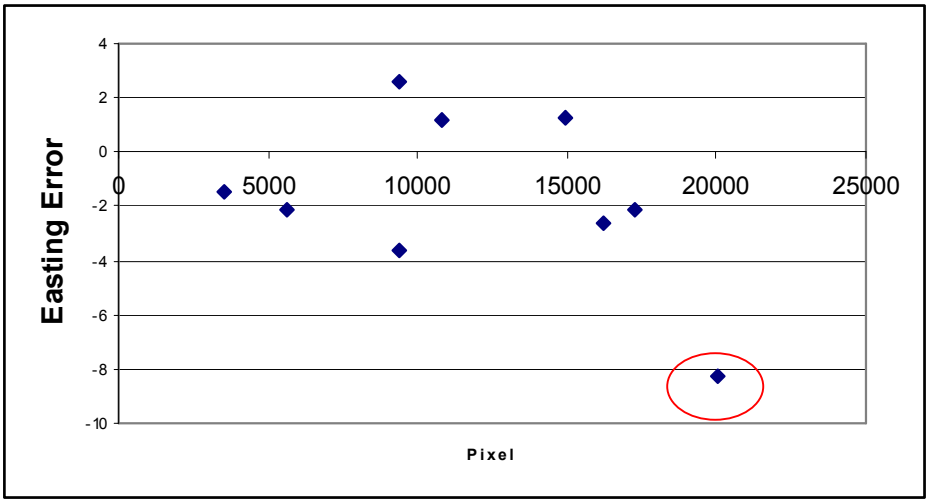


fig. 11 - Inconsistent results, Easting / pixel.

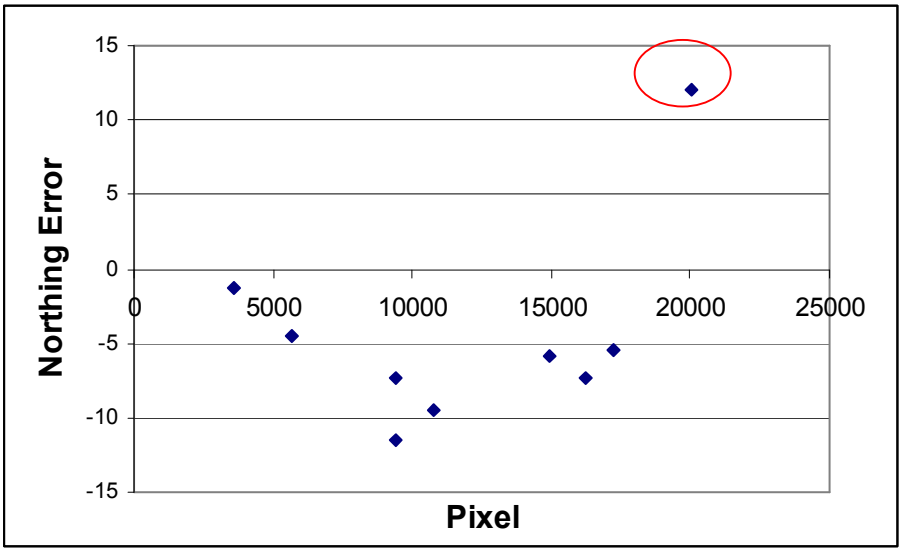


fig. 12 - Inconsistent results, Norhting / altitude.

