

Fjärranalysdagarna 10-11 mars 2009

Automatic geo-registration of satellite imagery

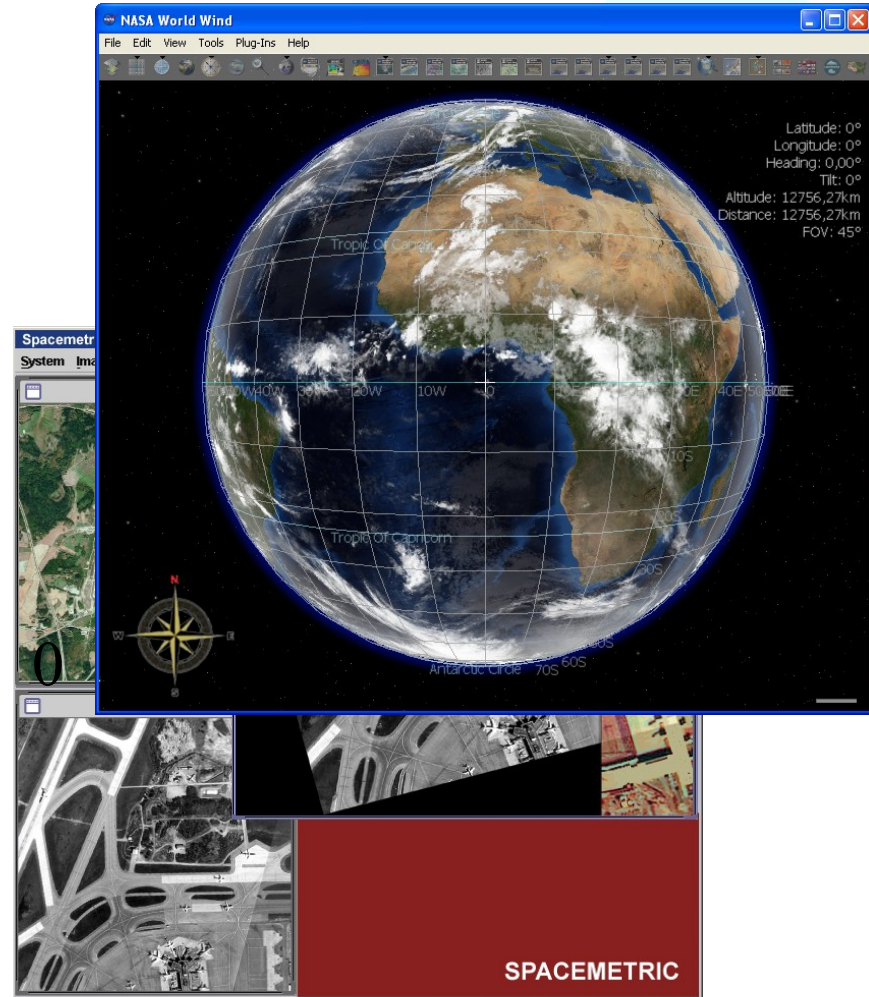
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Keystone Image Server

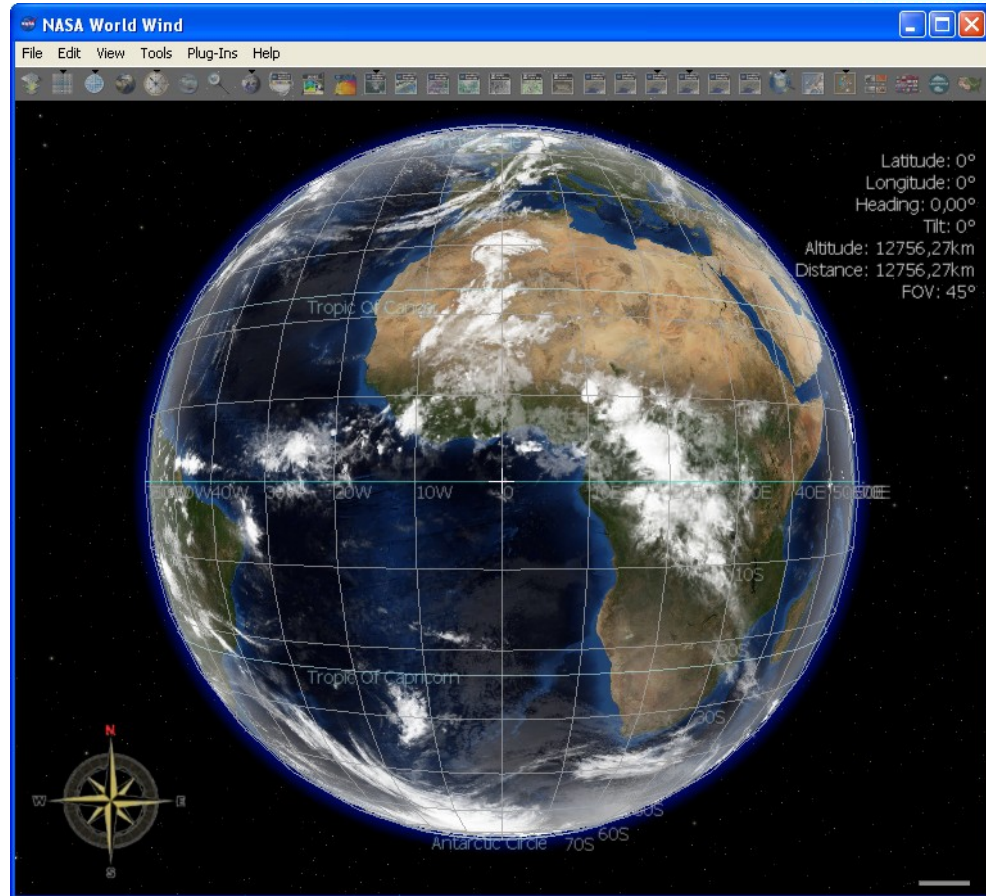
Keystone is an automatic system for archiving, cataloguing and processing digital images from satellites and other digital sensors. Image data can be stored in Keystone and accessed in a uniform way, either using web-based interfaces for overview or as full resolution products.

