HIGH ACCURACY 3D PROCESSING OF SATELLITE IMAGERY

A. Gruen, L. Zhang, S. Kocaman

Institute of Geodesy and Photogrammetry, ETH Zurich, CH-8092 Zurich, Switzerland

http://www.photogrammetry.ethz.ch

outline

- introduction
- sensor modeling of HRSI
- DTM/DSM generation from HRSI
- performance evaluation
- 3D city modeling with HRSI
- conclusions

• High-resolution PAN & MS imagery

+ Quickbird (0.7 m)

+ IKONOS (1.0 m)

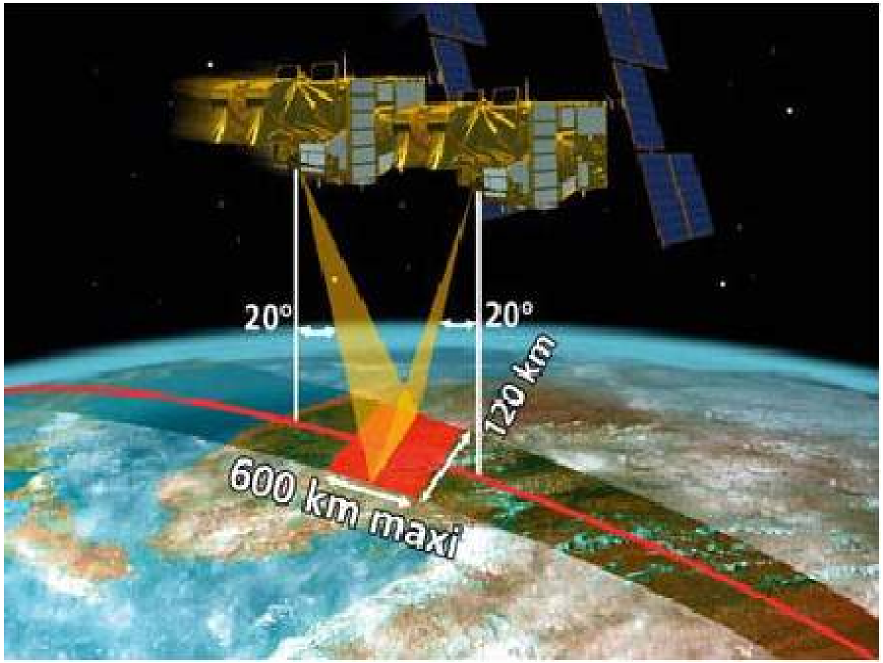
+ SPOT (2.5-10 m)

+ ALOS / PRISM (2.5 m) …….

• More than 8-bit images, higher dynamic range

• Along- / cross-track stereo;

Possibly multiple view terrain coverage

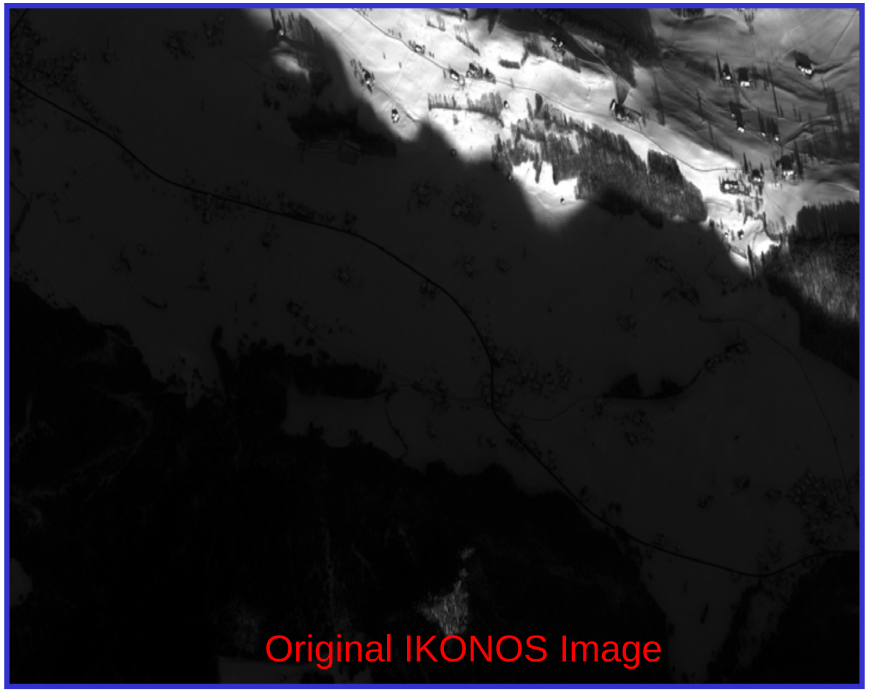


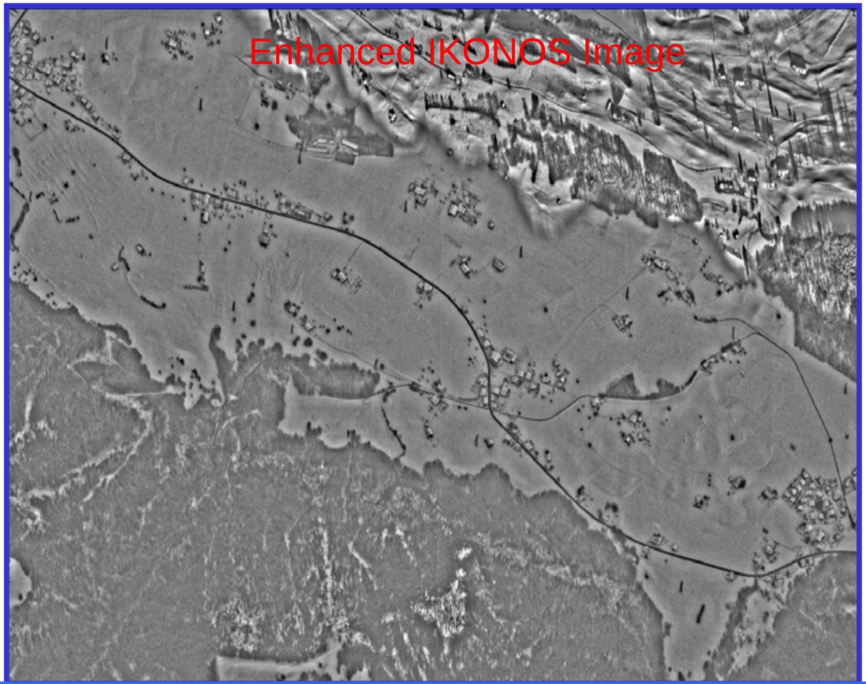
• Challenge:

+ Algorithmic redesign

+ Improvements

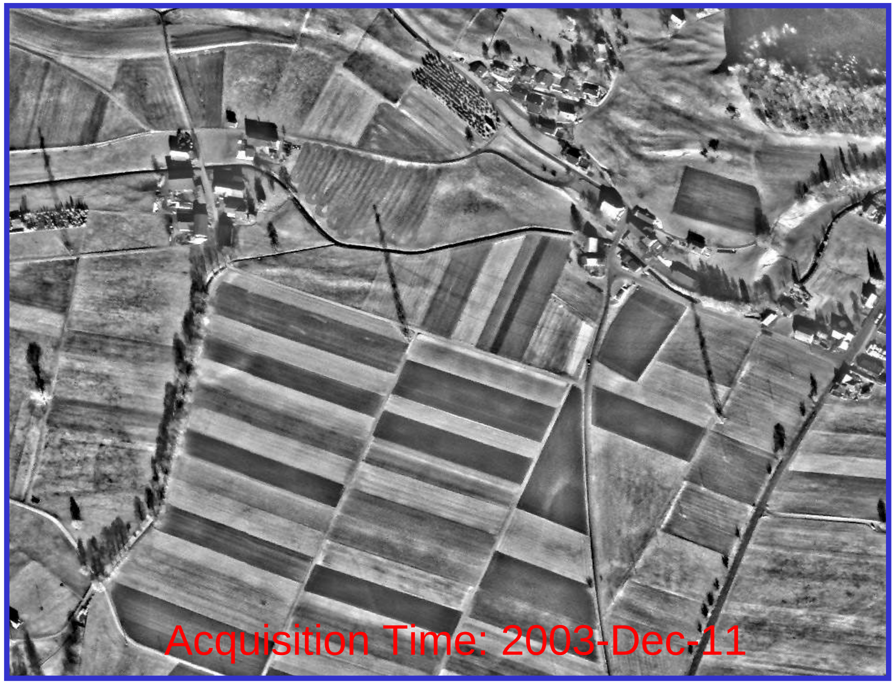
More than 8-bit images, higher dynamic range





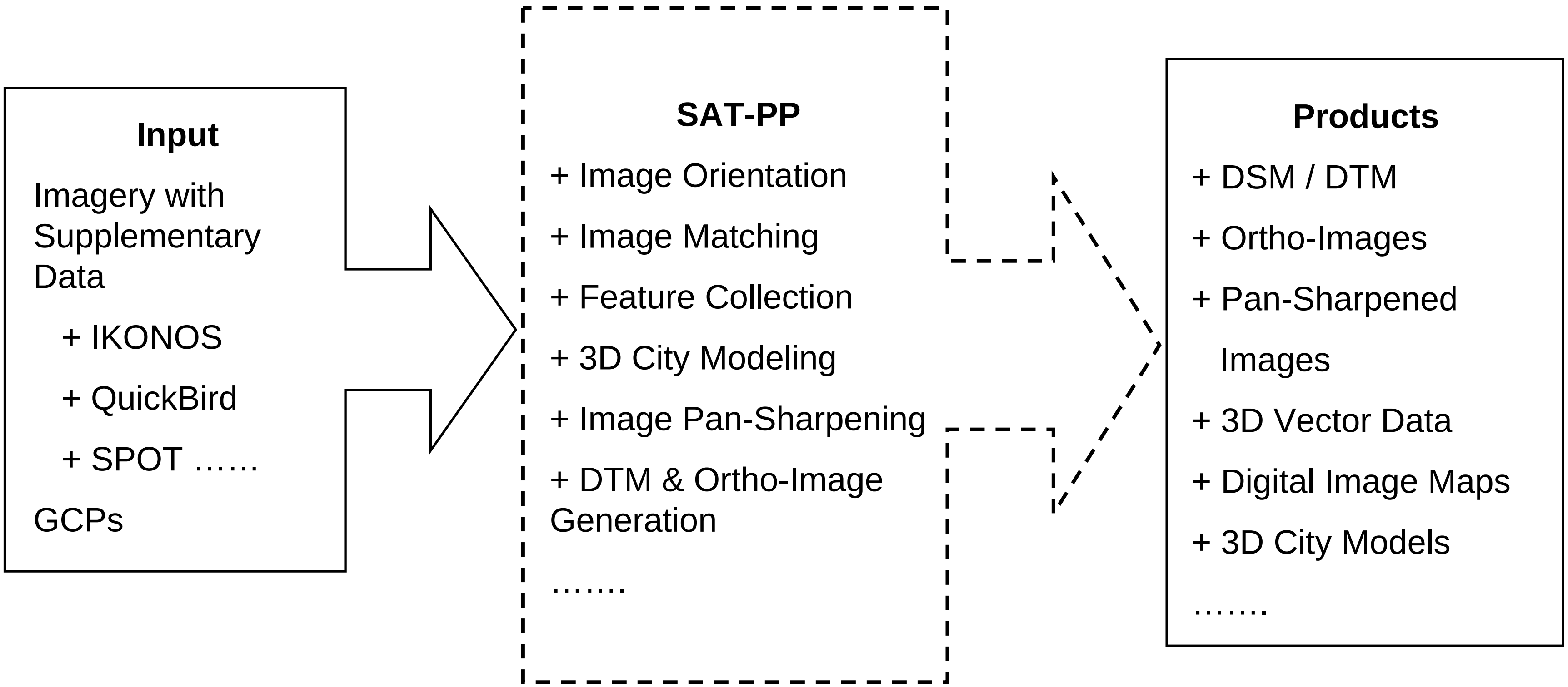
- Along- / cross-track stereo;

  Possibly multiple view terrain coverage

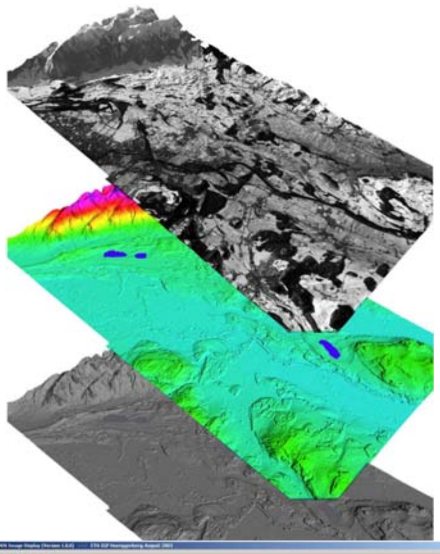


SAT-PP (**Sat**ellite Image **P**recision **P**rocessing) -- High-Res Satellite Imagery (HRSI): ≤ 5 m

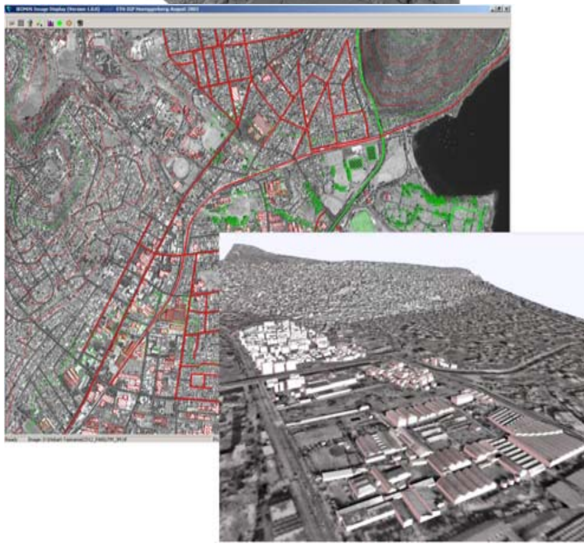
+ *New Processing Methods / Products for HRSI*
+ *Joint Sensor Model for* IKONOS, QuickBird, SPOT, ALOS/RPISM and etc.
+ *Specially Designed Image Matching Procedure for Linear Array Imagery*



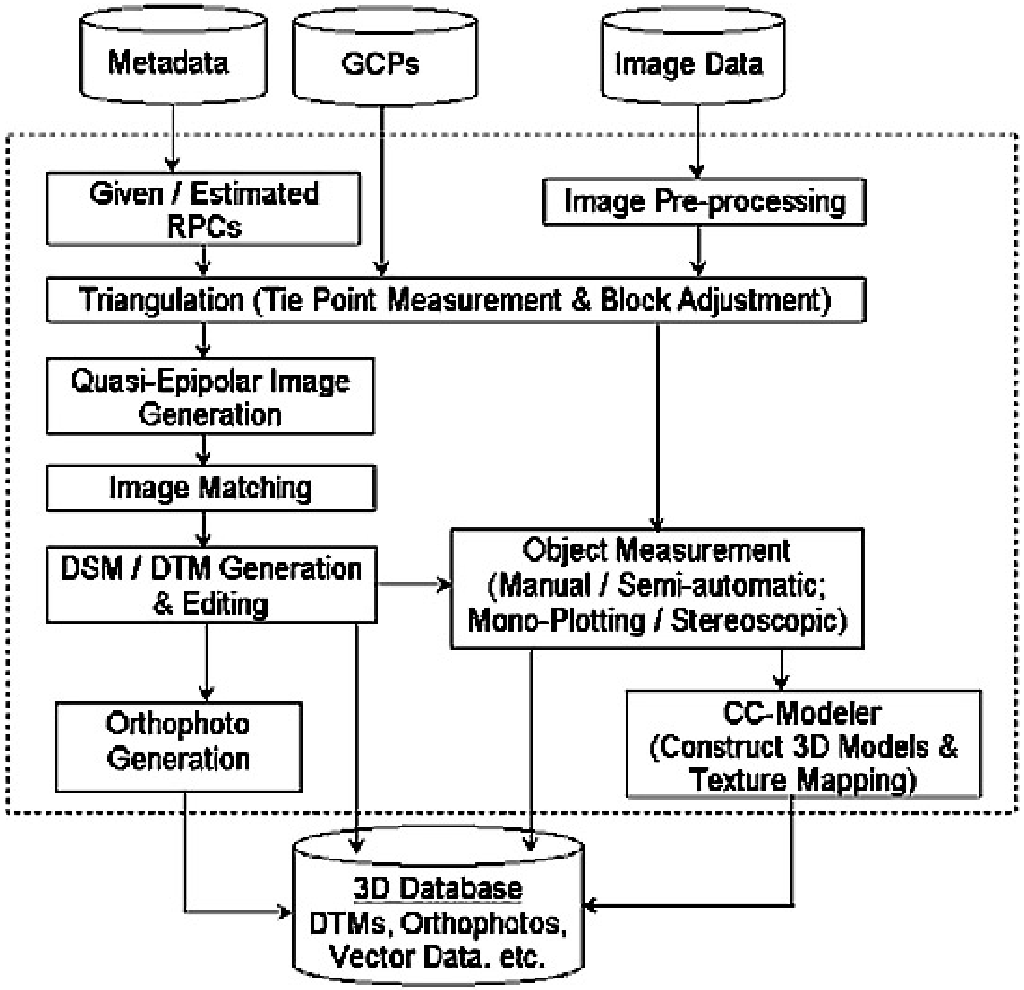
Functionality of SAT-PP



- ✓ Project and data management tools, image format conversion and pre-processing, image display / roaming in mono and stereo modes
- ✓ Sensor models (RFM, affine and projective DLT model)
- ✓ Orientation of single stereo models
- ✓ On-line quality control and error analysis via interaction of graphics elements
- ✓ GCP and tie point measurement in manual and semi-automated modes
- ✓ Derivation of quasi-epipolar images for stereo mapping and feature collection
- ✓ Automated DSMs generation
- ✓ Generation of orthorectified images
- ✓ Mono-plotting functions with DTMs
- ✓ Manual and semi-automatic object extraction in mono/stereo
- ✓ 3D city modeling by using CyberCity Modeler™
- ✓ Pansharpening image generation. Fully automated sub-pixel image registration between multispectral and panchromatic imagery



Workflow of SAT-PP



Sensor Modeling and Blockadjustment

- Rigorous sensor model

  + Physical imaging geometry (nearly parallel projection in along-track and perspective projection in cross-track); high accuracy; easier for statistic analysis

  - Mathematically more complicated; depends on type of sensors

- Sensor model based on RFM

  + Given (for IKONOS, Quickbird) and computed RFM parameters (RPCs)

$$px_n = \frac{f_1(X_n, Y_n, Z_n)}{f_2(X_n, Y_n, Z_n)}$$

$$py_n = \frac{f_3(X_n, Y_n, Z_n)}{f_4(X_n, Y_n, Z_n)}$$

- Blockadjustment model (Grodecki & Dial; 2003)

  + Calibrated system with a very narrow FOV; accurate a priori exterior orientation data (HRSI -- OK !)