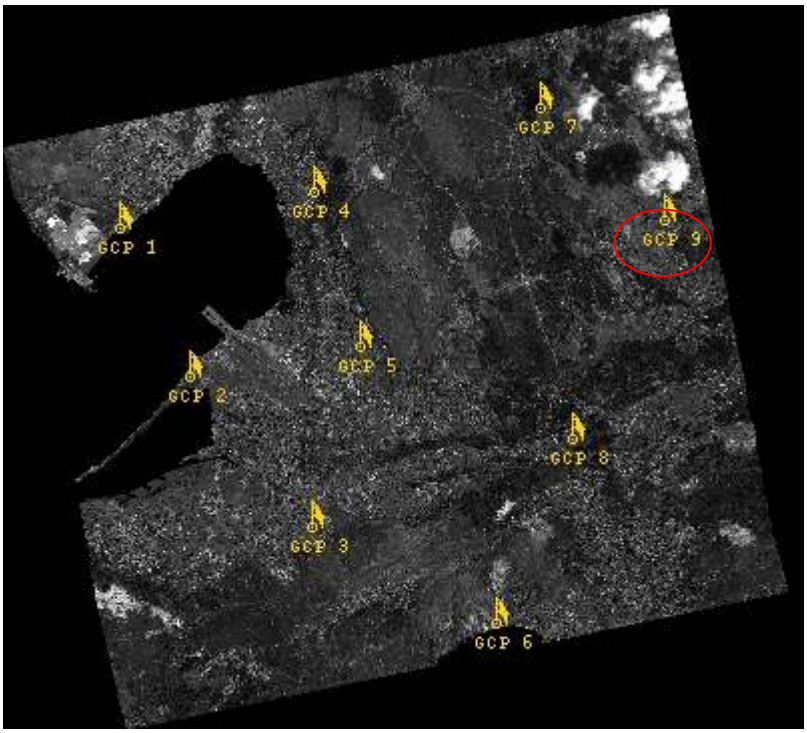


fig. 13 - Overview of Ground control points.

3.2 Disparity Analysis and ortho product comparison

The objective is to analyse the disparities between the both ortho product in order to assess difference occurring in the internal geometry of the product.

3.2.1 Method

The method is based on correlation algorithm that perform sub pixel matching. The results obtained are then filtered and the shear (angle) is computed. The disparity results are expressed within a line/pixel coordinate system such are depicted just here after.

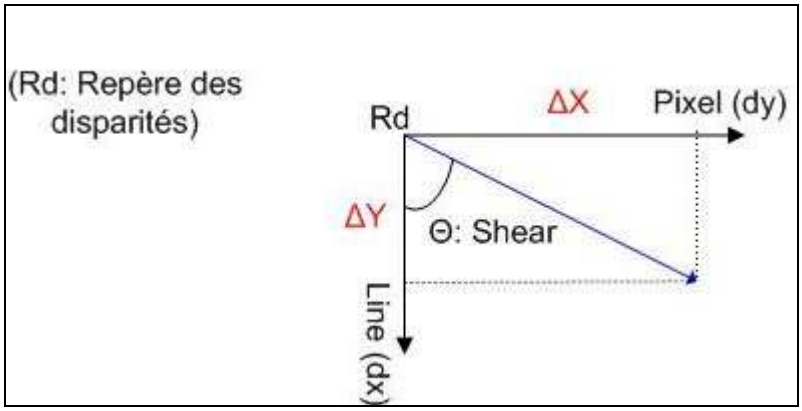


fig. 14 - Coordinate system for disparity analysis.

The disparity analysis provides 'relative' results and not absolute. It is then difficult to make a status and define which geometry is better than the other one.

On the other hand, the previous results are obtained using absolute ground control points derived from GPS measurements. These results can be used to anchor the disparity analysis and then determined which product is the best one.

The ground control point number 7 has been used as test point (refer to fig13).

Its absolute geo-location measurement will be compared with the results obtained using the disparity analysis. Around this image region, the absolute accuracy of K2PS is better than the KARI one. The following measurement results are retrieved.

	line	pixel	Altitude	Delta (m)	DeltaX (m)	DeltaY (m)
REF-K2PS	3004,6	16226,4	159,7	3,9	-1,7	-3,5
REF-KARI	3114,9	16246,4	159,7	6,6	-2,1	-6,3

fig. 15 - GCP 7; location accuracy.

The comparison will be based on the shear value, that is the angle between line / pixels displacements. The relationship between the absolute location accuracy assessment and the disparity analysis results is no straightforward. The respective coordinate systems shall be detailed/ The figure just here after depicts the procedure.