Keystone minimises manual intervention in the image supply process and significantly shortens image delivery times. Users interact with the system in a geographically oriented, map-based view.



Keystone: OGC standards

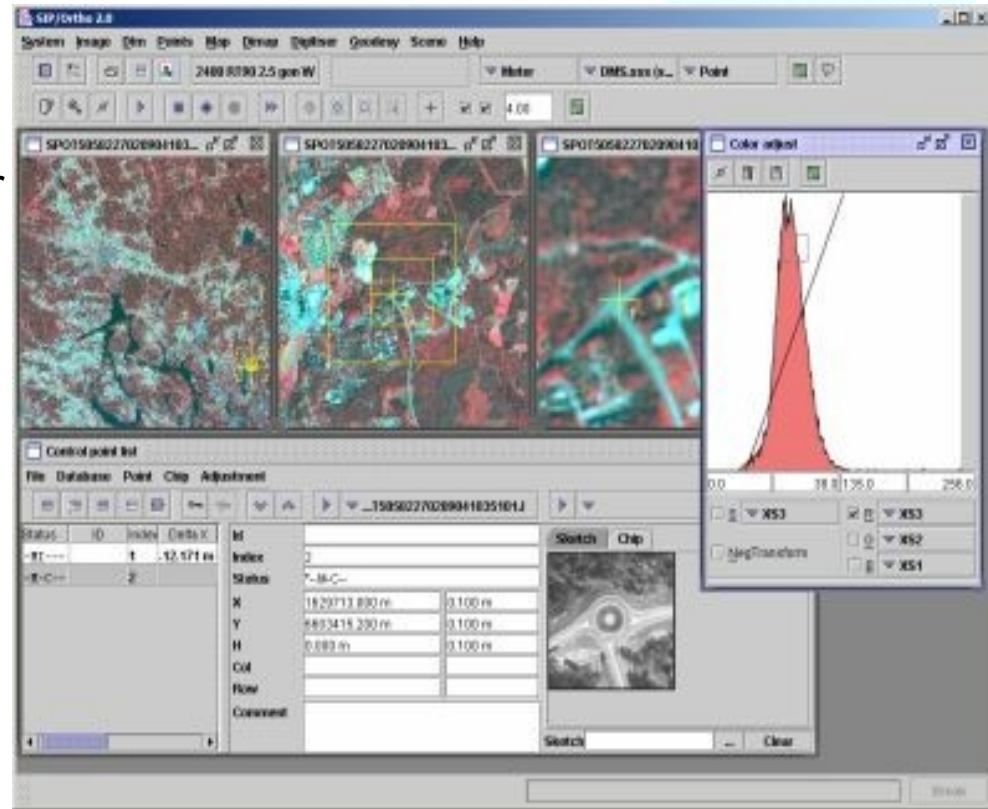
- WMS 1.3
- CSW 2.0



Keystone workstation

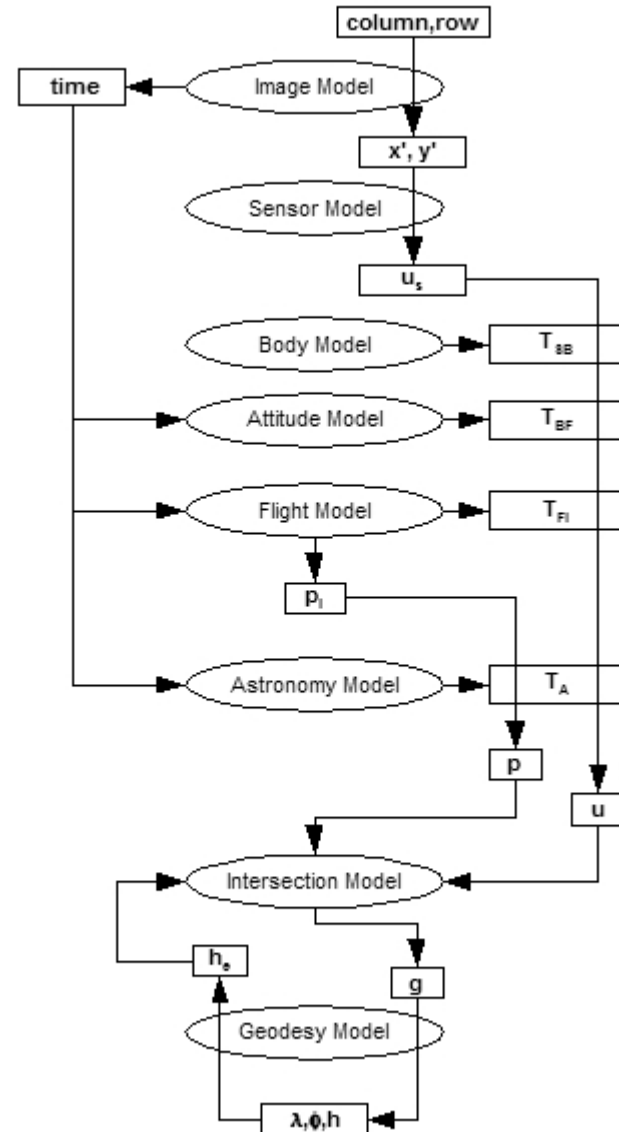
Keystone workstation is an integrated satellite orthoimage production suite. It provides an expandable production capability for the latest satellite sensors that uses rigorous photogrammetric methods to give high-accuracy image products at low cost.

Keystone workstation includes image data I/O, DTM import, model adjustment, image rectification, and comprehensive tools for the creation and management of Ground Control Points.



Analytical models

- Highest possible geometrical accuracy for given input data
- Stable solution also with very few control points



Semi-automatic approach (cont.)