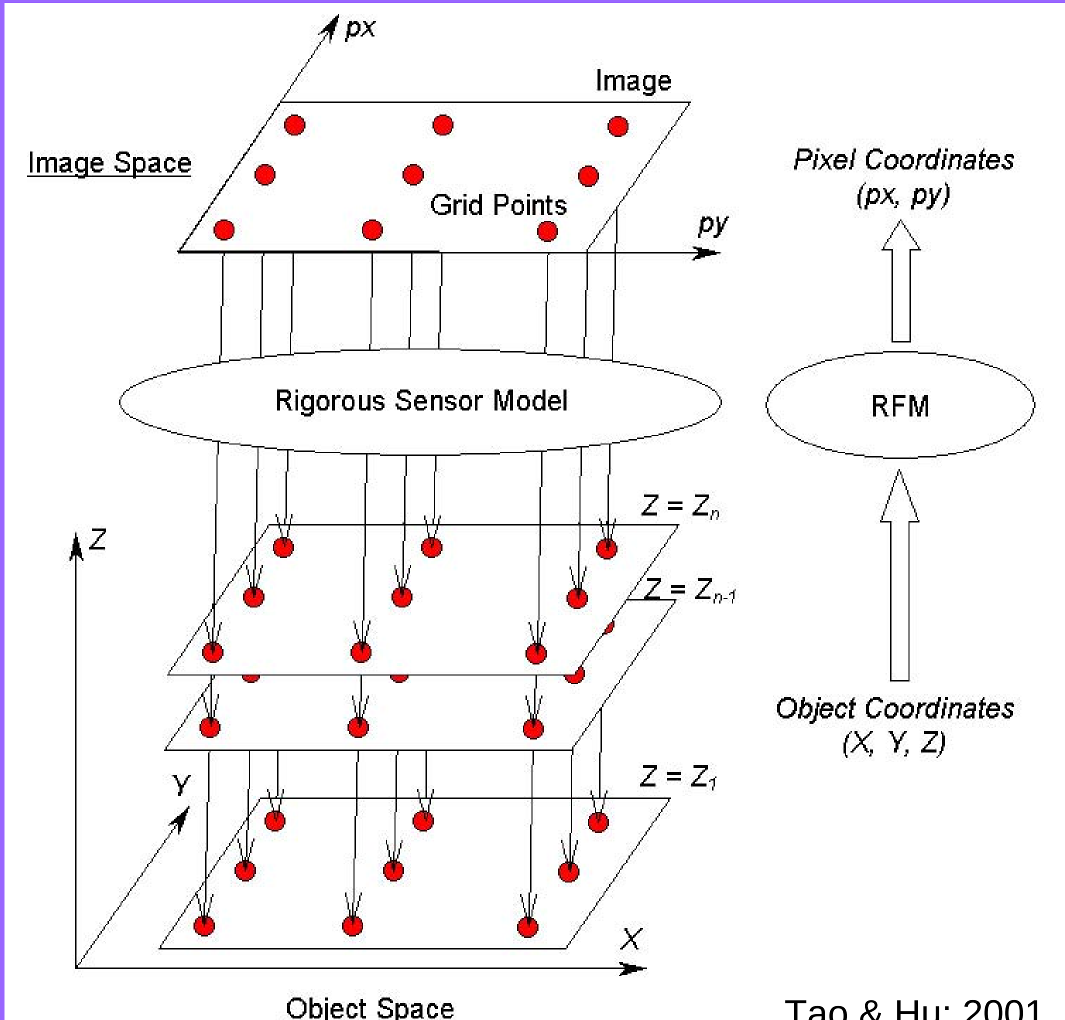
$$x + \Delta x = x + a_0 + a_1 x + a_2 y = RPC_x(\varphi, \lambda, h)$$

$$y + \Delta y = y + b_0 + b_1 x + b_2 y = RPC_y(\varphi, \lambda, h)$$

- Other simpler sensor models

  + 3D affine; relief-corrected 2D affine; DLT ……

Sensor model based on RFM



Tao & Hu; 2001

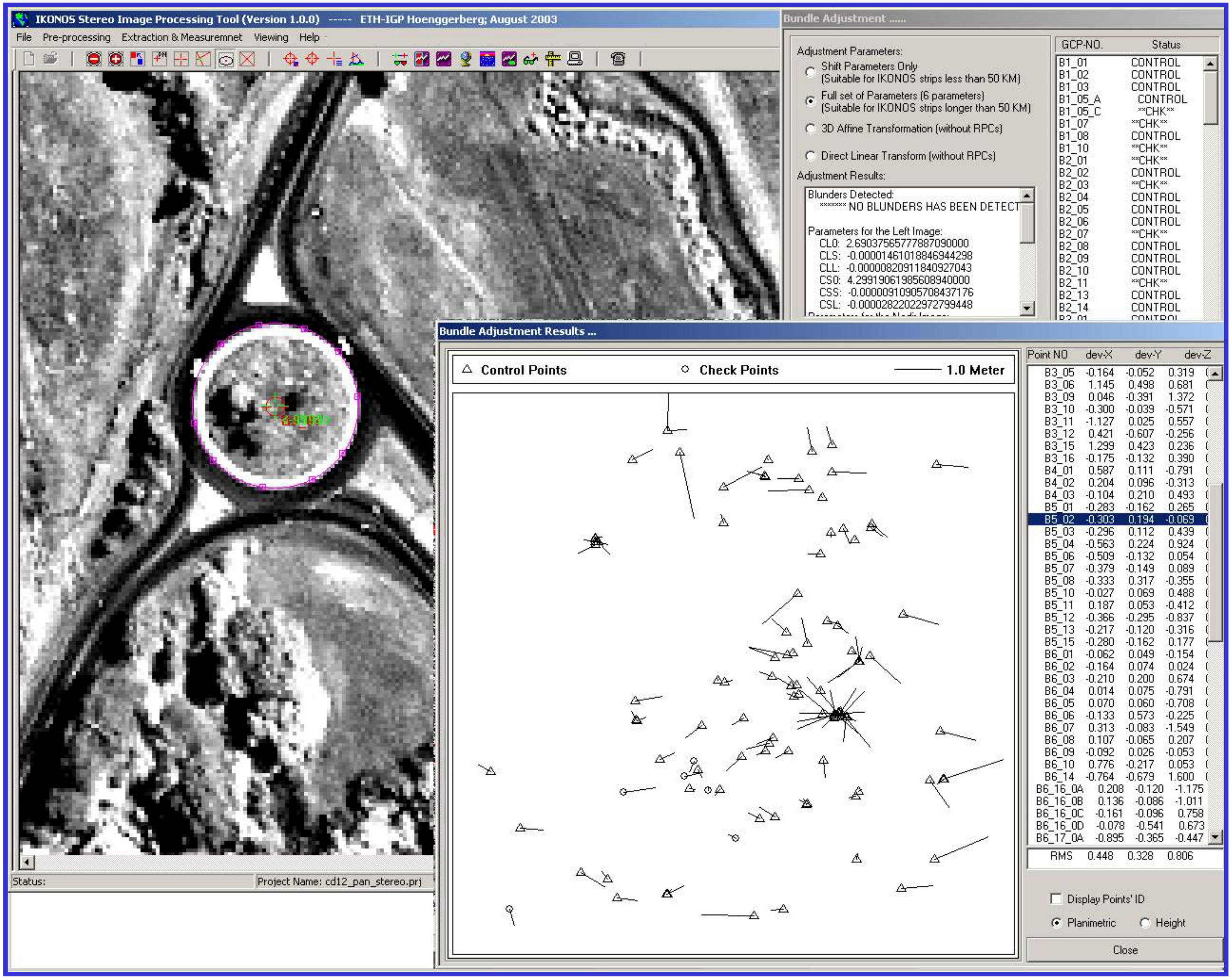
$$px_n = \frac{f_1(X_n, Y_n, Z_n)}{f_2(X_n, Y_n, Z_n)}$$

$$py_n = \frac{f_3(X_n, Y_n, Z_n)}{f_4(X_n, Y_n, Z_n)}$$

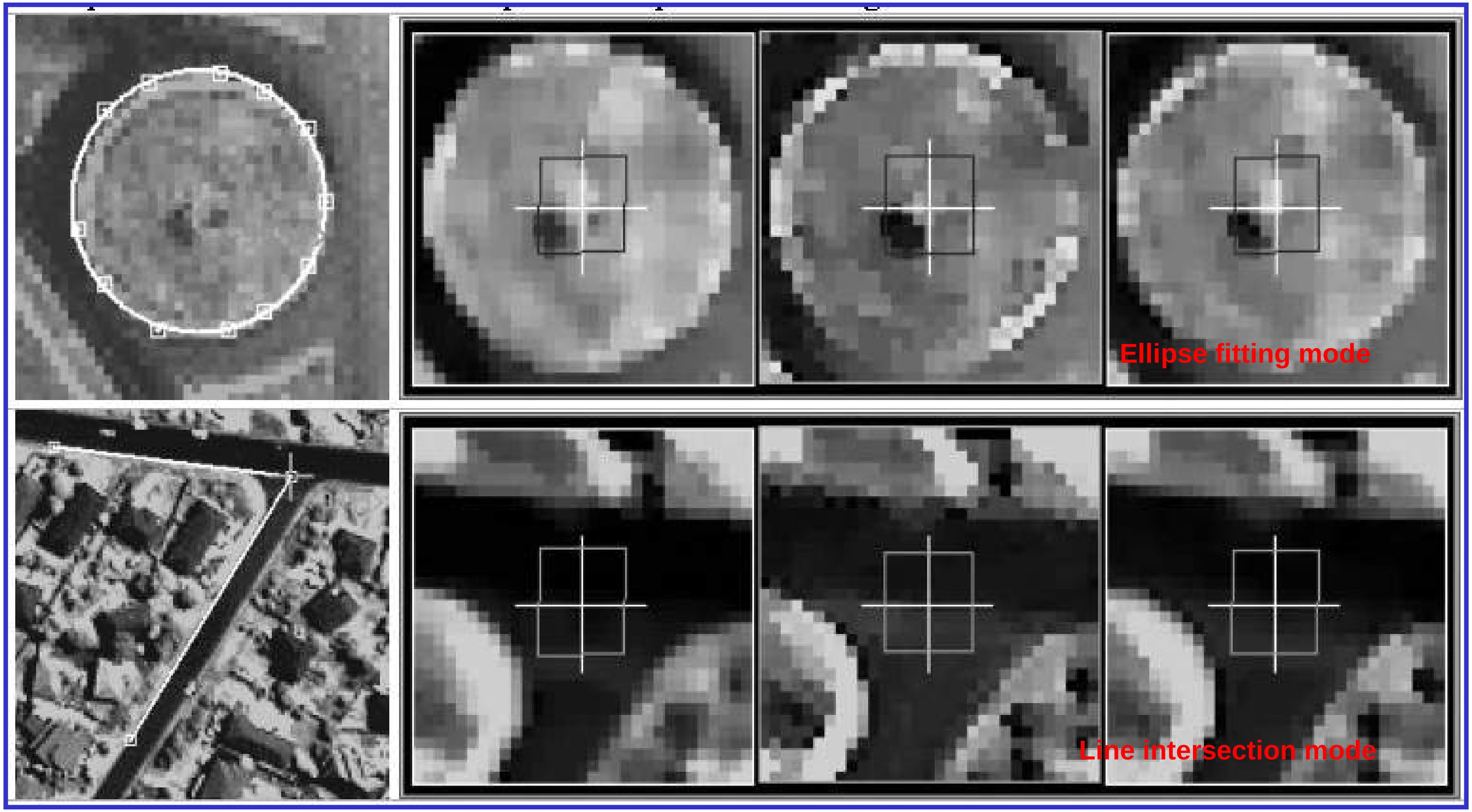
For SPOT5 HRS / HRG

Fitting accuracy: 1/20 - 1/100 pixels

User interface for block adjustment



Ellipse fitting method GCP measurement



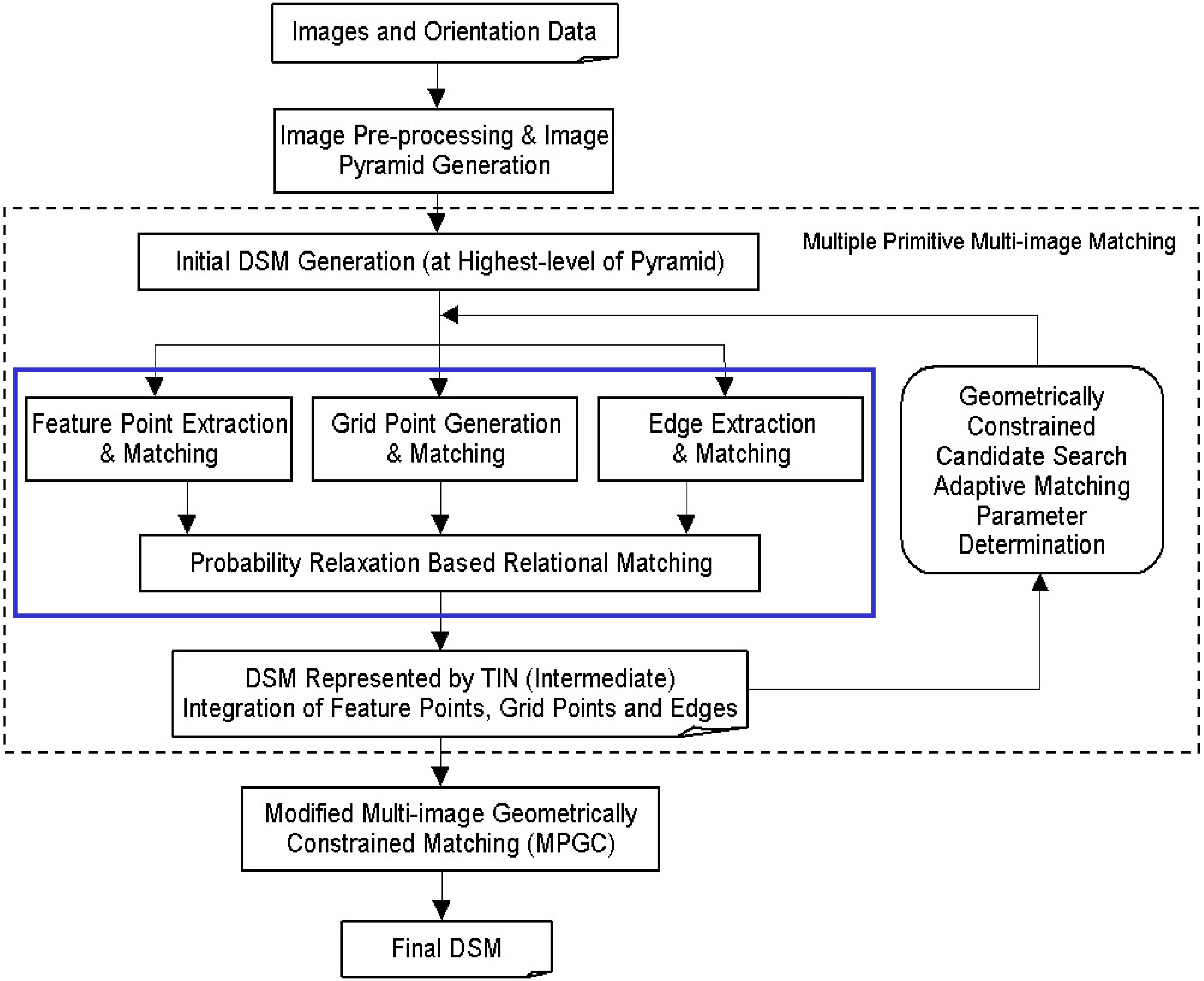
Detailed DSM Generation

The approach uses a coarse-to-fine hierarchical solution with an effective combination of several image matching algorithms and automatic quality control.