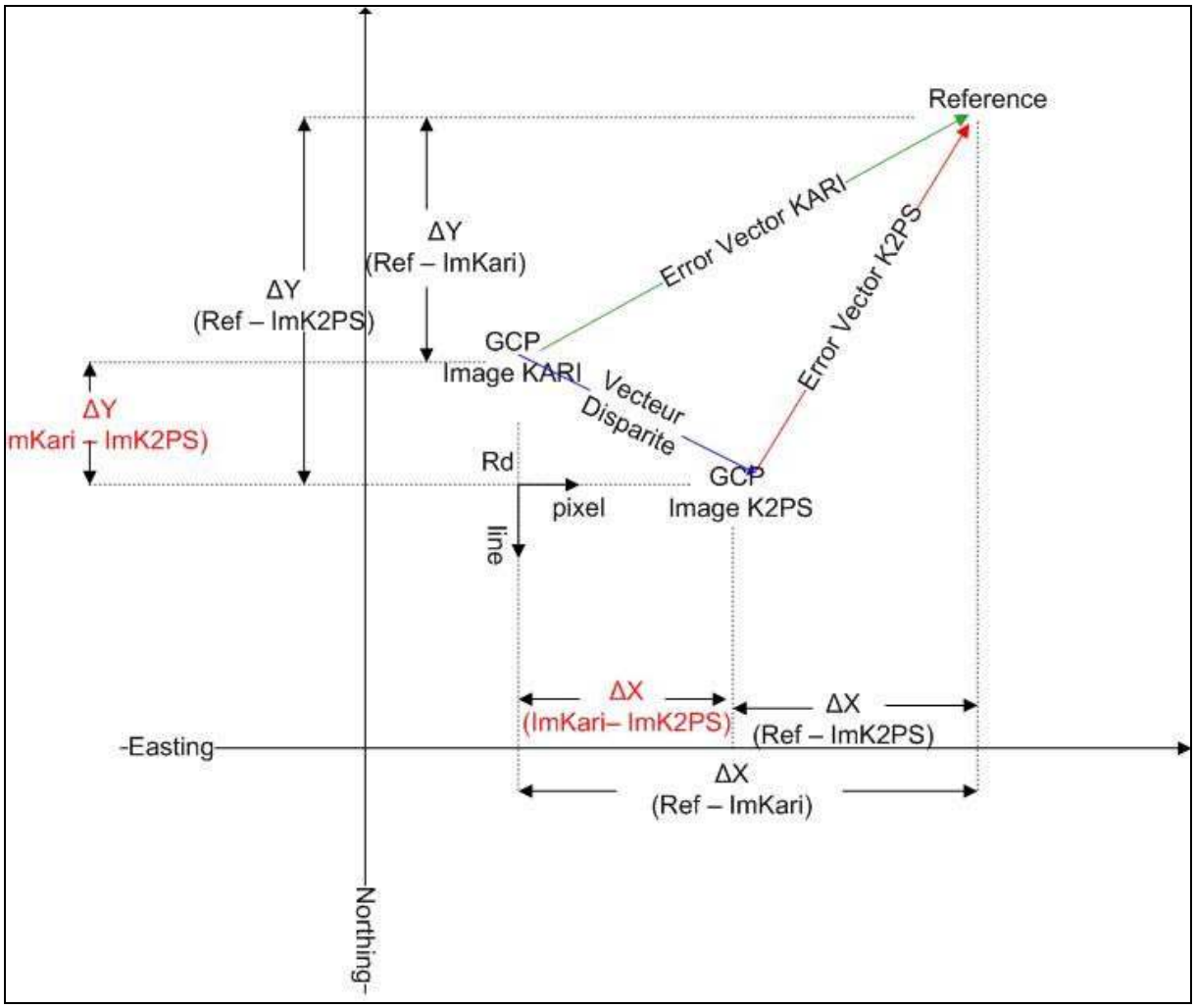


fig. 16 - Absolute geolocation coordinate system and disparity analysis coordinate system.

In order to check the results reliability two test window will be dispatched over the working image (see figure just here after).