Advantages

- Possible to select only chips that have features that perform well in correlation
- Less affected by gross errors in correlation
- Faster correlation as fewer number of chips are used

Dis-advantages

- Requires a large manual work to populate the database
- Risk for too low density in chip distribution
- Different types of target images require chips of different resolution and spectral bands
- “Pull-in” range can be too large

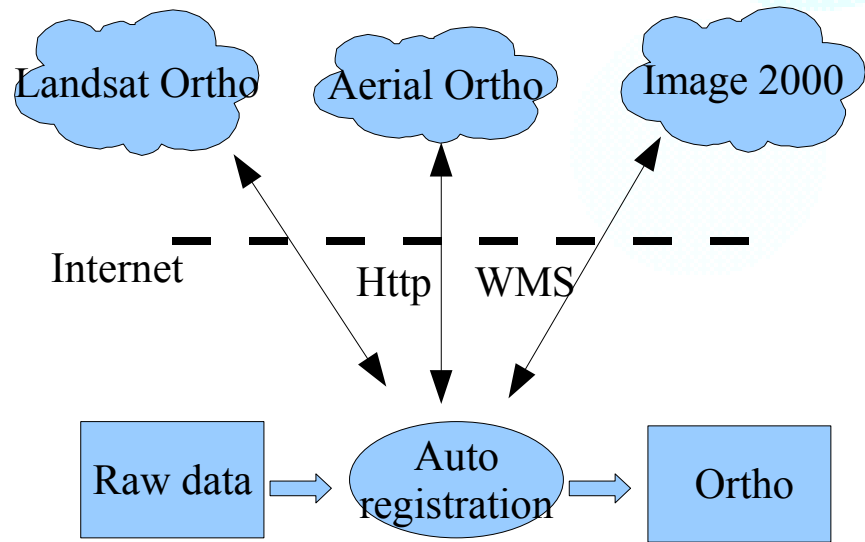
Case study: NLR Military reconnaissance

- Automated reception and processing of Eros and Spot 4
- NATO HRF-HQ Allied Warrior exercise November 2004



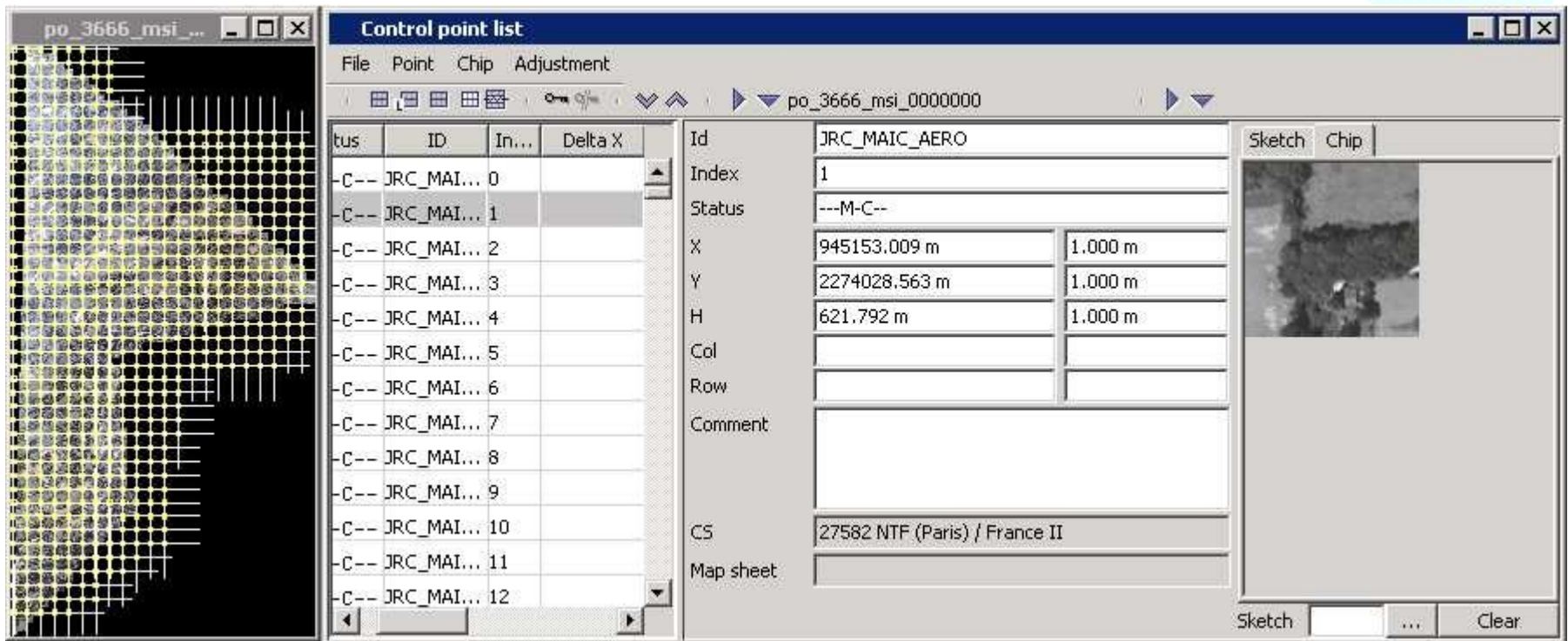
Automatic approach

- Makes direct use of already available reference data sets
- Access to WMS servers anywhere in the world
- Alternatively, locally stored data sets
- Dynamical extraction of temporary GCP chips (not preselected)



Three-stage process (1/3)

Generate dense grid of control points. Create image chips from reference imagery by WMS calls. Add elevations from global DEM (e. g. SRTM)