The new characteristics provided by the IKONOS and Quickbird imaging systems, i.e. the multiple-view terrain coverage and the high quality image data, are also efficiently utilized.

It was originally developed for multi-image processing of the very high-resolution TLS/StarImager aerial Linear Array images. Now it has been extended and has the ability to process other linear array images as well.

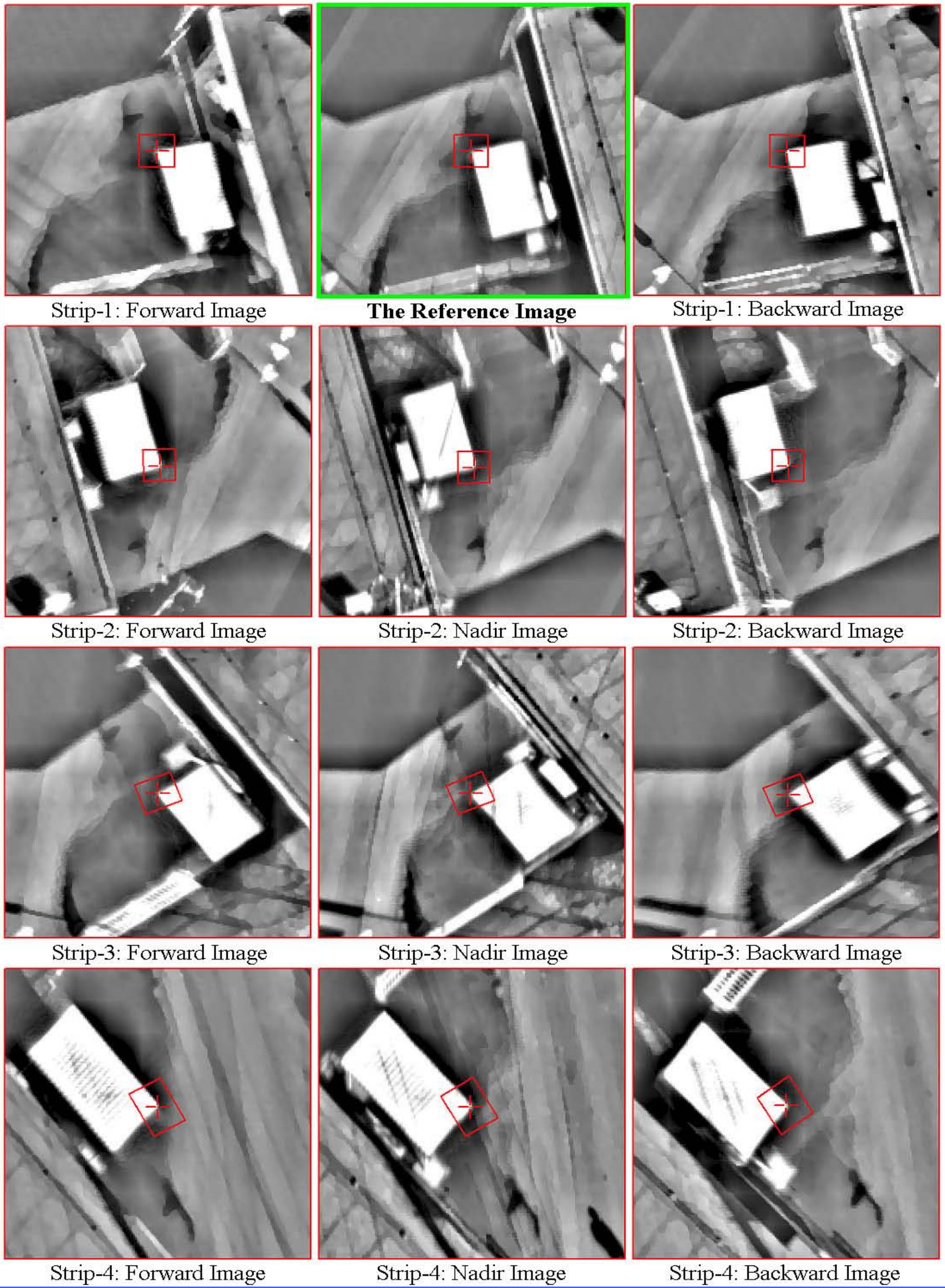
Workflow of Automated DSM Generation



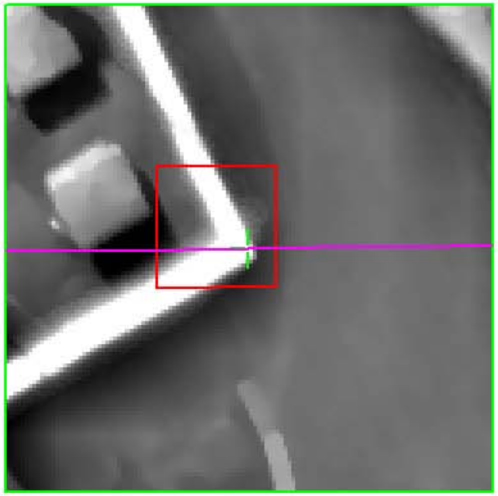
Automated DSM Generation Procedure

- Multiple image matching
  + Matching guided from object space
  + Simultaneouslly multiple images (>= 2) with
    Geometrically Constrained Cross-Correlation
- Matching with multiple primitives --- points + edges
- Self-tuning matching parameters
- High matching redundancy
- Efficient surface modeling
  + TIN (from a constrained Delauney triangulation method)
- Coarse-to-fine Hierarchical strategy

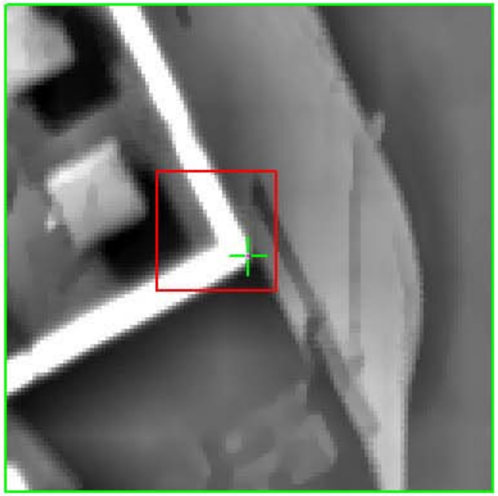
Matching guided from object space



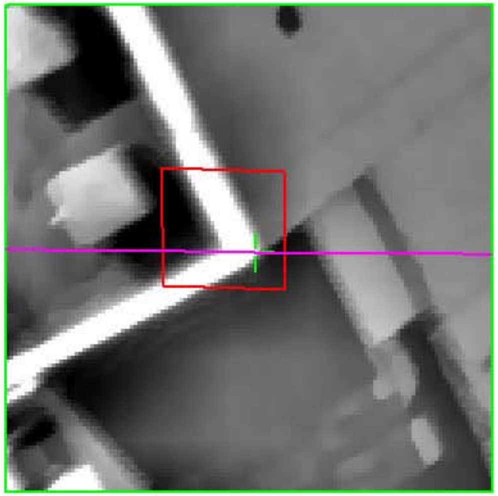
Self-tuning matching parameters



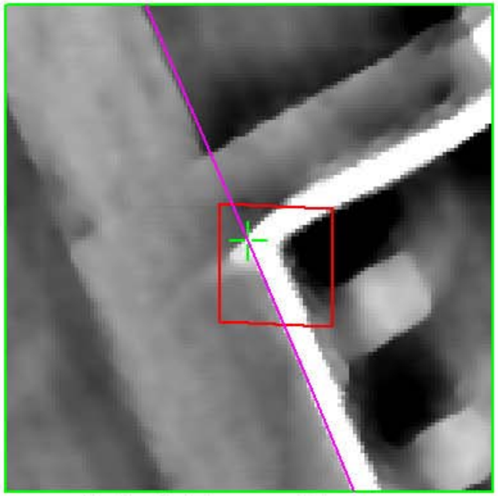
Strip-1: Forward Image



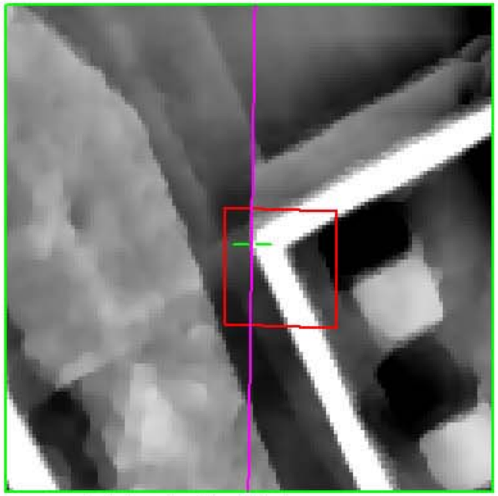
The Reference Image



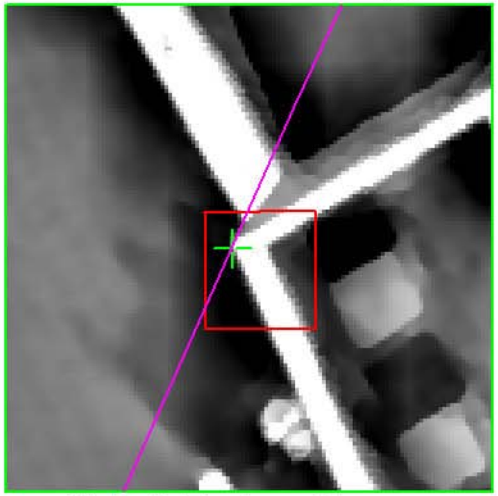
Strip-1: Backward Image



Strip-2: Forward Image

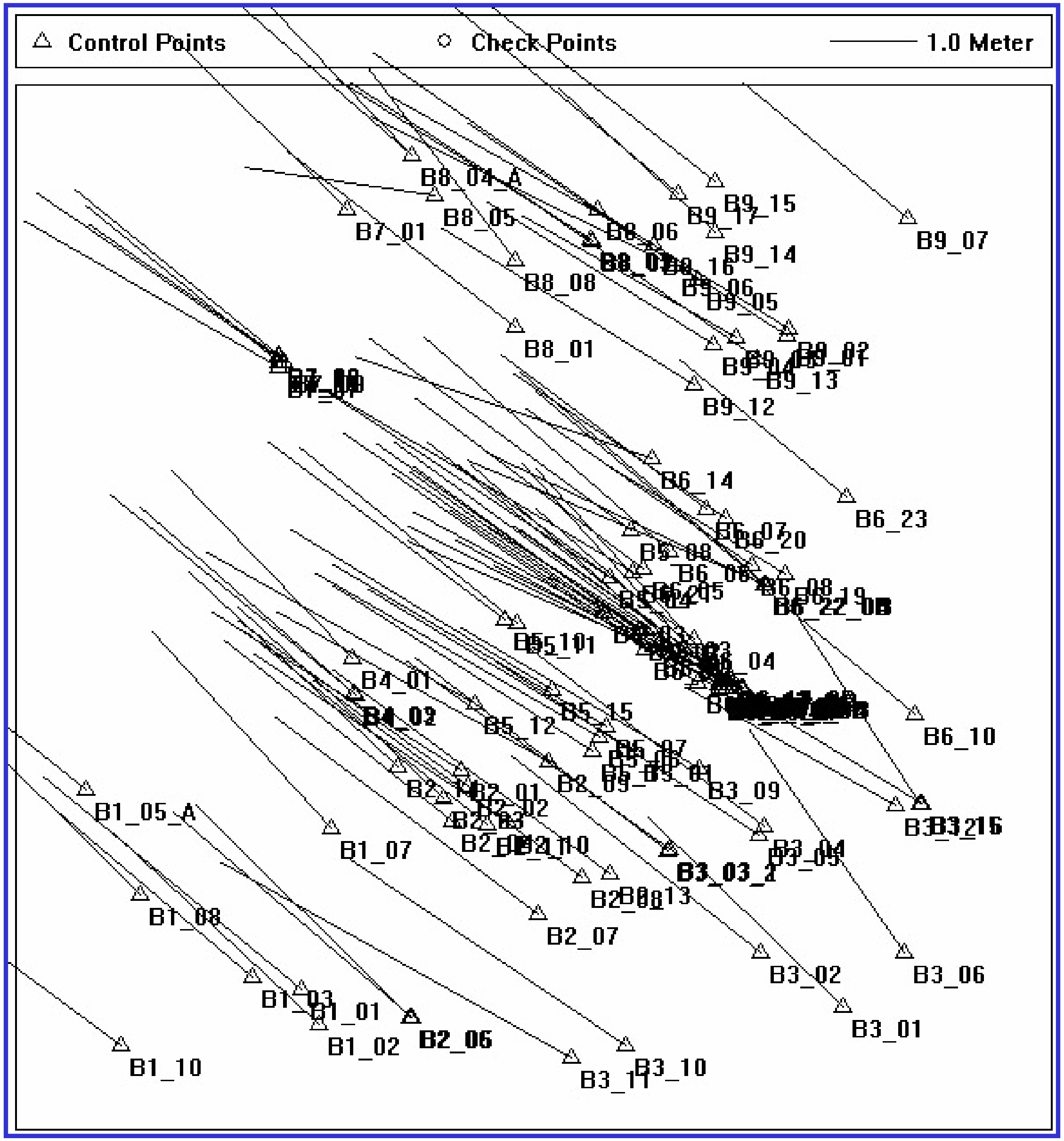


Strip-2: Nadir Image



Strip-2: Backward Image

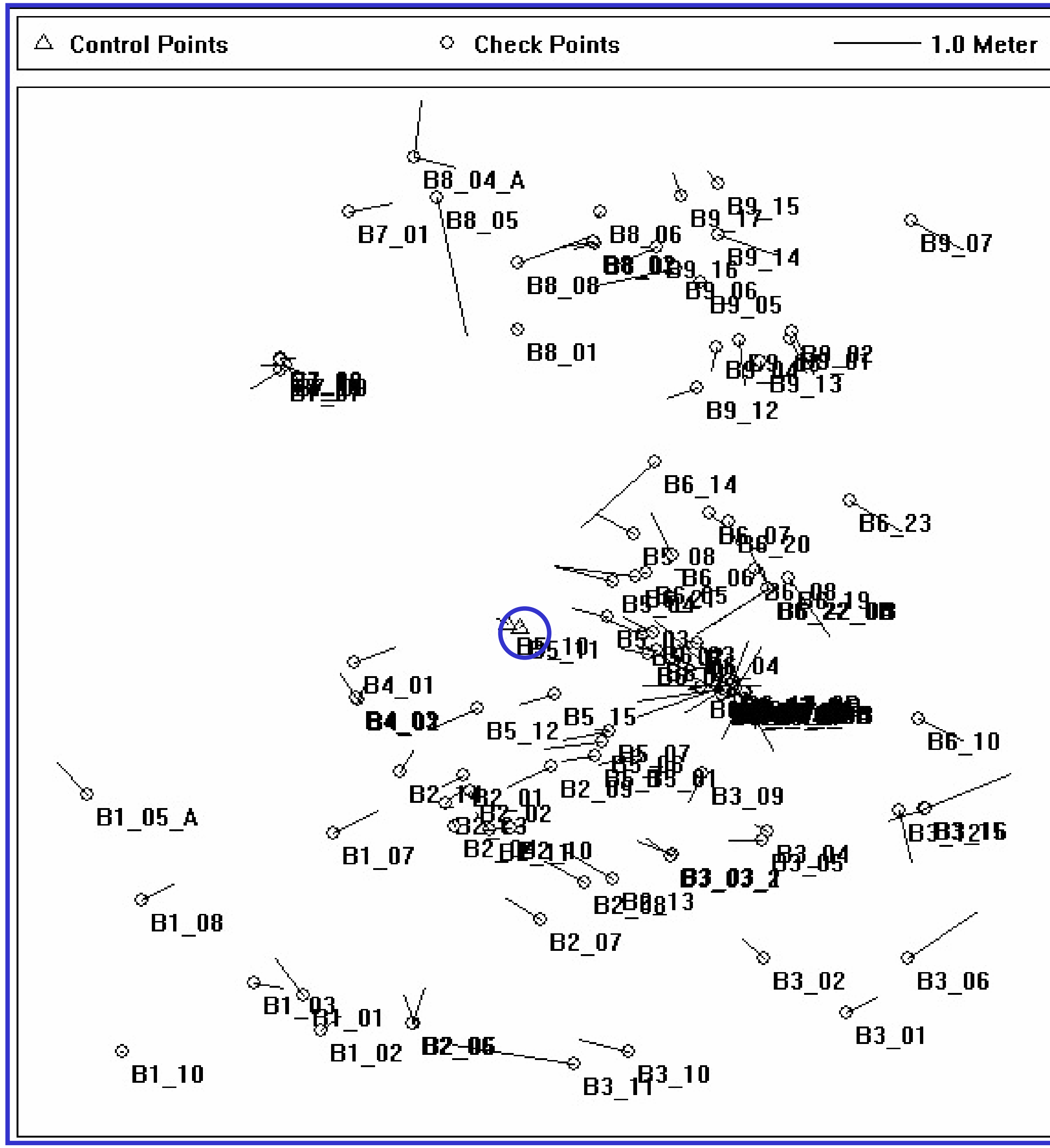
IKONOS Triplet, Hobart, Australia



RPC + 2 Translates

GCPs(CPs)	RMSE-X	RMSE-Y	RMSE-Z
0 (124)	2.75	2.00	1.97
1 (123)	0.48	0.35	0.90
4 (120)	0.49	0.36	0.86
124 (0)	0.45	0.33	0.81