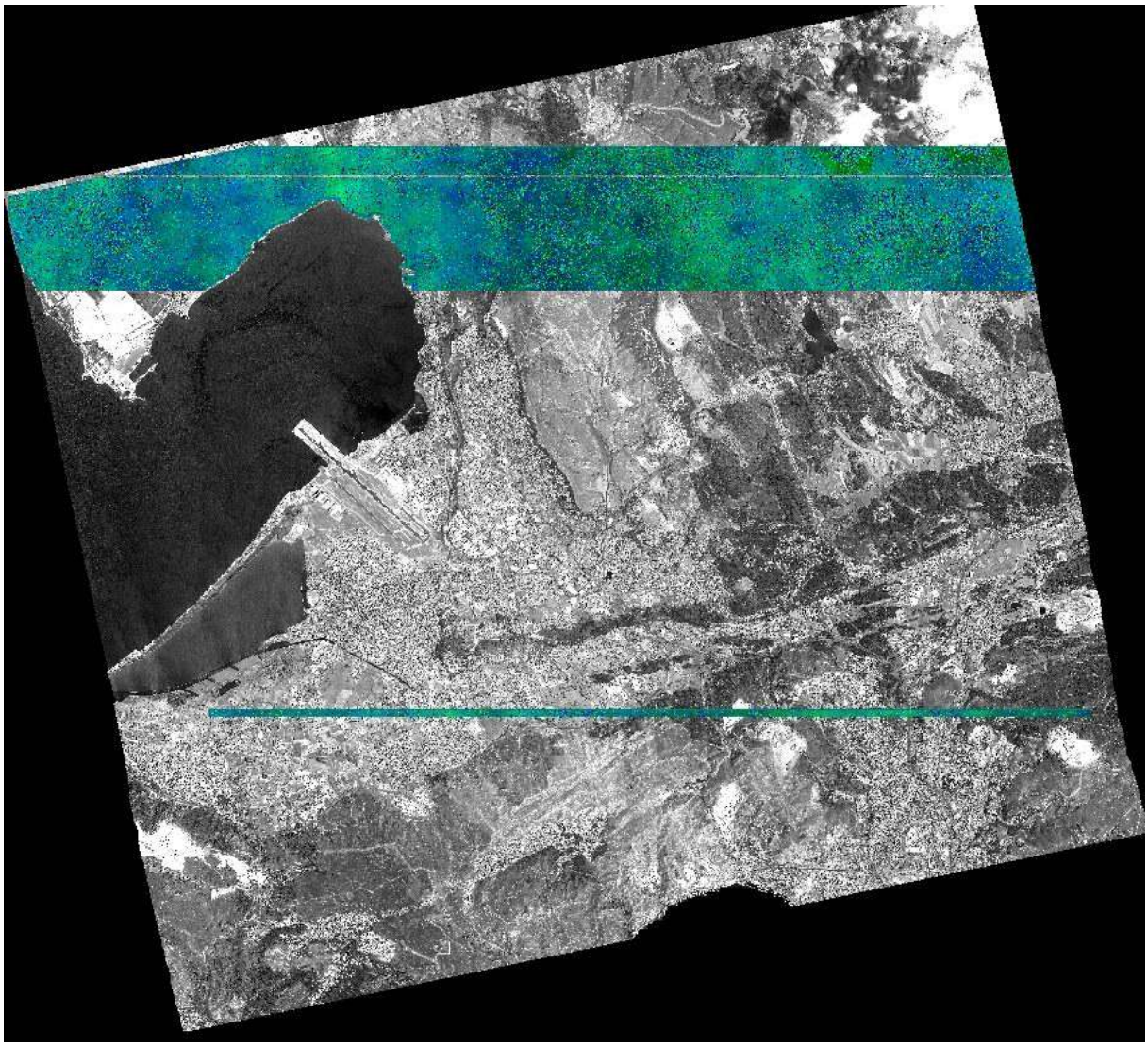


fig. 17 - Two Test windows selected for the disparity analysis.

3.2.2 Results

The both test windows provide similar results. CCD boundaries are still visible. The image deformation or image registration between the both pan is strong.

The raw results of disparity analysis are illustrated just here after. A confidence threshold has been applied.

The displacement in the line direction fig 18) looks more pronounced than displacement in pixel direction (fig 19).