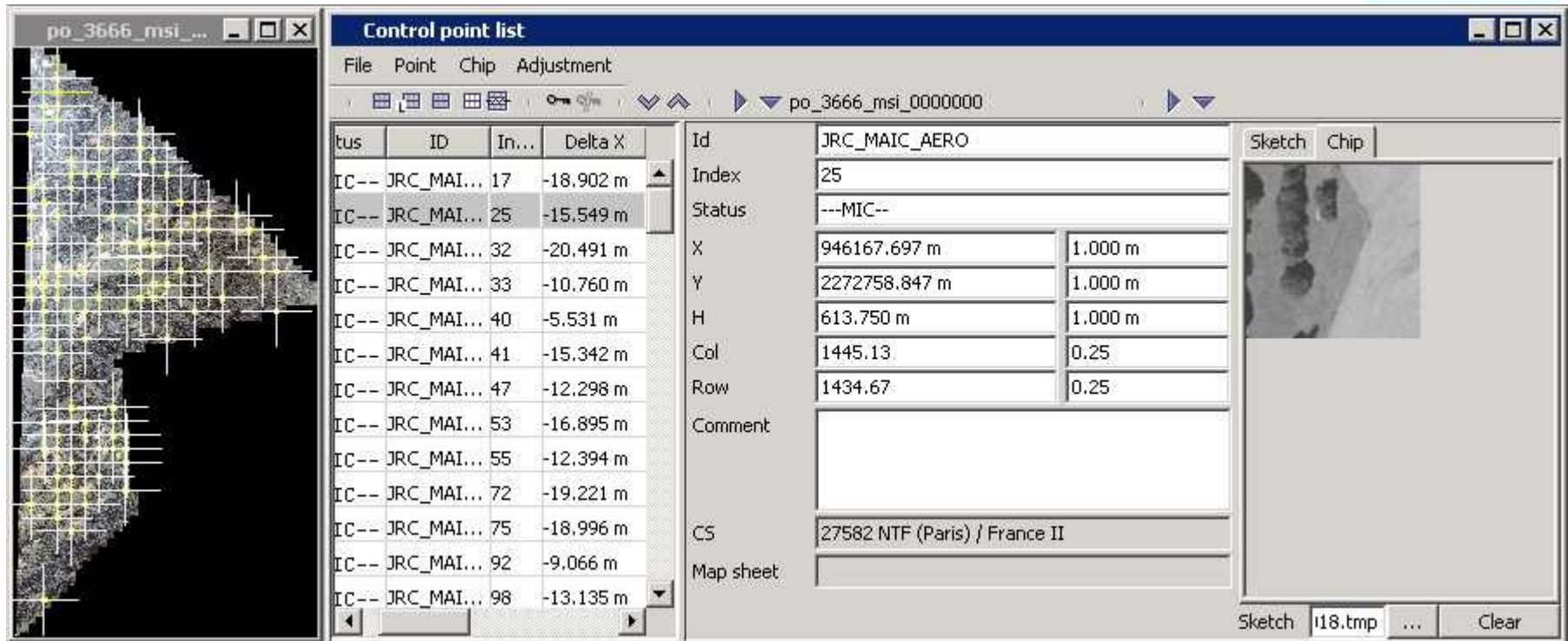
The screenshot displays a software interface with two main windows. On the left is a window titled 'po_3666_msi ...' showing a dense grid of control points. On the right is a window titled 'Control point list' with a menu bar (File, Point, Chip, Adjustment) and a toolbar. The main area of the 'Control point list' window is divided into a table on the left and a form on the right. The table lists control points with columns for 'tus', 'ID', 'In...', and 'Delta X'. The form on the right shows details for a selected control point, including its ID, index, status, coordinates (X, Y, H), and map sheet information. A 'Sketch' tab is active, showing a small image chip of the ground. At the bottom right of the 'Control point list' window, there are buttons for 'Sketch', '...', and 'Clear'.

tus	ID	In...	Delta X
-C--	JRC_MAI... 0		
-C--	JRC_MAI... 1		
-C--	JRC_MAI... 2		
-C--	JRC_MAI... 3		
-C--	JRC_MAI... 4		
-C--	JRC_MAI... 5		
-C--	JRC_MAI... 6		
-C--	JRC_MAI... 7		
-C--	JRC_MAI... 8		
-C--	JRC_MAI... 9		
-C--	JRC_MAI... 10		
-C--	JRC_MAI... 11		
-C--	JRC_MAI... 12		

Id	JRC_MAIC_AERO	
Index	1	
Status	---M-C--	
X	945153.009 m	1.000 m
Y	2274028.563 m	1.000 m
H	621.792 m	1.000 m
Col		
Row		
Comment		
CS	27582 NTF (Paris) / France II	
Map sheet		

Three-stage process (2/3)

Position control points by correlation with chips. Apply threshold to correlation coefficient to eliminate initial set of bad points.



The screenshot displays a software window titled "Control point list" with a menu bar (File, Point, Chip, Adjustment) and a toolbar. On the left, a small window shows a point cloud visualization. The main window contains a table of control points and a detailed view of a selected point.

bus	ID	In...	Delta X
IC--	JRC_MAI...	17	-18.902 m
IC--	JRC_MAI...	25	-15.549 m
IC--	JRC_MAI...	32	-20.491 m
IC--	JRC_MAI...	33	-10.760 m
IC--	JRC_MAI...	40	-5.531 m
IC--	JRC_MAI...	41	-15.342 m
IC--	JRC_MAI...	47	-12.298 m
IC--	JRC_MAI...	53	-16.895 m
IC--	JRC_MAI...	55	-12.394 m
IC--	JRC_MAI...	72	-19.221 m
IC--	JRC_MAI...	75	-18.996 m
IC--	JRC_MAI...	92	-9.066 m
IC--	JRC_MAI...	98	-13.135 m