IKONOS Triplet, Hobart, Australia



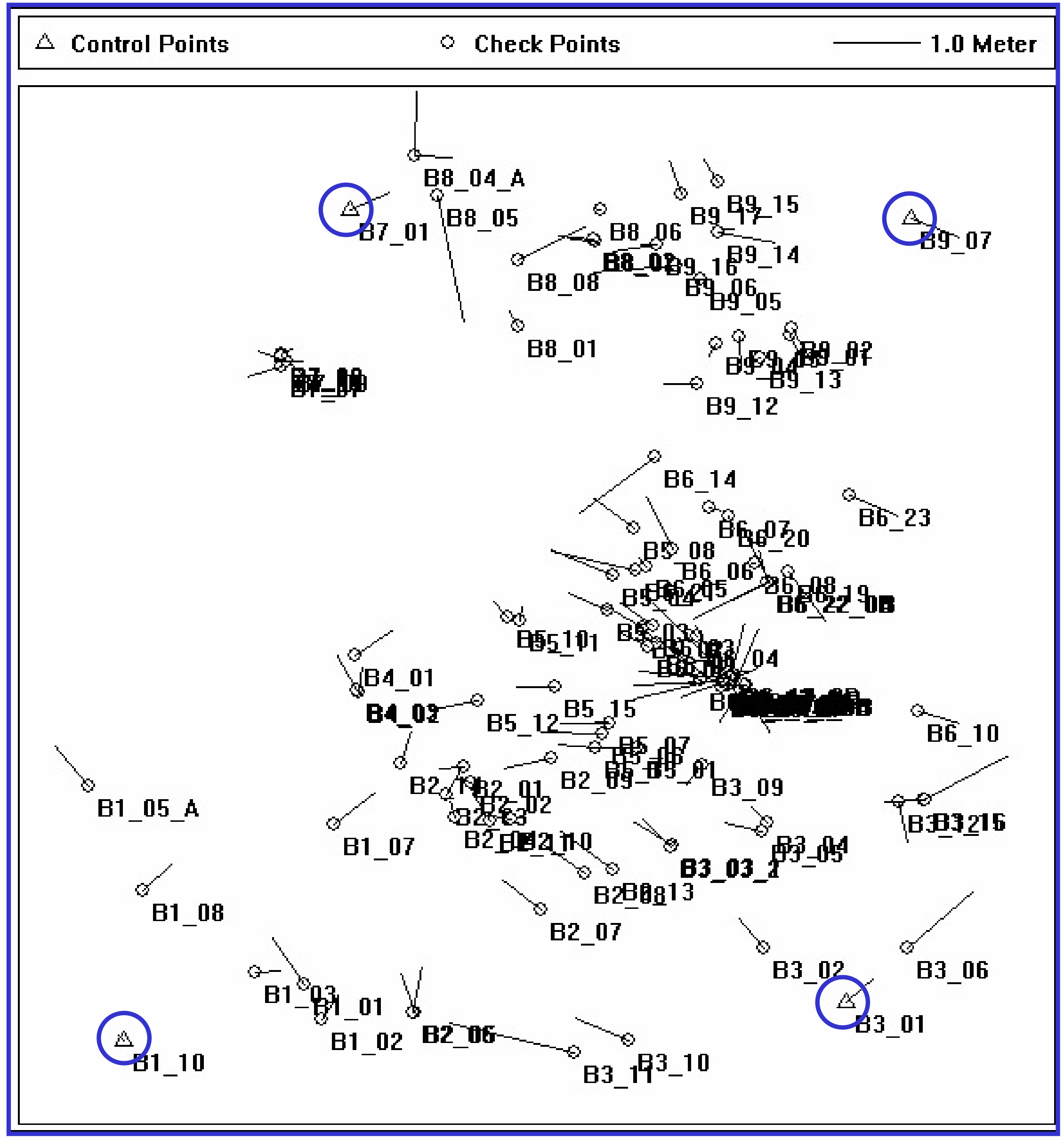
RPC + 2 Translates

GCPs(CPs)	RMSE-X	RMSE-Y	RMSE-Z
0 (124)	2.75	2.00	1.97
1 (123)	0.48	0.35	0.90
4 (120)	0.49	0.36	0.86
124 (0)	0.45	0.33	0.81

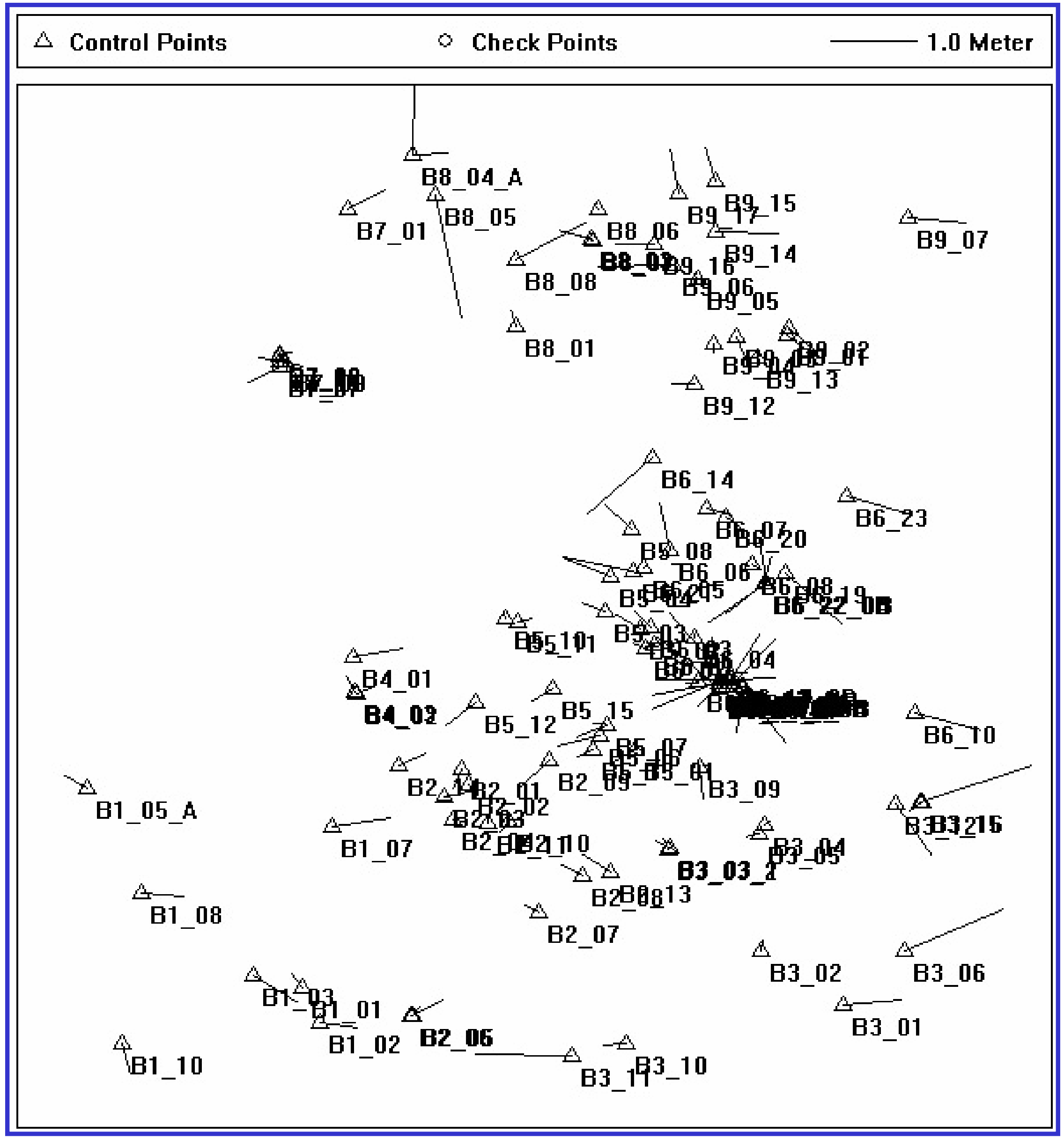
IKONOS Triplet, Hobart, Australia

RPC + 2 Translates

GCPs(CPs)	RMSE-X	RMSE-Y	RMSE-Z
0 (124)	2.75	2.00	1.97
1 (123)	0.48	0.35	0.90
4 (120)	0.49	0.36	0.86
124 (0)	0.45	0.33	0.81



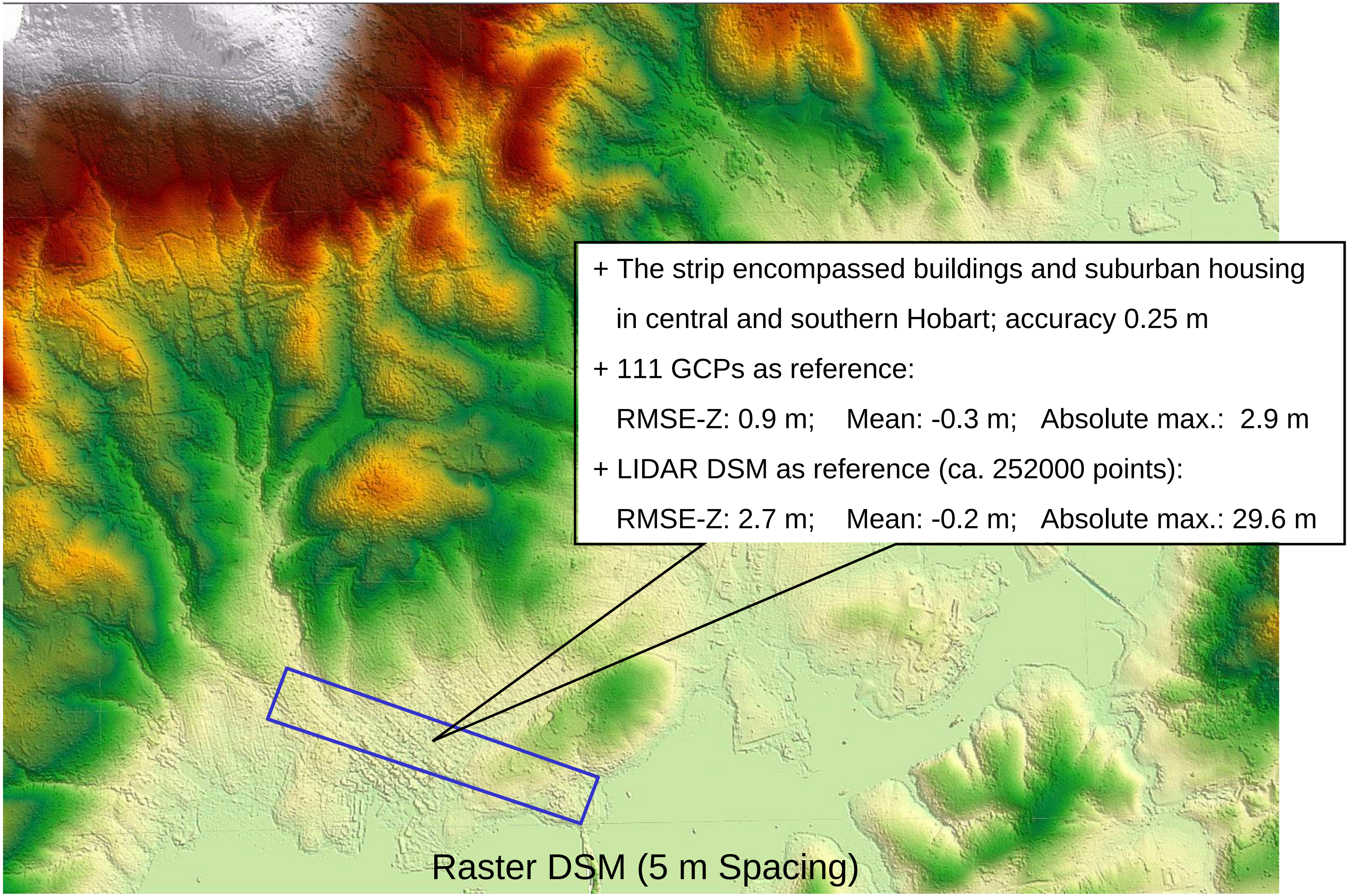
IKONOS Triplet, Hobart, Australia



RPC + 2 Translates

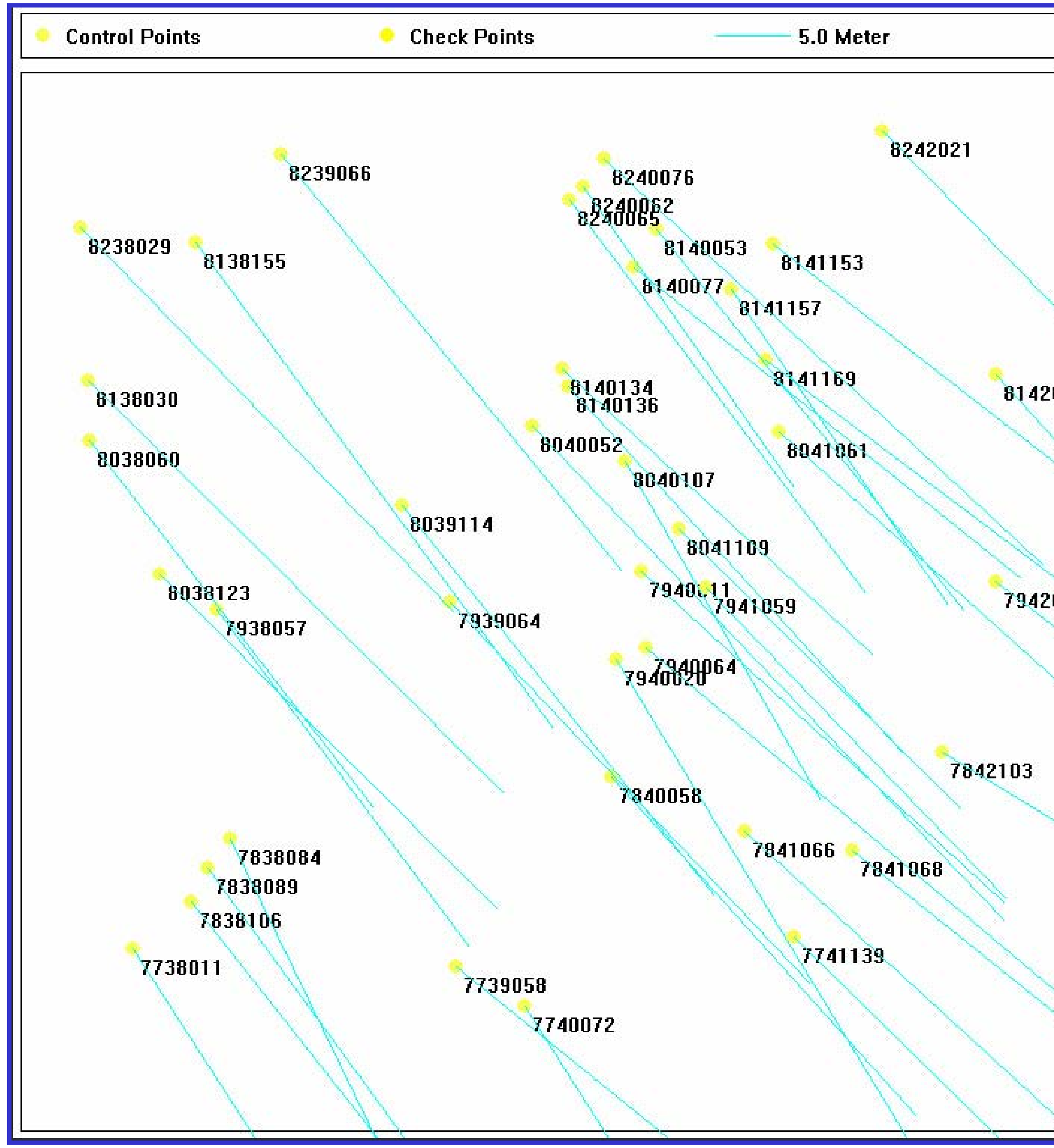
GCPs(CPs)	RMSE-X	RMSE-Y	RMSE-Z
0 (124)	2.75	2.00	1.97
1 (123)	0.48	0.35	0.90
4 (120)	0.49	0.36	0.86
124 (0)	0.45	0.33	0.81