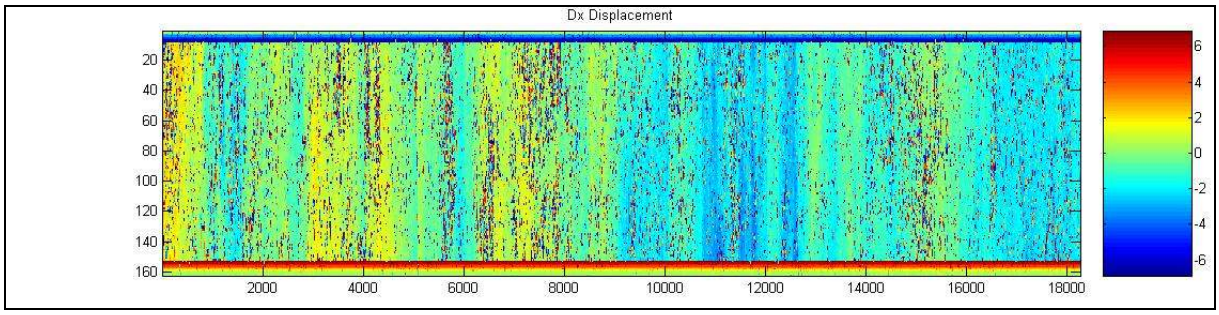


fig. 18 - DX Displacements

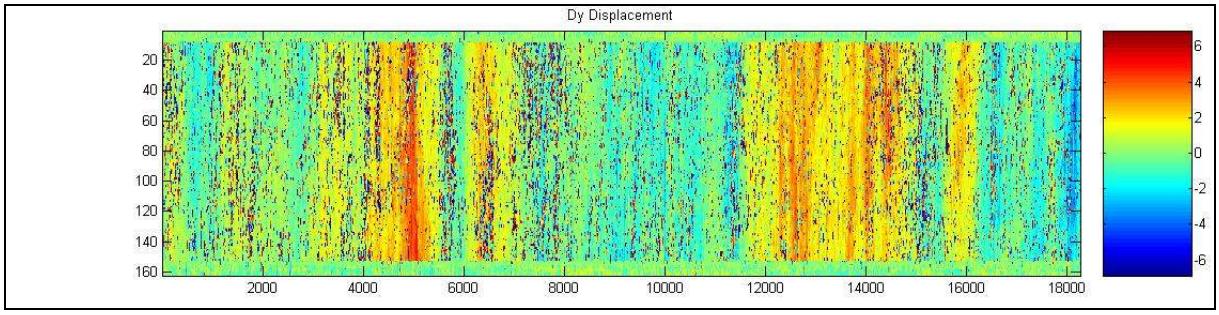


fig. 19 - DY Displacements

After filtering the shear measurement computation along with pixel values provides the following results.

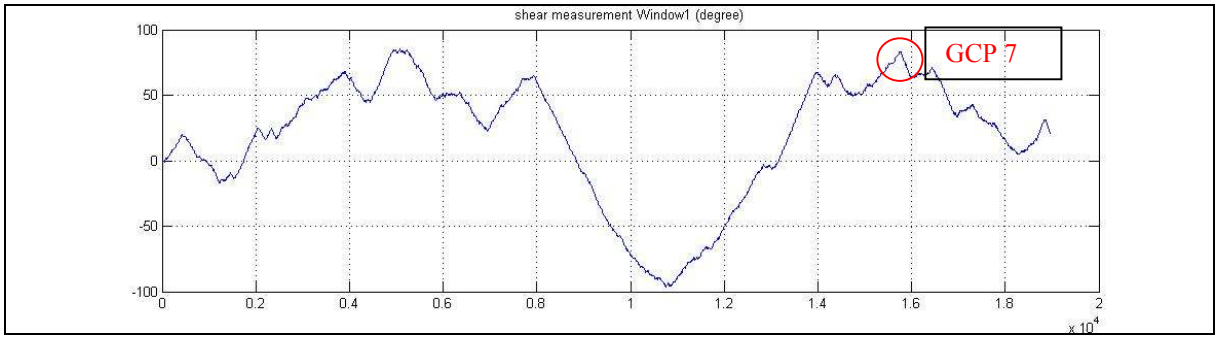


fig. 20 - Shear measurement window 1.

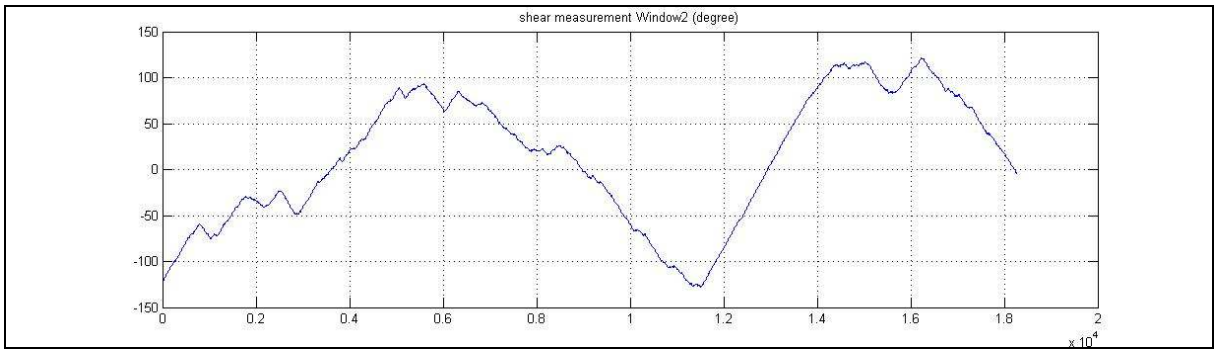


fig. 21 - Shear measurement window 2.