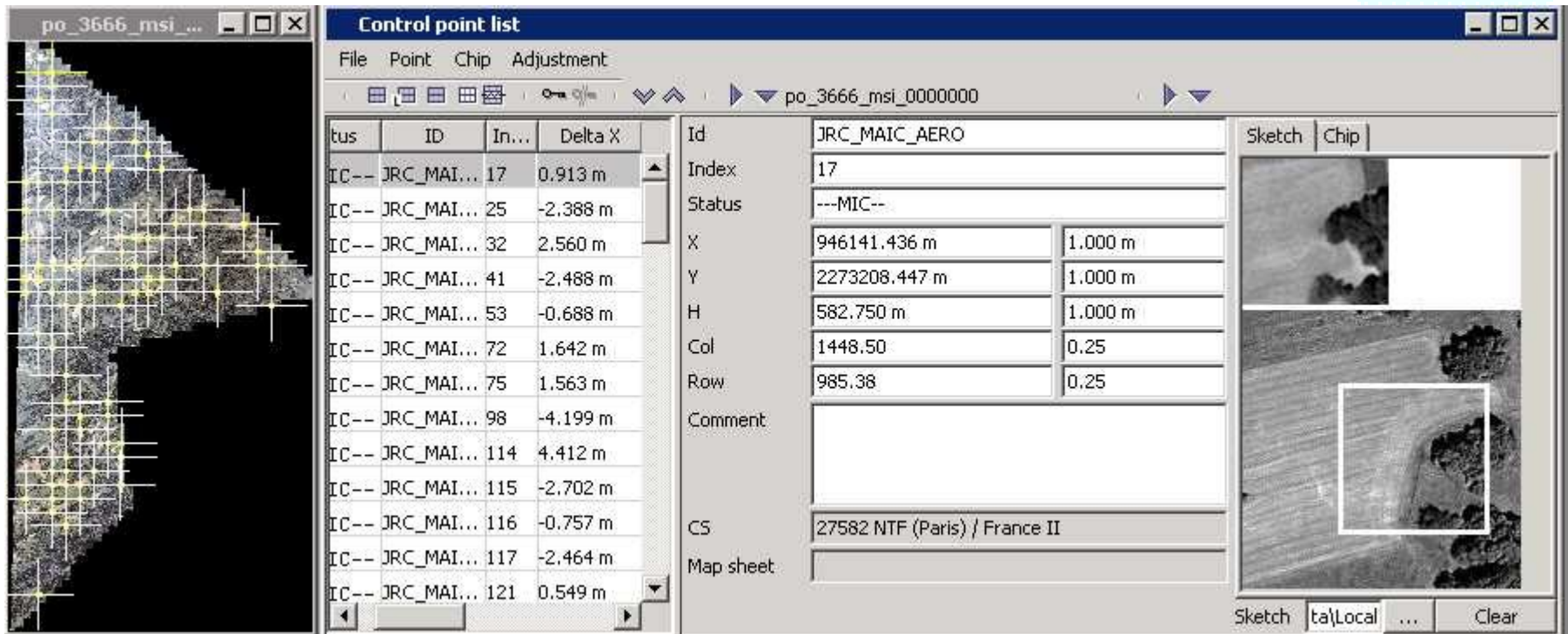
The detailed view for the selected point (ID: JRC_MAIC_AERO, Index: 25) shows the following data:

Id	JRC_MAIC_AERO	
Index	25	
Status	---MIC--	
X	946167.697 m	1.000 m
Y	2272758.847 m	1.000 m
H	613.750 m	1.000 m
Col	1445.13	0.25
Row	1434.67	0.25
Comment		
CS	27582 NTF (Paris) / France II	
Map sheet		

At the bottom right, there is a "Sketch" tab with a thumbnail image and a "Chip" tab. Below the thumbnail are buttons for "Sketch", "118.tmp", and "Clear".

Three-stage process (3/3)

Control point adjustment with gross error detection eliminates bad points with false high correlation coefficient.



The screenshot displays a software interface for control point adjustment. On the left, a 3D point cloud visualization shows a grid of points with a yellow crosshair. The main window is titled "Control point list" and contains a table of control points. The table has columns for "ID", "In...", and "Delta X". The data is as follows:

ID	In...	Delta X
JRC_MAI... 17	17	0.913 m
JRC_MAI... 25	25	-2.388 m
JRC_MAI... 32	32	2.560 m
JRC_MAI... 41	41	-2.488 m
JRC_MAI... 53	53	-0.688 m
JRC_MAI... 72	72	1.642 m
JRC_MAI... 75	75	1.563 m
JRC_MAI... 98	98	-4.199 m
JRC_MAI... 114	114	4.412 m
JRC_MAI... 115	115	-2.702 m
JRC_MAI... 116	116	-0.757 m
JRC_MAI... 117	117	-2.464 m
JRC_MAI... 121	121	0.549 m

Below the table, the "Id" field is set to "JRC_MAIC_AERO" and the "Index" is "17". The "Status" is "---MIC--". The "X", "Y", and "H" coordinates are 946141.436 m, 2273208.447 m, and 582.750 m, respectively. The "Col" and "Row" values are 1448.50 and 985.38. The "Comment" field is empty. The "CS" field is "27582 NTF (Paris) / France II". The "Map sheet" field is empty. On the right side of the interface, there are two image windows: "Sketch" and "Chip". The "Sketch" window shows a small image of a control point, and the "Chip" window shows a larger image of the same point with a white box around it. At the bottom right, there are buttons for "Sketch", "ta\Local", "...", and "Clear".

Reference datasets examples

- Landsat GLCF. Global coverage (15 m) but not available as WMS
- Aerial orthophotografy. Locally available as WMS but usually no public access
- Globe DEM (1000 m grid)
- SRTM DEM (100 m grid) between +/- 60° lat.