Automatic DTM/DSM Generation (IKONOS, Hobart, Australia)



Raster DSM (5 m Spacing)

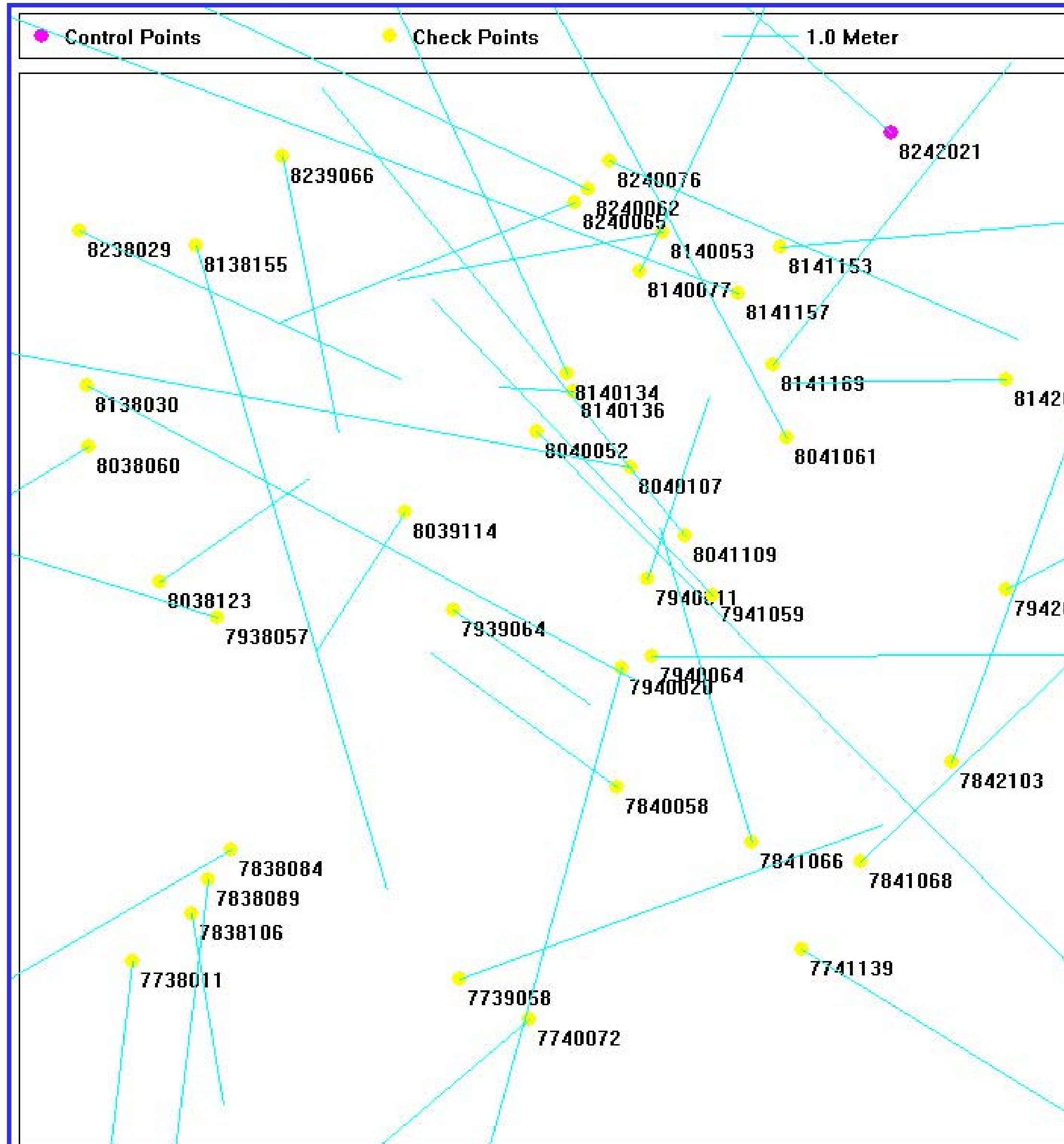
SPOT5-HRS, Bavaria, Germany



RPC + 2 Translates

GCPs(CPs)	RMSE-X	RMSE-Y	RMSE-Z
0 (43)	23.11	25.17	75.76
1 (42)	4.69	4.38	2.26
4 (39)	4.68	4.35	2.25
43 (0)	4.63	3.66	2.20

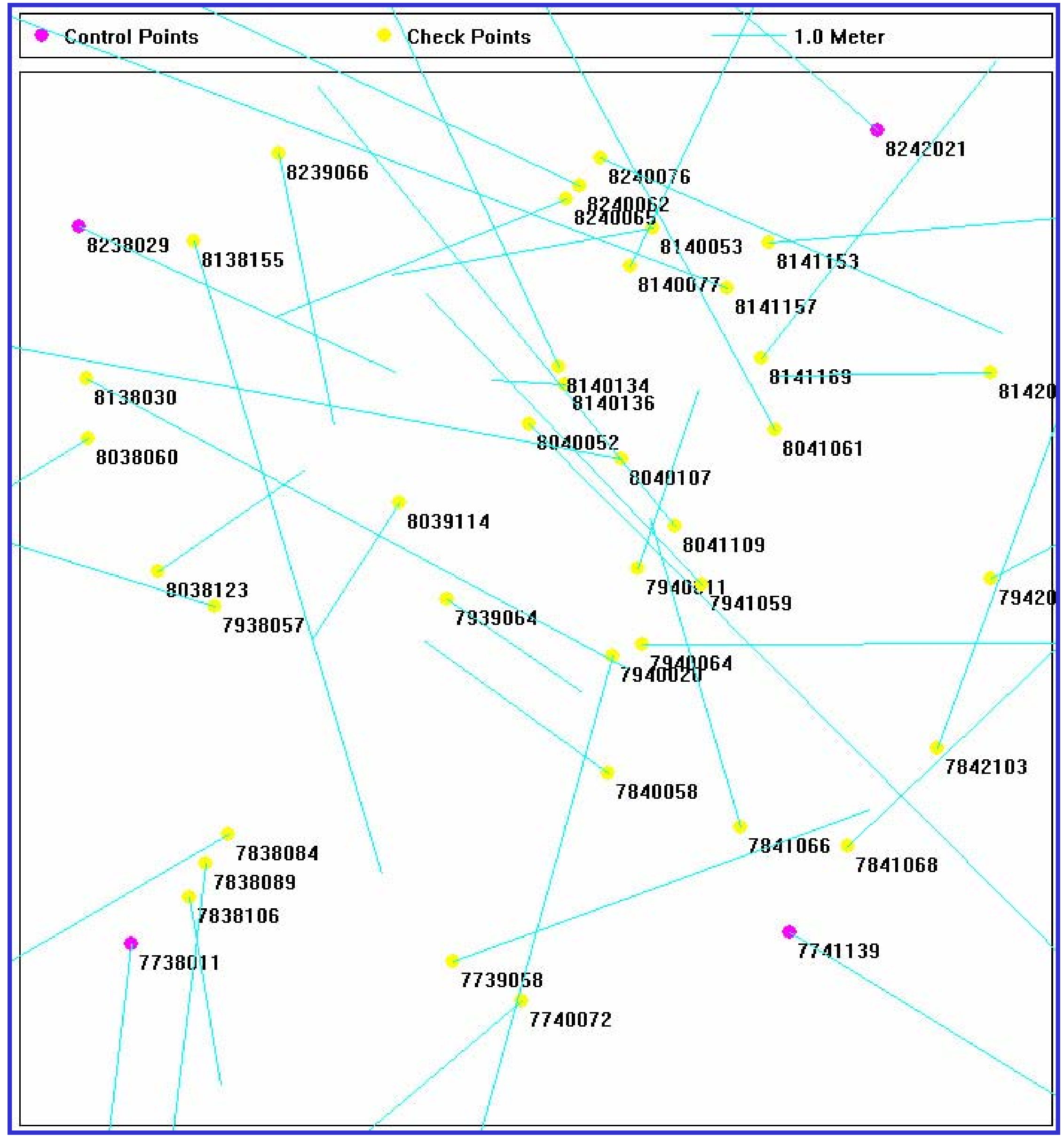
SPOT5-HRS, Bavaria, Germany



RPC + 2 Translates

GCPs(CPs)	RMSE-X	RMSE-Y	RMSE-Z
0 (43)	23.11	25.17	75.76
1 (42)	4.69	4.38	2.26
4 (39)	4.68	4.35	2.25
43 (0)	4.63	3.66	2.20

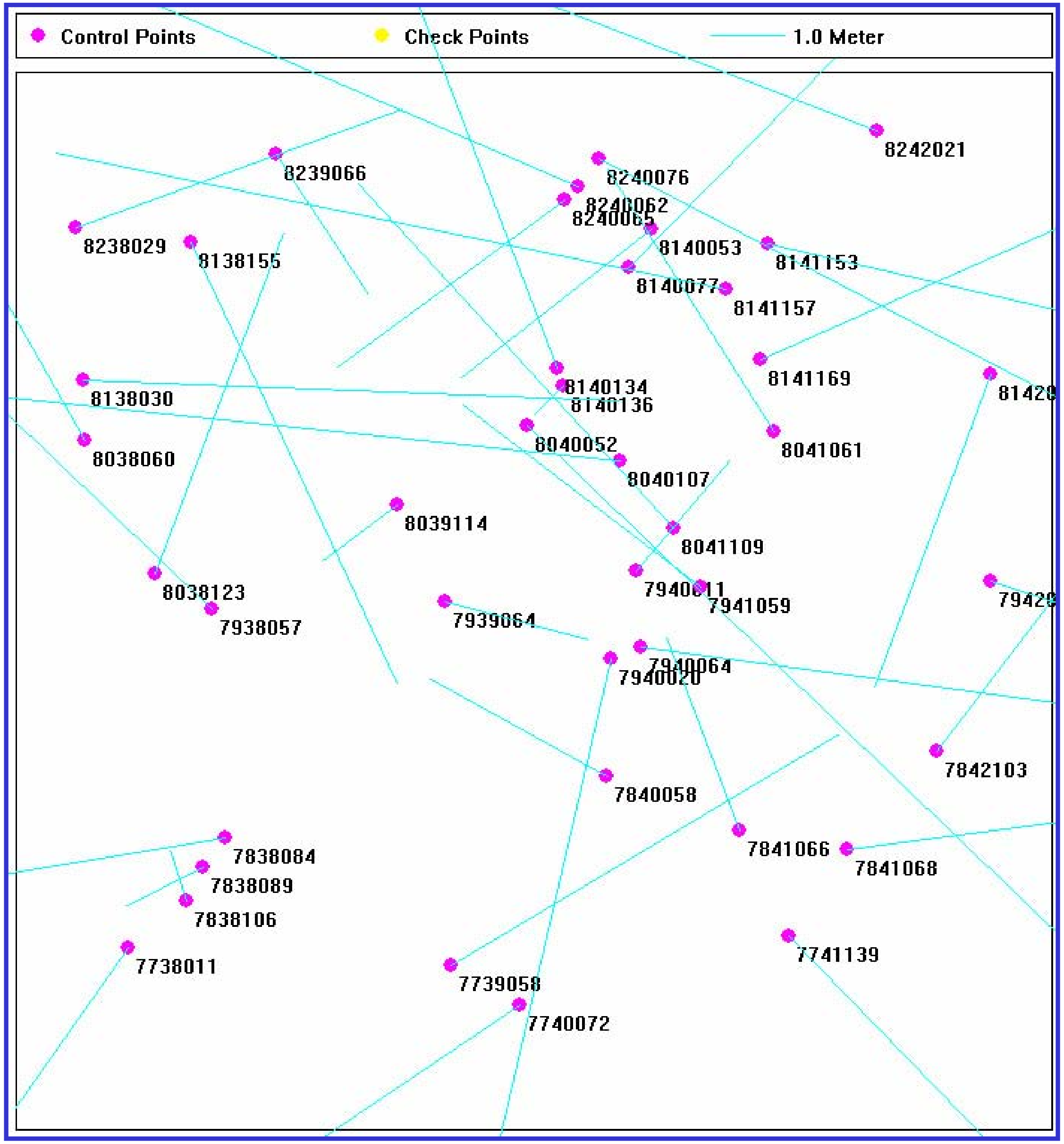
SPOT5-HRS, Bavaria, Germany



RPC + 2 Translates

GCPs(CPs)	RMSE-X	RMSE-Y	RMSE-Z
0 (43)	23.11	25.17	75.76
1 (42)	4.69	4.38	2.26
4 (39)	4.68	4.35	2.25
43 (0)	4.63	3.66	2.20

SPOT5-HRS, Bavaria, Germany



RPC + 2 Translates

GCPs(CPs)	RMSE-X	RMSE-Y	RMSE-Z
0 (43)	23.11	25.17	75.76
1 (42)	4.69	4.38	2.26
4 (39)	4.68	4.35	2.25
43 (0)	4.63	3.66	2.20

Automatic DTM/DSM Generation (SPOT5-HRS, Bavaria, Germany)

Study area: Bavaria, Germany

+ Area: 120 × 60 Km^2

+ Height range: ca. 1600 m

SPOT HRS stereo pair

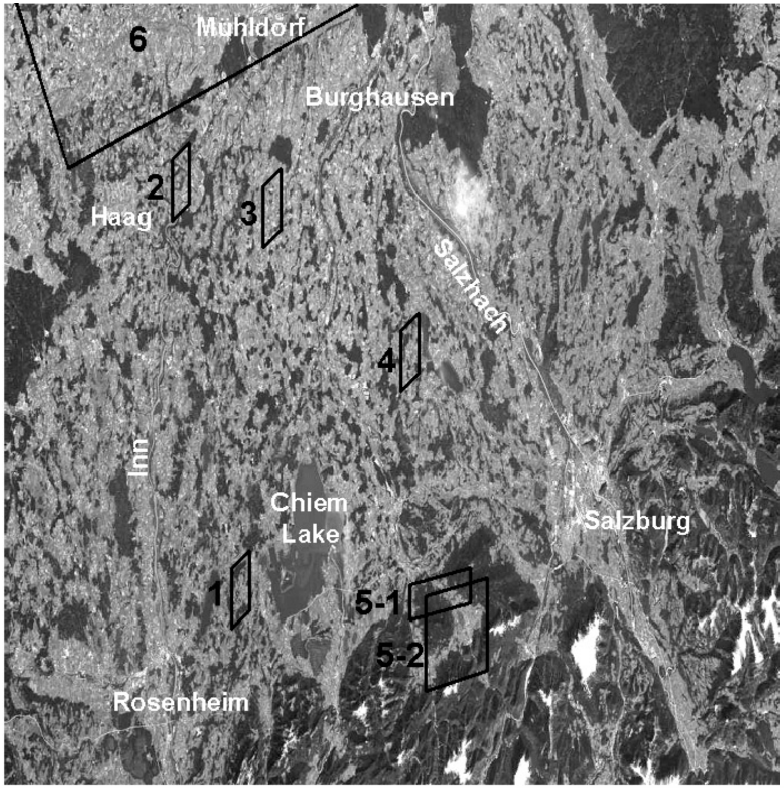
+ Acquisition time: 1st October, 2002

+ 5m / 10m res. In along-/cross-track

Reference data:

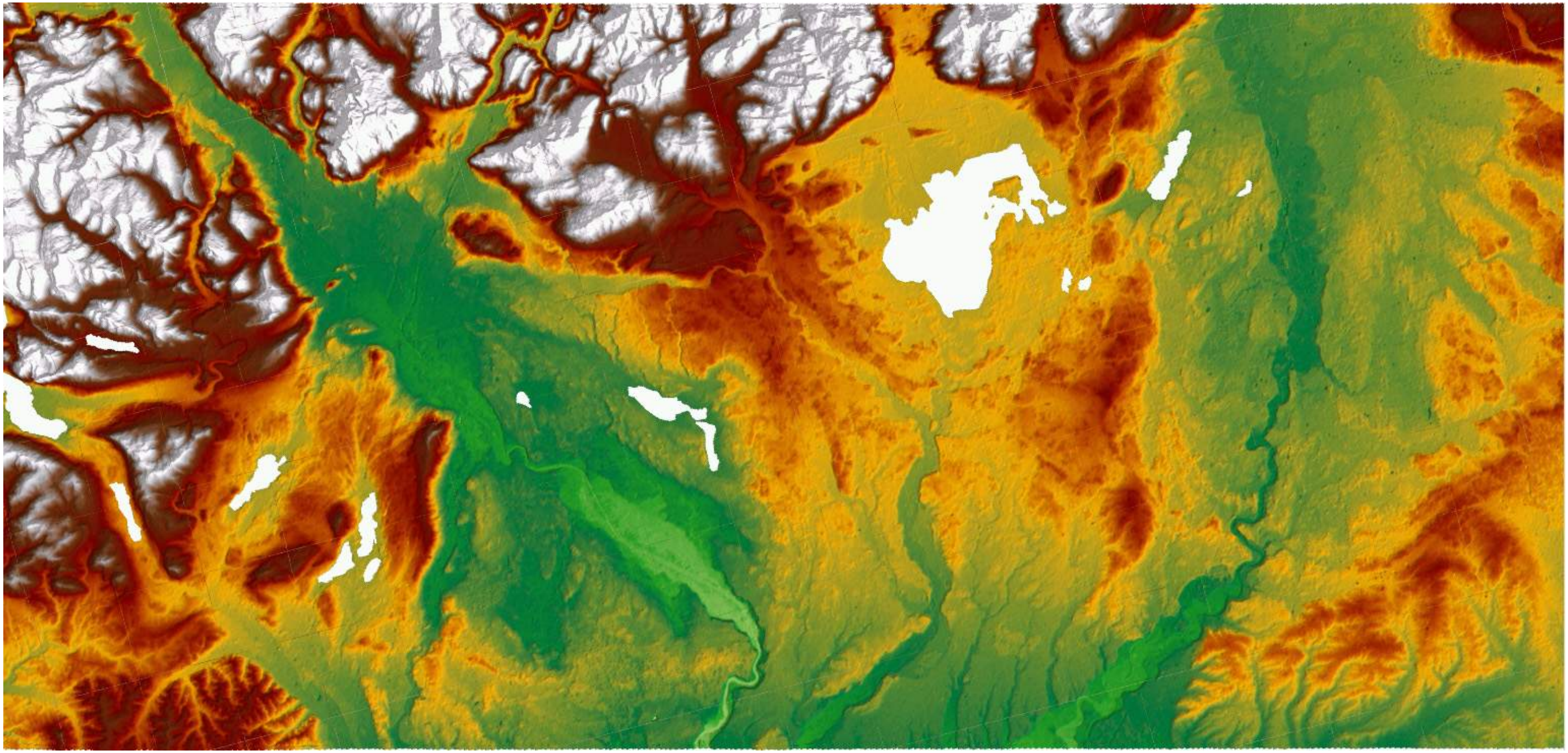
+ 81 GPS GCPs (only 41 used)

+ 6 reference DTMs



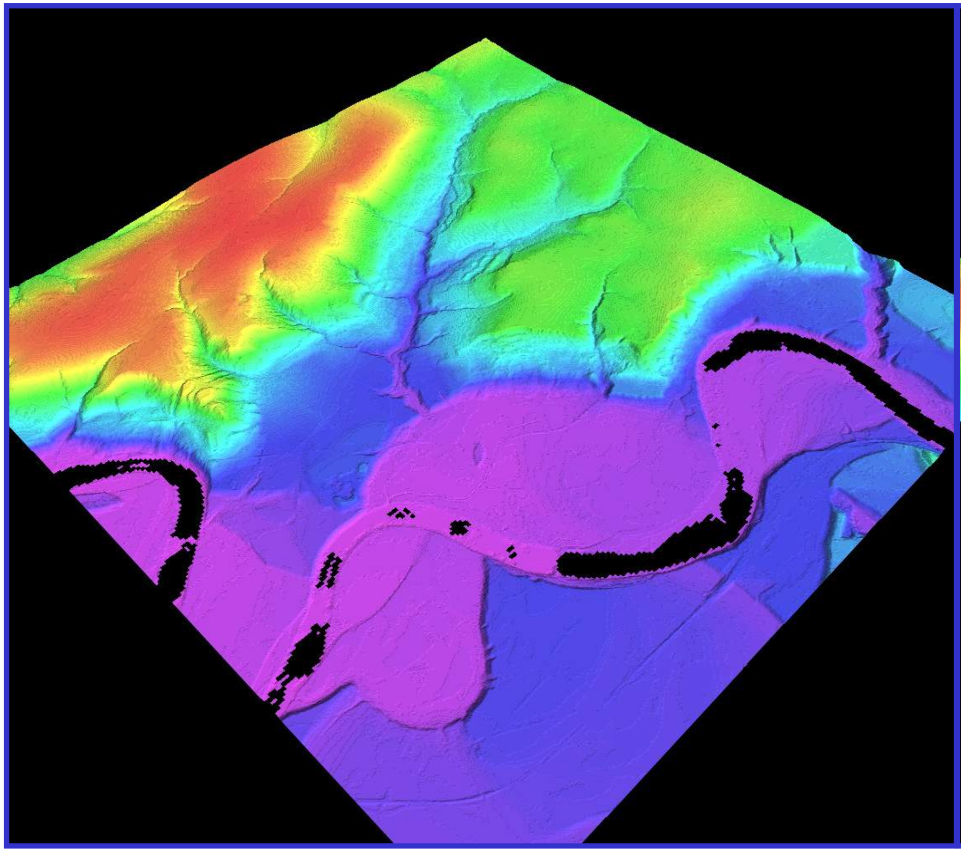
DTM Name	Location	DTM Spacing (m)	Source	DTM Size	Height Accuracy (m)
DTM-1	Prien	5 × 5	Laser Scanner	5km × 5km	0.5
DTM-2	Gars	5 × 5	Laser Scanner	5km × 5km	0.5
DTM-3	Peterskirchen	5 × 5	Laser Scanner	5km × 5km	0.5
DTM-4	Taching	5 × 5	Laser Scanner	5km × 5km	0.5
DTM-5-1	Inzell-North	25 × 25	Laser Scanner	10km × 1.3km	0.5
DTM-5-2	Inzell-Sourth	25 × 25	Contour lines	10km × 7.7km	5.0
DTM-6	Vilsbiburg	50 × 50	Photogrammetry	50km × 30km	2.0

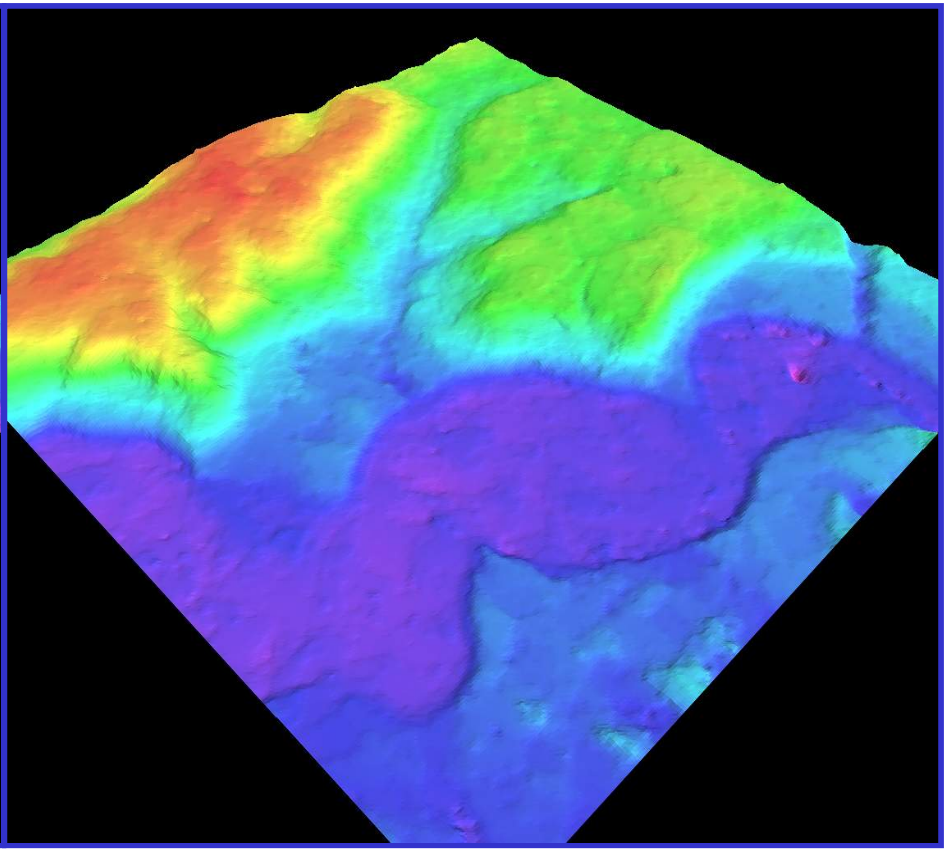
Automatic DTM/DSM Generation (SPOT5-HRS, Bavaria, Germany)



Raster DSM (25 m Spacing,120 × 60 km^2)

Automatic DTM/DSM Generation (SPOT5-HRS, Bavaria, Germany)

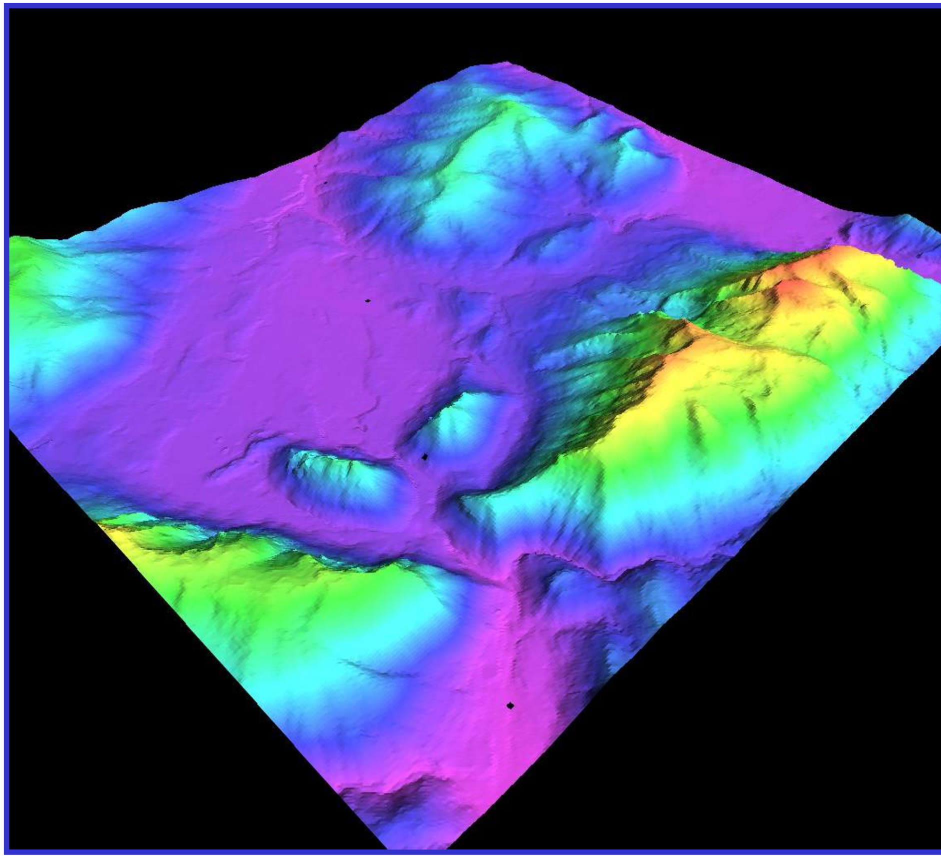




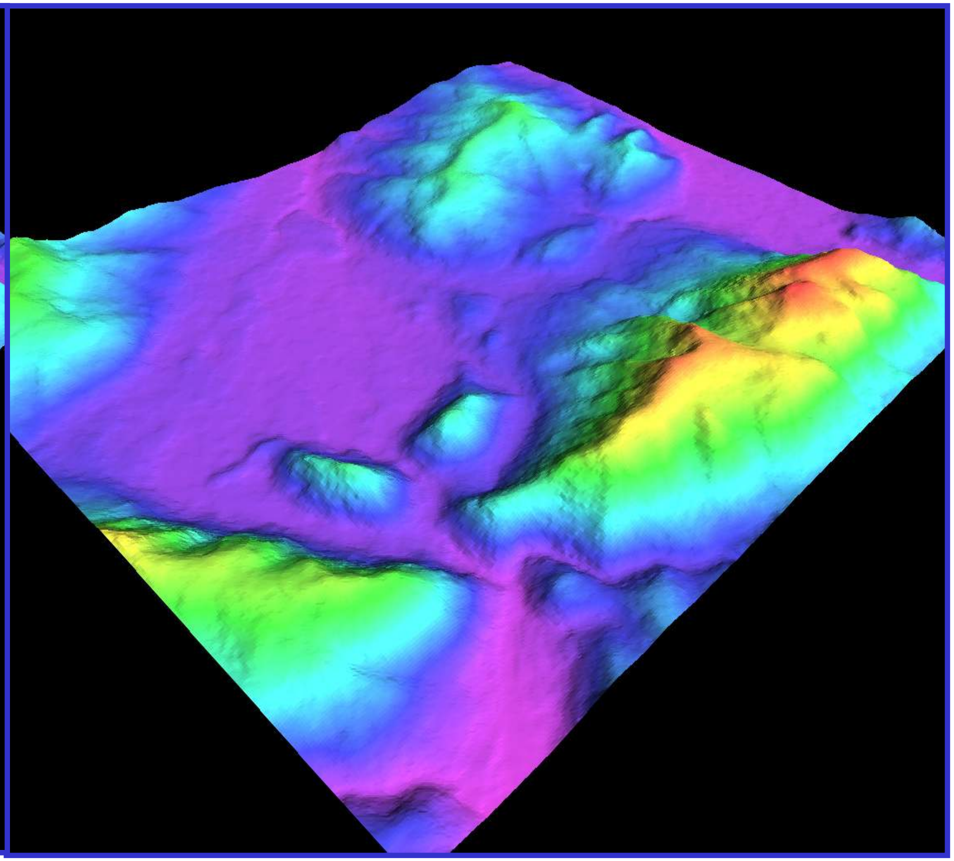
Reference DSM (5 m)

SPOT5 DSM (25 m)

Automatic DTM/DSM Generation (SPOT5-HRS, Bavaria, Germany)



Reference DSM (25 m)



SPOT5 DSM (25 m)

Automatic DTM/DSM Generation (SPOT5-HRS, Bavaria, Germany)

DSM Accuracy (All Reference Data)