The overall shape of the both plots remains similar and are fortunately comparable. It means that the effect of the terrain has been well compensated with the geometric model.

The second test window is located at the bottom part of the image. We observe that the deformation magnitude has increased with image record number .

For the first measurement performed on the second test window, the shear looks more important (-100 degree) than when computing on the first test window (0 degree).

It is exactly what we observe at the absolute geo location assessment stage; the upper left part of the image is quite well registered to the absolute reference.

From fig 15, table of GCP 7 results, when computing the shear from the absolute location results the pixel shift between the both image is 0.4 metre and the line shift is 2.8 metre.

The shear angle derived from these both shift results is 81 degree. When looking at fig 20, the red circle highlights the position of the GCP 7, the corresponding shear is about 80 degree.

First conclusion about the methodology, the absolute location results are consistent with the disparity analysis results.

Second conclusion regarding the quality of products, at GCP 7 location the absolute registration of the K2PS is better than the KARI one. So that, everything let us think that the deformation and overall trend of the shear are mainly due to the quality of the KARI internal geometry.

The whole of these assertions shall be confirmed.

3.3 Disparity Analysis and comparison with SPOT 3D Ortho products (DRAFT)

3.3.1 Method

SPOT 3D took as reference data.

K-2 data pan downsize to match a spatial resolution of 10 m.

Only window number 2 (top of the image, see fig 17) took as test window.

The disparity results are filtered to remove inconsistent value, remove the noise and output a trend.

3.3.2 Results

3.3.2.1 Line displacements

The 2 nd order polynomial model fit quit well, the R^2 coefficient is above 0.8. One can notice that the model is the same except the bias that is different.

KARI : y = 1E-06x2 - 0,0033x + 3,5555 / R2 = 0,8127

K2PS; y = 1E-06x2 - 0,0031x + 1,8498 / R2 = 0,9004

A bias in line direction is magnified.

The absolute accuracy in line direction of the K2PS is better.

Around pixel 1600 (spot 3D scale <=> 16 000 for K2 imagery), following 2nd order interpolation, more residual errors are observed for the KARI data sample. After, the KARI data sample drop.

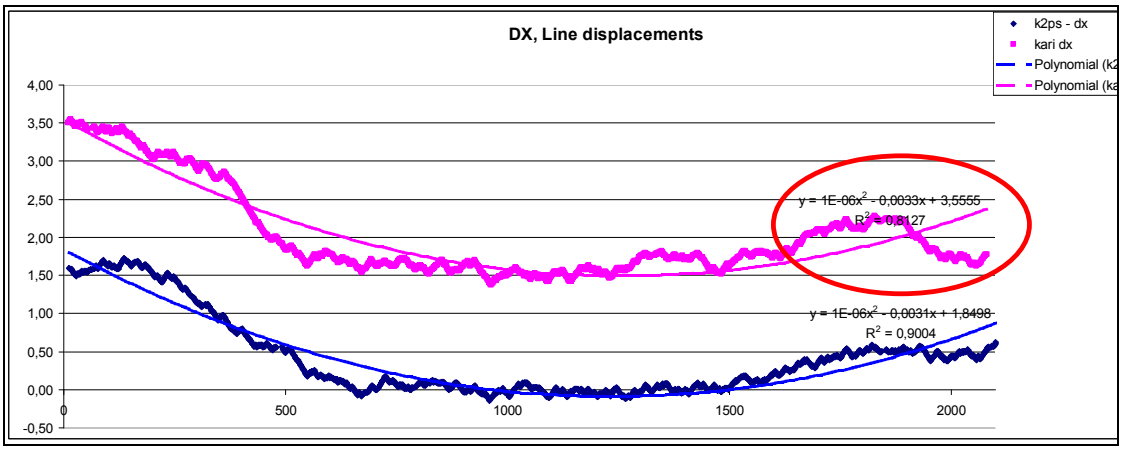


fig. 22 - Disparity analysis, line displacements.

3.3.2.2 Pixel displacements

A same comment about the noise, such as formulated previously.

The 5 nd order polynomial model fit quit well, the R^2 coefficient is above 0.8. As opposite to the line displacement results, one can notice that the model fit better for the KARI data sample.