Example 1:

HR image registration to HR reference data sets

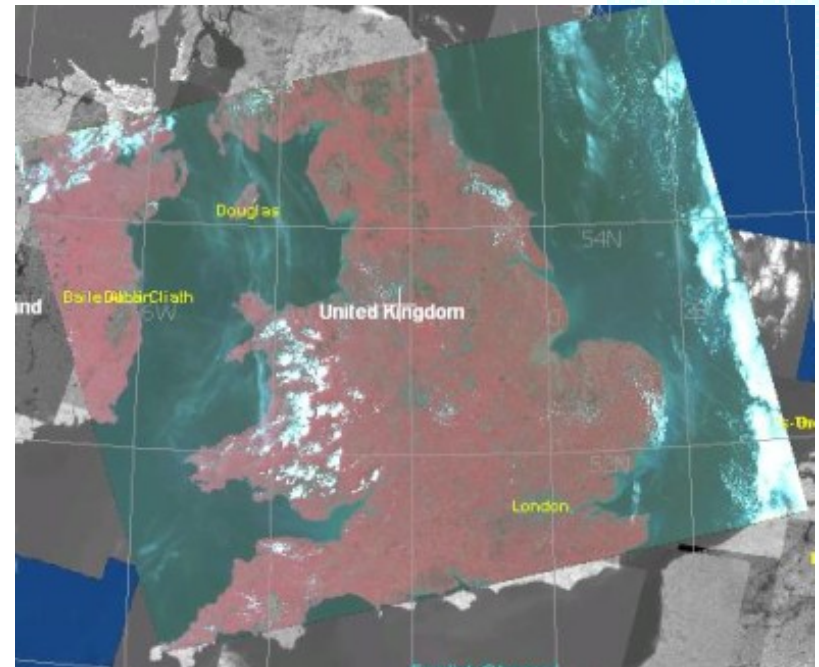
Reference:

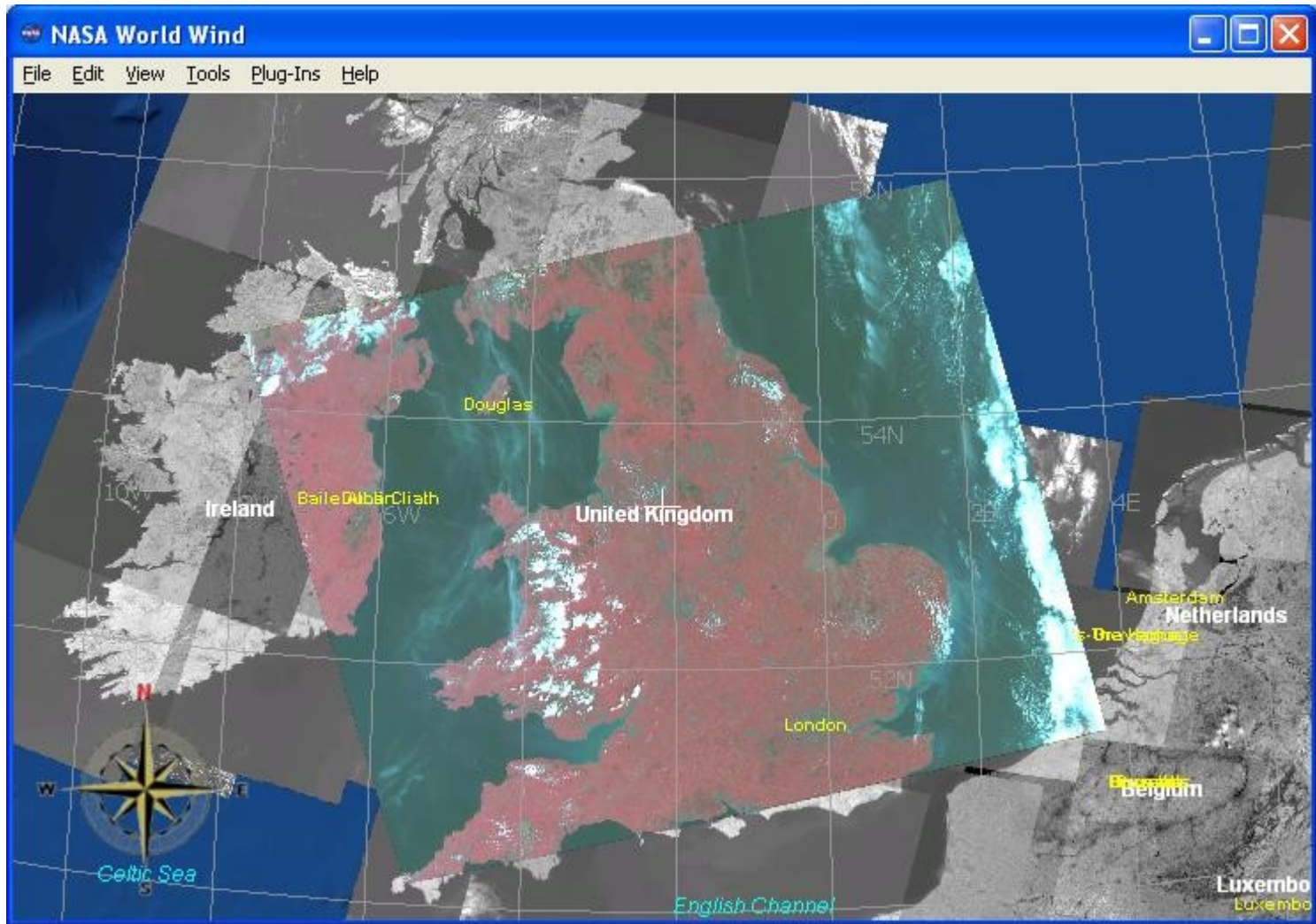
- Landsat TM GLCF
- Globe DEM

Target:

- DMC satellites 32 m data

Used operationally by DMCii in system correction of DMC scenes. Reduces location error from 10 – 20 km to 50 – 100 m





Example 2:

VHR image registration to HR reference data sets

Reference:

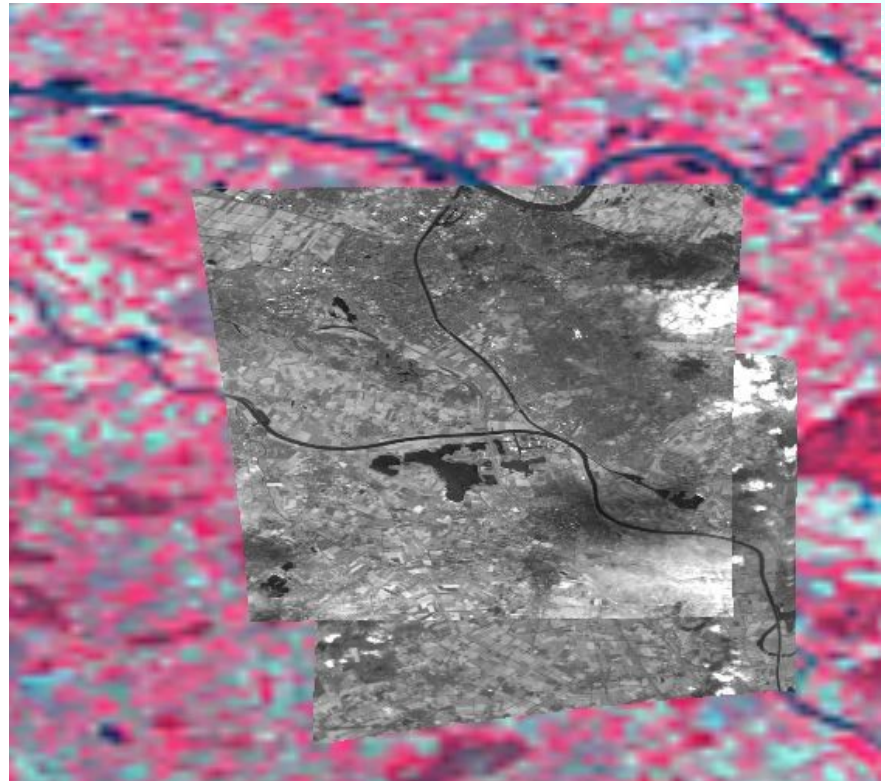
- Landsat TM GLCF
- Globe DEM

Target:

- Eros-A1 1.8 m data

Reduces location error from
1 - 3 km to 20 - 50 m

Facilitates the subsequent
manual GCP measurements
procedure



JRC test dataset

- 50 scenes (Ikonos, Quickbird, Eros, Spot, Landsat)
- Aerial orthoimagery used as reference (but GLCF for Landsat)
- Local DEM when available, SRTM elsewhere

JRC results

- Spot and Landsat results 100% successful
- VHR results primarily limited by reference data quality
- VHR results affected by bias due to long shadows in reference images
- VHR scene results 100% successful in areas with reference images of good enough quality and without long shadows

Example 3:

VHR image registration to VHR reference data sets

Reference:

- Aerial orthophotos 1 m
- Local DEM

Target:

- Quickbird Mul 2.4 m data

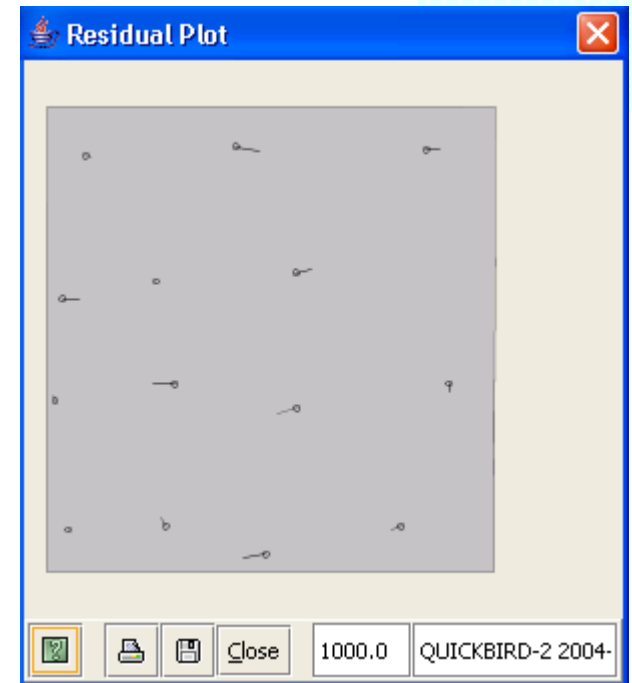
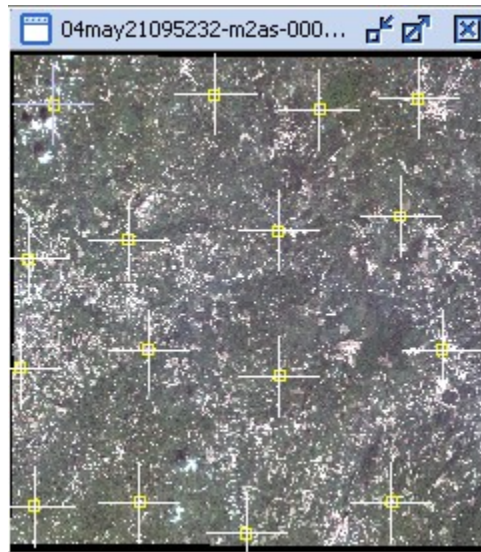
Test of automatic ortho-rectification of 14 Quickbird scenes in the Campobasso province of Italy



Example 3: (cont.)

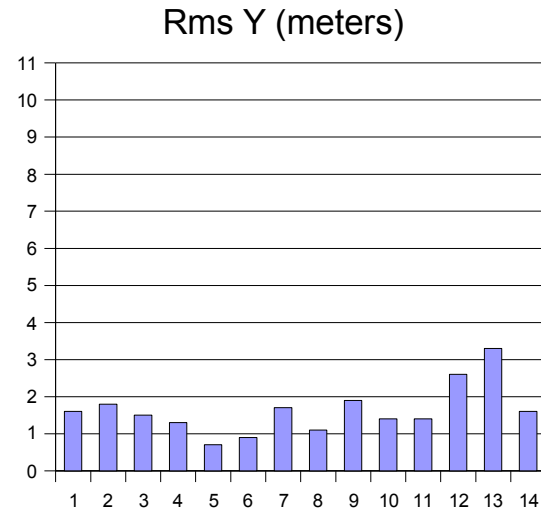
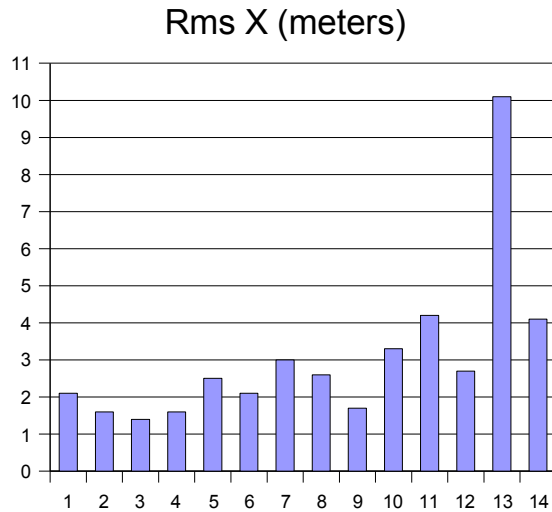
Checkpoints

Orthorectification
validated using
16 independent
checkpoints
per scene



Example 3: (cont.)