Ref. DTM	Terrain Characteristic	No. of Points		Max. Diff.	Min. Diff.	Average (m)	RMSE (m)
		Matched	Reference				
DTM-1	Smooth, weakly inclined	35448	1000000	25.1	-32.9	-2.6	5.7
DTM-2	Smooth, weakly inclined	32932	1000000	29.1	-37.1	-1.2	5.0
DTM-3	Smooth, weakly inclined	33450	1000000	20.7	-17.2	-0.5	3.2
DTM-4	Smooth, weakly inclined	32067	1000000	13.6	-23.1	-2.5	4.7
DTM-5-1	Rough, strongly inclined	10327	21200	19.2	-33.5	-5.8	8.3
DTM-5-2	Rolling, strongly inclined	71795	139200	136.8	-89.3	-4.3	9.5
DTM-6	Rough, weakly inclined	130558	600000	26.8	-27.1	1.5	4.0

DSM Accuracy (Without Trees)

Ref. DTM	Terrain Characteristic	Max. Diff.	Min. Diff.	Average (m)	RMSE (m)
DTM-1	Smooth, weakly inclined	15.4	-23.7	-1.7	4.6
DTM-2	Smooth, weakly inclined	29.1	-31.7	0.2	3.6
DTM-3	Smooth, weakly inclined	20.7	-13.6	0.1	2.9
DTM-4	Smooth, weakly inclined	10.5	-18.4	-1.2	3.2
DTM-5-1	Rough, strongly inclined	19.1	-13.3	-1.7	4.9
DTM-5-2	Rolling, strongly inclined	49.8	-66.8	-1.3	6.7
DTM-6	Rough, weakly inclined	26.8	-25.9	2.1	4.4

IKONOS Images, Thun, Switzerland

Sub-pixel accuracy in planimetry; ca. pixel accuracy in height

Comparison of sensor models for the IKONOS stereo pair. CPs are check points.
M_RPC1: RPCs+2 translations; M_RPC2: RPCs+6 affine parameters; M_3DAFF: 3D affine transformation

Sensor Model	GCPs	CPs	x-RMSE [m]	y-RMSE [m]	z-RMSE [m]	max. Δx [m]	max. Δy [m]	max. Δz [m]
M_RPC1	22	-	0.49	0.57	0.93	1.02	0.97	2.08
M_RPC2	22	-	0.48	0.57	0.83	1.01	0.96	1.82
M_3DAFF	22	-	0.62	0.56	0.70	1.36	0.96	1.36
M_RPC1	18	4	0.50	0.57	0.93	1.04	0.96	1.94
M_RPC2	18	4	0.48	0.57	0.84	1.01	1.09	2.00
M_RPC1	12	10	0.50	0.57	0.93	1.13	0.92	2.10
M_RPC2	12	10	0.50	0.57	0.84	1.12	0.96	1.74
M_RPC1	5	17	0.50	0.58	0.93	1.02	0.96	2.00
M_RPC2	5	17	0.48	0.57	0.83	1.00	0.96	1.82

Comparison of sensor models and number of GCPs for the IKONOS triplet. CP are check points.

Sensor Model	GCPs	CPs	x-RMSE [m]	y-RMSE [m]	z-RMSE [m]	max. Δx [m]	max. Δy [m]	max. Δz [m]
M_RPC1	22	-	0.32	0.78	0.55	0.73	1.50	0.78
M_RPC2	22	-	0.32	0.78	0.55	0.95	1.53	0.78
M_3DAFF	22	-	0.35	0.41	0.67	0.82	0.91	0.80
M_RPC2	18	4	0.33	0.79	0.56	0.80	1.48	1.41
M_RPC2	12	10	0.32	0.82	0.60	0.73	1.64	1.04
M_RPC2	5	17	0.44	0.92	0.65	1.04	1.83	1.15

Comparison between M_RPC1 and M_RPC2 using all five images with different numbers of GCPs.

Sensor Model	GCPs	CPs	x-RMSE [m]	y-RMSE [m]	z-RMSE [m]	max. Δx [m]	max. Δy [m]	max. Δz [m]
M_RPC1	39	-	0.45	0.50	0.93	1.06	0.96	2.07
M_RPC2	39	-	0.40	0.49	0.79	0.92	0.86	1.82
M_RPC1	5	34	0.45	0.50	0.94	1.10	0.95	1.84
M_RPC2	5	34	0.42	0.67	1.07	1.18	1.41	2.25

IKONOS Images, Thun, Switzerland

Decreasing number of GCPs doesn't decreasing the accuracy significantly

Comparison of sensor models for the IKONOS stereo pair. CPs are check points.
M_RPC1: RPCs+2 translations; M_RPC2: RPCs+6 affine parameters; M_3DAFF: 3D affine transformation

Sensor Model	GCPs	CPs	x-RMSE [m]	y-RMSE [m]	z-RMSE [m]	max. Δx [m]	max. Δy [m]	max. Δz [m]
M_RPC1	22	-	0.49	0.57	0.93	1.02	0.97	2.08
M_RPC2	22	-	0.48	0.57	0.83	1.01	0.96	1.82
M_3DAFF	22	-	0.62	0.56	0.70	1.36	0.96	1.36
M_RPC1	18	4	0.50	0.57	0.93	1.04	0.96	1.94
M_RPC2	18	4	0.48	0.57	0.84	1.01	1.09	2.00
M_RPC1	12	10	0.50	0.57	0.93	1.13	0.92	2.10
M_RPC2	12	10	0.50	0.57	0.84	1.12	0.96	1.74
M_RPC1	5	17	0.50	0.58	0.93	1.02	0.96	2.00
M_RPC2	5	17	0.48	0.57	0.83	1.00	0.96	1.82

Comparison of sensor models and number of GCPs for the IKONOS triplet. CP are check points.

Sensor Model	GCPs	CPs	x-RMSE [m]	y-RMSE [m]	z-RMSE [m]	max. Δx [m]	max. Δy [m]	max. Δz [m]
M_RPC1	22	-	0.32	0.78	0.55	0.73	1.50	0.78
M_RPC2	22	-	0.32	0.78	0.55	0.95	1.53	0.78
M_3DAFF	22	-	0.35	0.41	0.67	0.82	0.91	0.80
M_RPC2	18	4	0.33	0.79	0.56	0.80	1.48	1.41
M_RPC2	12	10	0.32	0.82	0.60	0.73	1.64	1.04
M_RPC2	5	17	0.44	0.92	0.65	1.04	1.83	1.15

Comparison between M_RPC1 and M_RPC2 using all five images with different numbers of GCPs.

Sensor Model	GCPs	CPs	x-RMSE [m]	y-RMSE [m]	z-RMSE [m]	max. Δx [m]	max. Δy [m]	max. Δz [m]
M_RPC1	39	-	0.45	0.50	0.93	1.06	0.96	2.07
M_RPC2	39	-	0.40	0.49	0.79	0.92	0.86	1.82
M_RPC1	5	34	0.45	0.50	0.94	1.10	0.95	1.84
M_RPC2	5	34	0.42	0.67	1.07	1.18	1.41	2.25

IKONOS Images, Thun, Switzerland

Even M_3DAFF could achieve similar results (for IKONOS imagery)

Comparison of sensor models for the IKONOS stereo pair. CPs are check points.
M_RPC1: RPCs+2 translations; M_RPC2: RPCs+6 affine parameters; M_3DAFF: 3D affine transformation

Sensor Model	GCPs	CPs	x-RMSE [m]	y-RMSE [m]	z-RMSE [m]	max. Δx [m]	max. Δy [m]	max. Δz [m]
M_RPC1	22	-	0.49	0.57	0.93	1.02	0.97	2.08
M_RPC2	22	-	0.48	0.57	0.83	1.01	0.96	1.82
M_3DAFF	22	-	0.62	0.56	0.70	1.36	0.96	1.36
M_RPC1	18	4	0.50	0.57	0.93	1.04	0.96	1.94
M_RPC2	18	4	0.48	0.57	0.84	1.01	1.09	2.00
M_RPC1	12	10	0.50	0.57	0.93	1.13	0.92	2.10
M_RPC2	12	10	0.50	0.57	0.84	1.12	0.96	1.74
M_RPC1	5	17	0.50	0.58	0.93	1.02	0.96	2.00
M_RPC2	5	17	0.48	0.57	0.83	1.00	0.96	1.82

Comparison of sensor models and number of GCPs for the IKONOS triplet. CP are check points.

Sensor Model	GCPs	CPs	x-RMSE [m]	y-RMSE [m]	z-RMSE [m]	max. Δx [m]	max. Δy [m]	max. Δz [m]
M_RPC1	22	-	0.32	0.78	0.55	0.73	1.50	0.78
M_RPC2	22	-	0.32	0.78	0.55	0.95	1.53	0.78
M_3DAFF	22	-	0.35	0.41	0.67	0.82	0.91	0.80
M_RPC2	18	4	0.33	0.79	0.56	0.80	1.48	1.41
M_RPC2	12	10	0.32	0.82	0.60	0.73	1.64	1.04
M_RPC2	5	17	0.44	0.92	0.65	1.04	1.83	1.15

Comparison between M_RPC1 and M_RPC2 using all five images with different numbers of GCPs.

Sensor Model	GCPs	CPs	x-RMSE [m]	y-RMSE [m]	z-RMSE [m]	max. Δx [m]	max. Δy [m]	max. Δz [m]
M_RPC1	39	-	0.45	0.50	0.93	1.06	0.96	2.07
M_RPC2	39	-	0.40	0.49	0.79	0.92	0.86	1.82
M_RPC1	5	34	0.45	0.50	0.94	1.10	0.95	1.84
M_RPC2	5	34	0.42	0.67	1.07	1.18	1.41	2.25

Automatic DTM/DSM Generation (IKONOS, Thun, Switzerland)

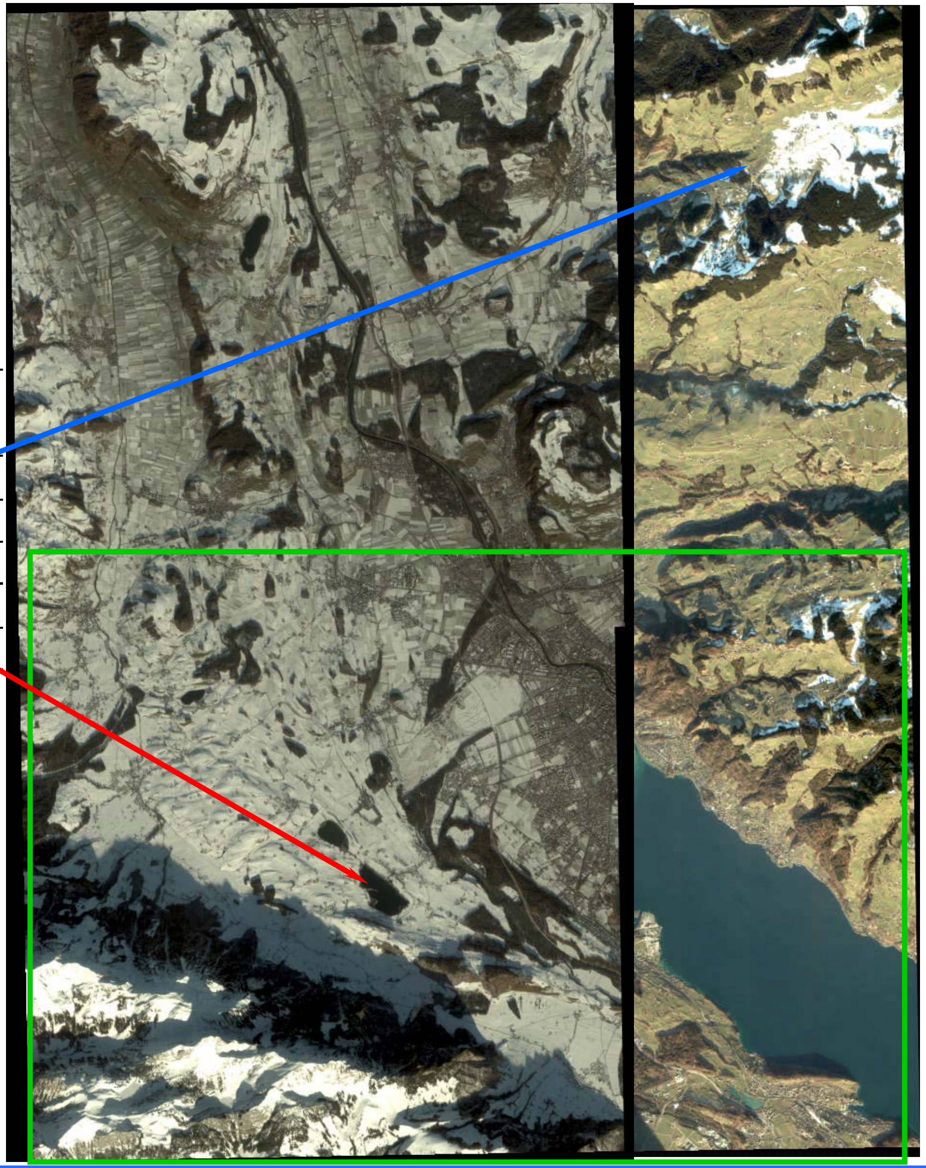
Study area: town of Thun, Switzerland

+ Area: 17 × 20 Km^2

+ Height Range: 1600 m

IKONOS Geo Product

IKONOS Image	Acquisition Date	Scanning mode	Sensor-Azimuth [°]	Sensor-Elevation [°]
Thun_49_000	2003-Dec-11	Reverse	140.35	62.78
Thun_49_100	2003-Dec-11	Reverse	66.41	63.56
Thun_51_000	2003-Dec-25	Reverse	180.39	62.95
Thun_51_100	2003-Dec-25	Reverse	72.206	82.15
Thun_54_000	2003-Dec-25	Forward	128.17	82.62



Reference

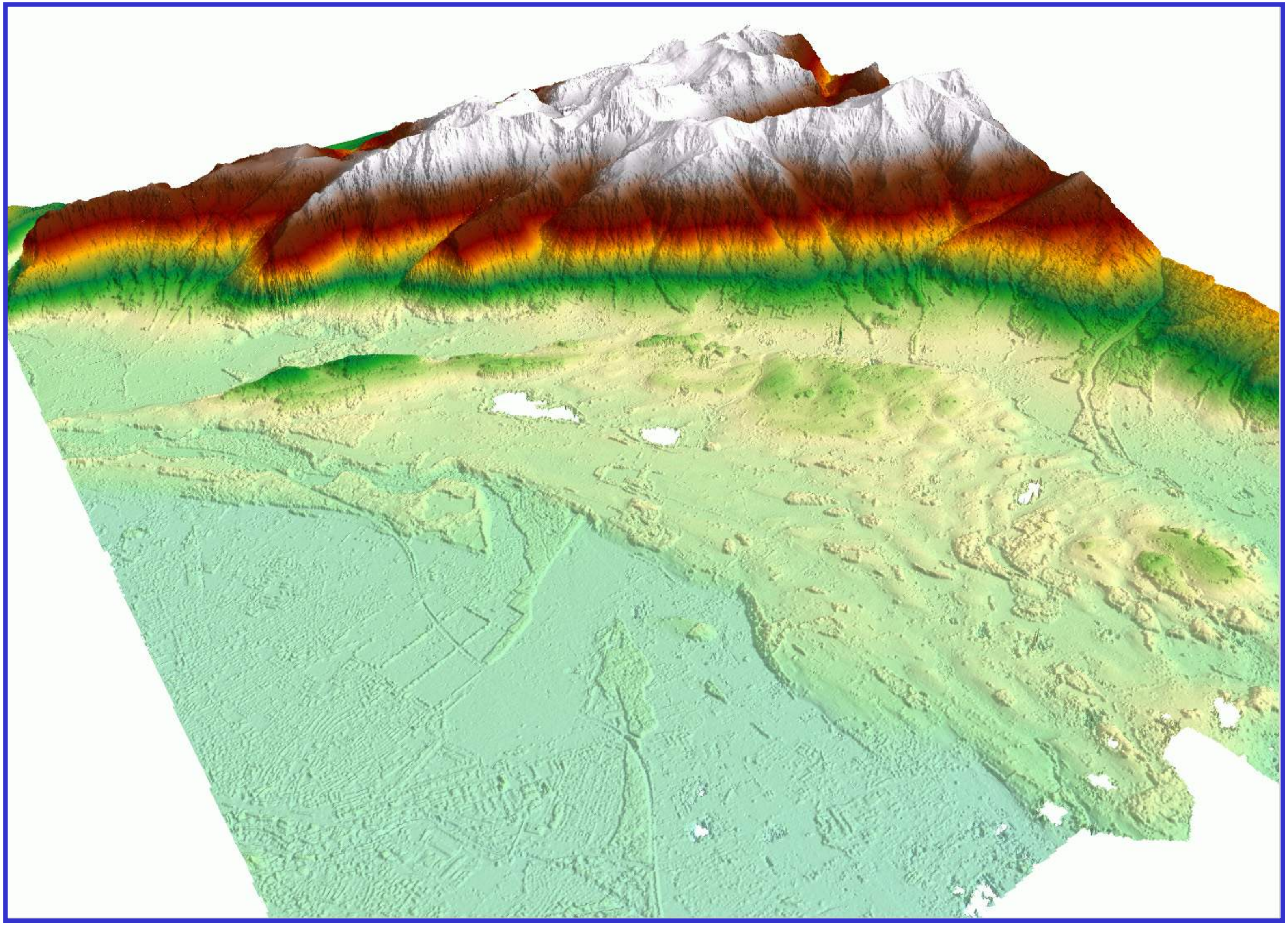
+ 2m spacing LIDAR DSM as reference

accuracy: 0.5 m (1σ) for open areas;