The model equations are the following ones

KARI: y = -2E-15x5 + 9E-12x4 - 2E-08x3 + 2E-05x2 - 0,0071x + 2,1661 R2 = 0,9214

K2PS: y = -2E-15x5 + 1E-11x4 - 2E-08x3 + 2E-05x2 - 0,0069x + 1,9966 R2 = 0,8399

The change of error direction magnified with the fig 21, is confirmed with the absolute comparison. A difference of about 0.4 pixel is observed at pixel 1200 (again 12 000 for K2 image).

The pixel size is 10 metres, it leads to an amplitude of 4 metres (4 K-2 pixels). This on the order of relative disparities observed with fig 19.

At pixel 650, a difference is also highlighted between values from the two plots.

In addition, in pixel direction, it is obvious that a scale difference is observed between the two products. Its magnitude increases along with pixel index, out off the NADIR of the satellite.

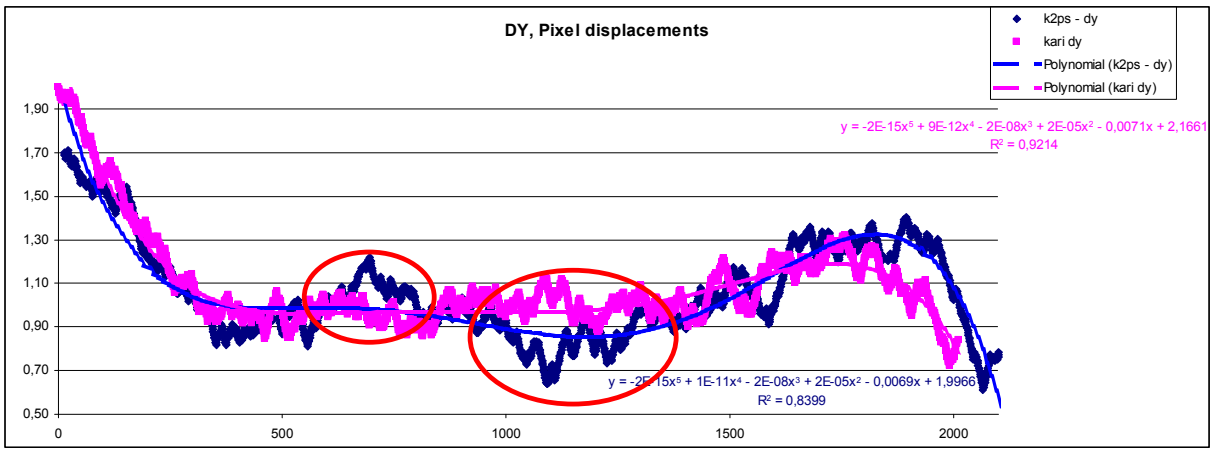


fig. 23 - Disparity analysis, pixel displacements.

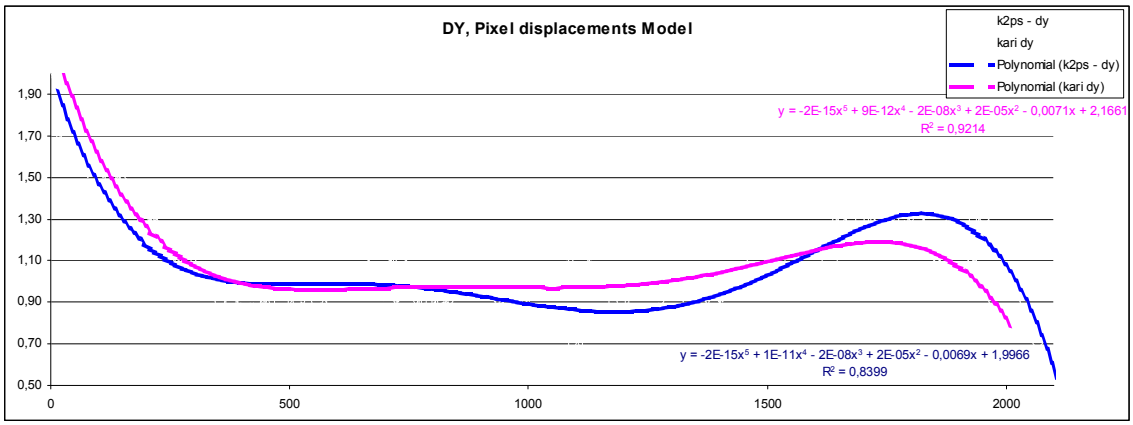


fig. 24 - Disparity analysis, pixel displacements, model.