Results



Example 3: (cont.)

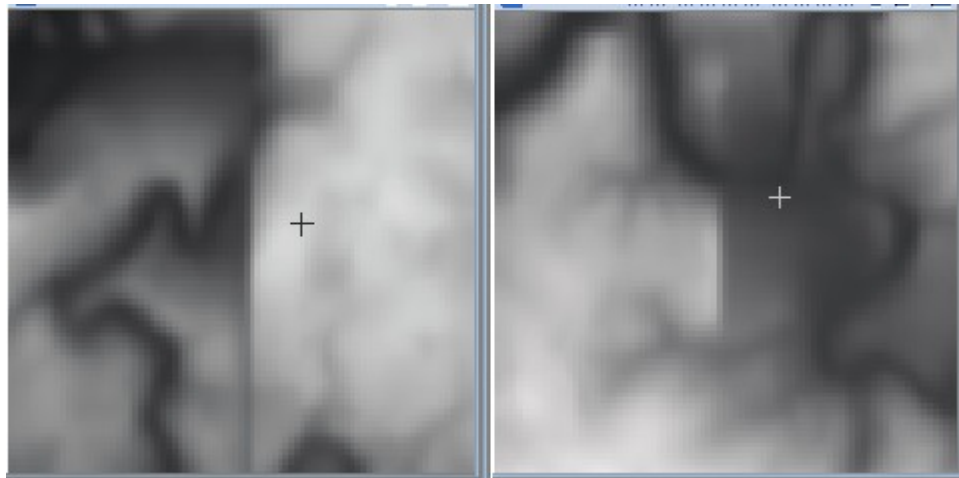
Analysis

- Subpixel accuracy achieved in a majority of scenes
- An analysis of the large errors in scene 12 and 13 reveals that they are caused by errors in the reference images
- Reference image errors probably also affects the results in other images
- More accurate reference data must be used to find the true potential of the method



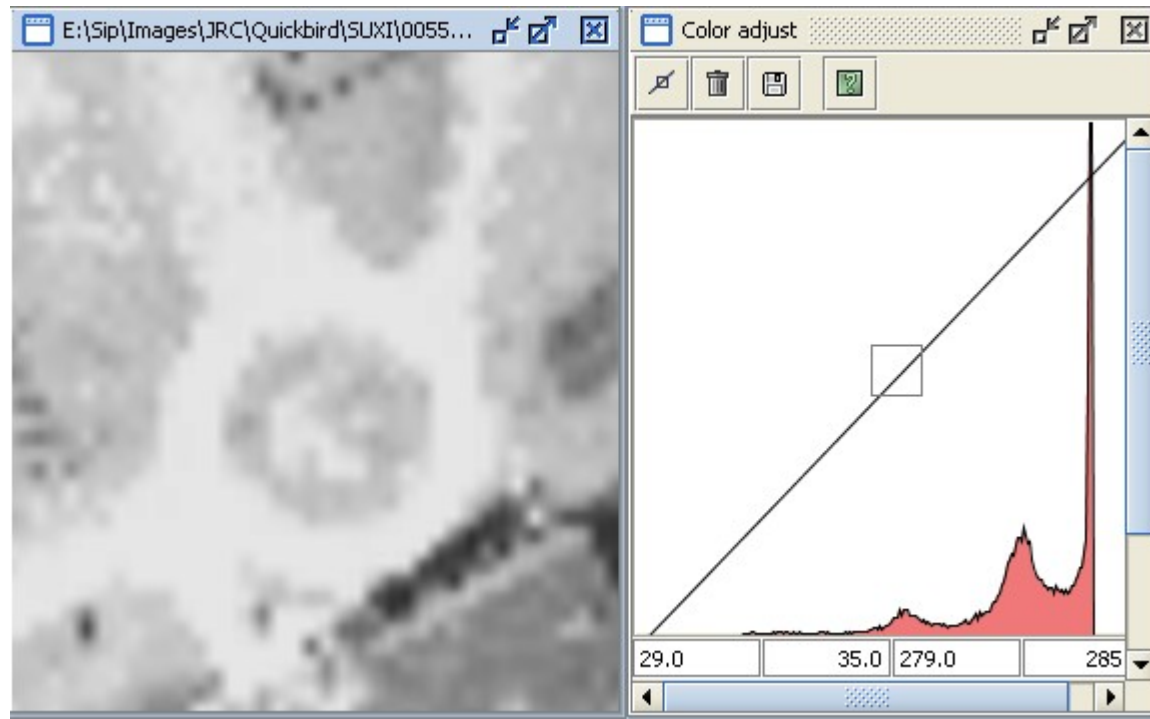
Example of dislocation in aerial reference images (~11 m)

Reference data quality problems



Discontinuity in local DEM

Reference data quality problems



Oversaturated orthophotos

Reference data quality problems

Ikonos



Aerial orthophoto



Long shadows

Conclusion

- Very high success rate for HR imagery (Spot, Landsat, DMC)
- Quality of reference data often limits the success of VHR imagery
- Long shadows due to morning or late afternoon aerial photo acquisitions is a difficult problem for VHR