1.5 m for vegetation & build-up areas

+ 50 GPS GCPs (only 39 used)

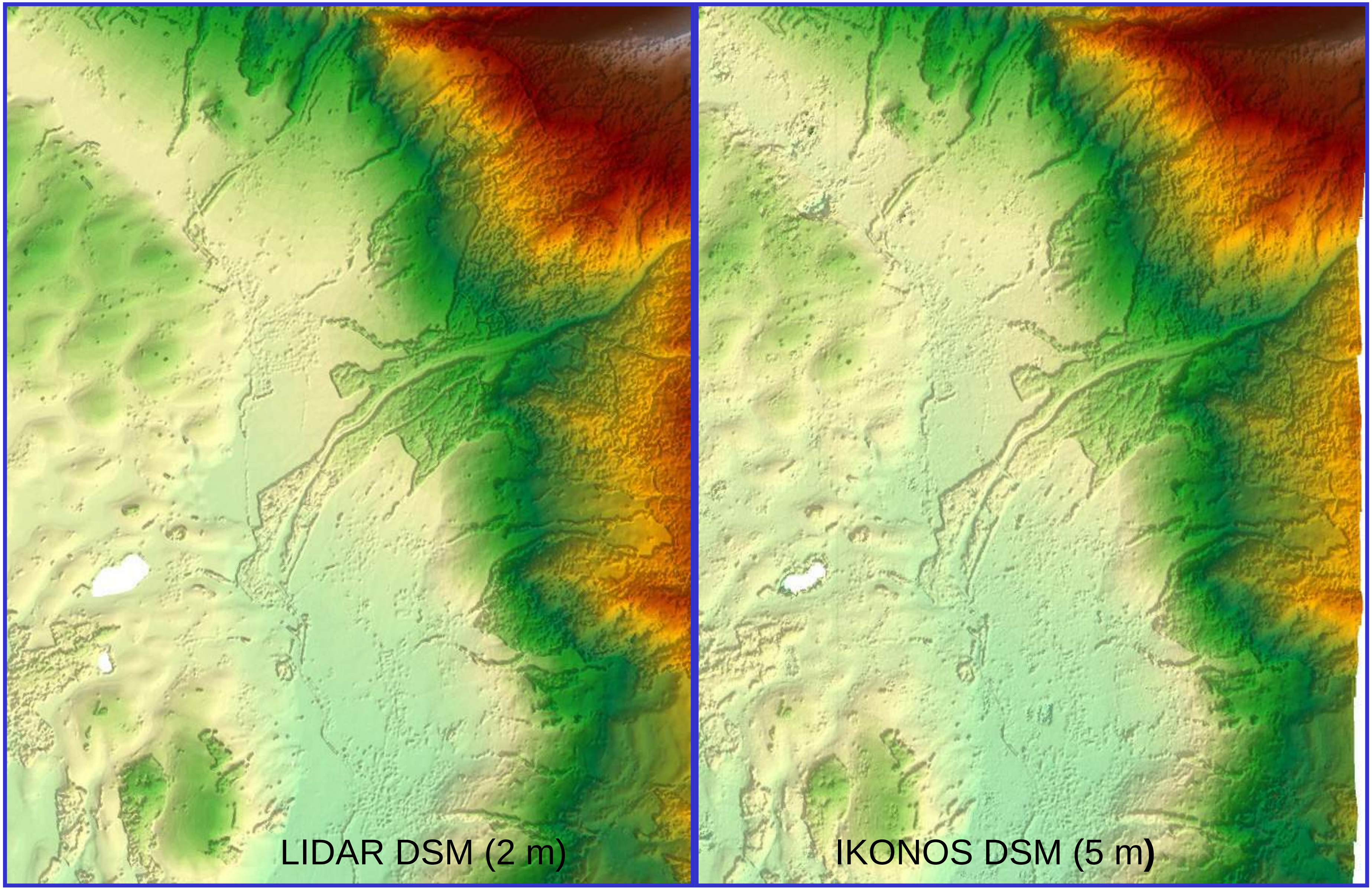
Automatic DTM/DSM Generation (IKONOS, Thun, Switzerland)



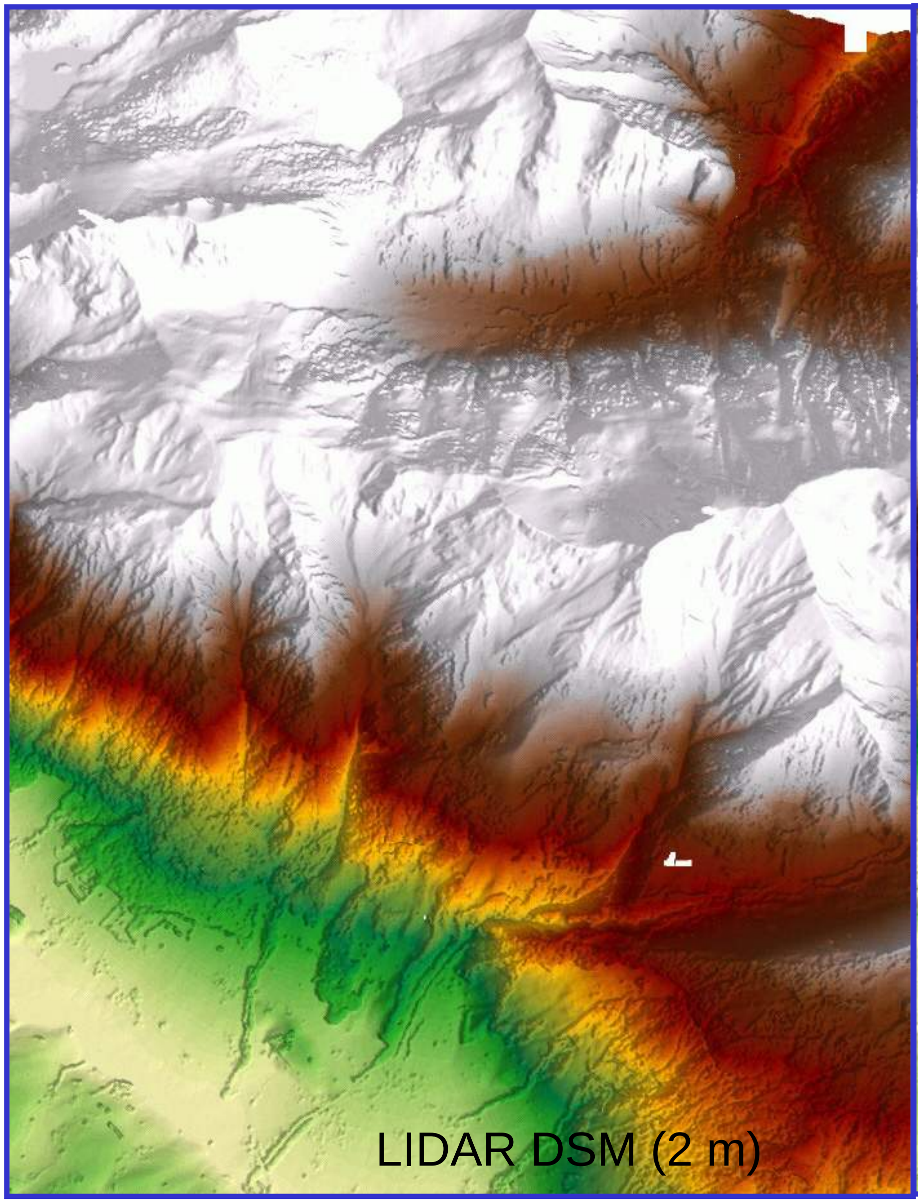
Raster DSM (5 m Spacing) Generated from IKONOS Images

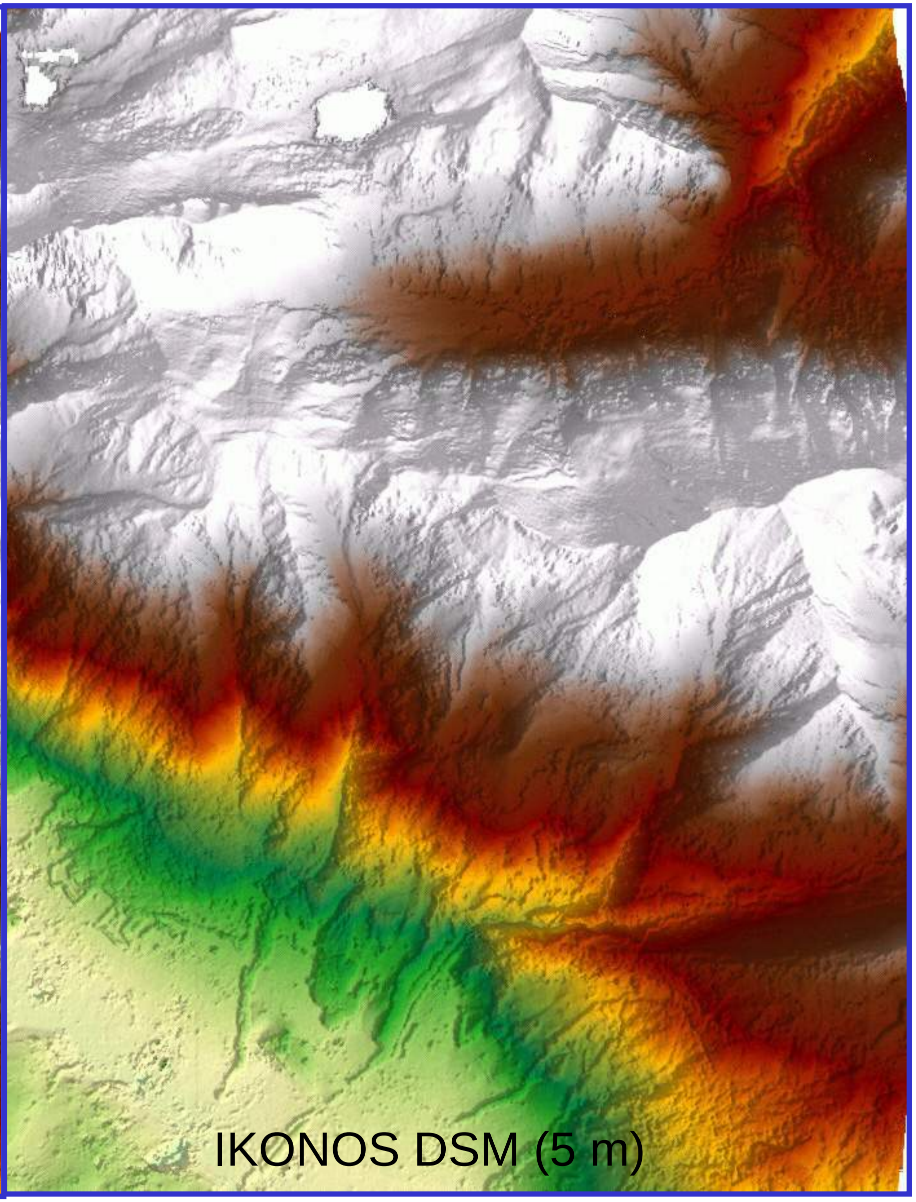
Automatic DTM/DSM Generation (IKONOS, Thun, Switzerland)

Automatic DTM/DSM Generation (IKONOS, Thun, Switzerland)



Automatic DTM/DSM Generation (IKONOS, Thun, Switzerland)





Automatic DTM/DSM Generation (IKONOS, Thun, Switzerland)

Z_diff = LIDAR_DSM_Z - Interpolation(IKONOS_DSM)

DSM accuracy evaluation results (triplet part of test area).
O-Open areas; C-City areas; T-Tree areas; A-Alpine areas.

Area	No. of compared points	Mean (m)	RMSE (m)	< 2.0 m	2.0-5.0 m	> 5.0 m
O+C+T+A	29,210,494	-1.21	4.80	60.7%	16.8%	21.3%
O+C+A	17,610,588	-1.11	2.91	77.0%	13.9%	10.1%
O+A	14,891,390	-1.24	2.77	79.8%	12.2%	8.0%
O	11,795,795	-1.00	1.28	90.3%	8.5%	1.2%

DSM accuracy evaluation results (stereo part of test area).

Area	No. of compared points	Mean (m)	RMSE (m)	< 2.0 m	2.0-5.0 m	> 5.0 m
O+C+T	20,336,024	0.45	4.78	57.7%	21.3%	20.9%
O+C	13,496,226	-0.33	3.38	68.7%	20.8%	10.3%
O	3,969,734	-0.97	1.54	83.0%	15.0%	2.0%

Z_diff = Matched_POINT_Z - Interpolation(LIDAR_DSM)

(dense LIDAR points --> Less surface modeling errors)

+ Point number: ca. 14,327,000
+ RMSE: 3.30 m
+ Mean: -0.32 m

Semi-automated Feature Extraction with SAT-PP

- Currently available for some kind of objects, such as points, lines and polygons

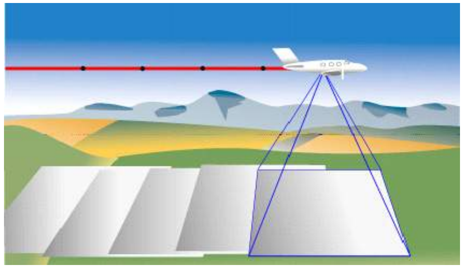
- The user only needs to measure, for example, the outlines of buildings in one image. The correspondences of building outlines in other images are computed automatically.

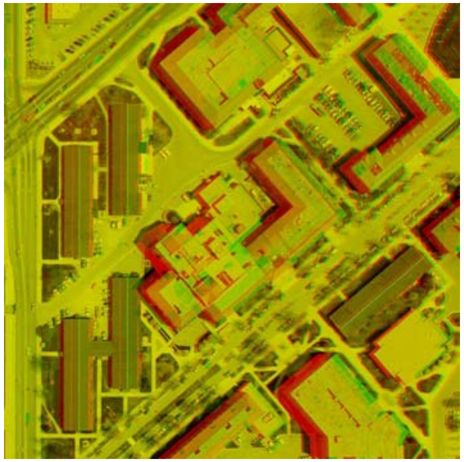
- User intervention is possible for editing the polygon/line nodes when mismatching occurs

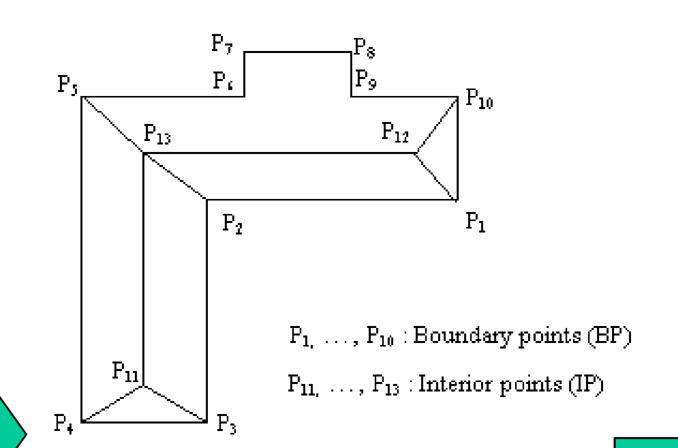
An extracted building from an IKONOS stereopair. The left building is measured manually and the right one is matched automatically.

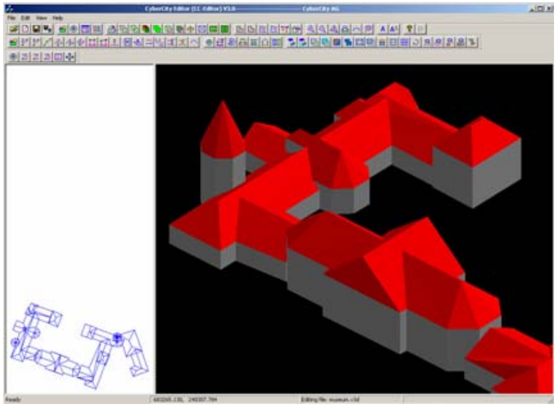
CyberCity Modeler approach,

from stereo images and laser data



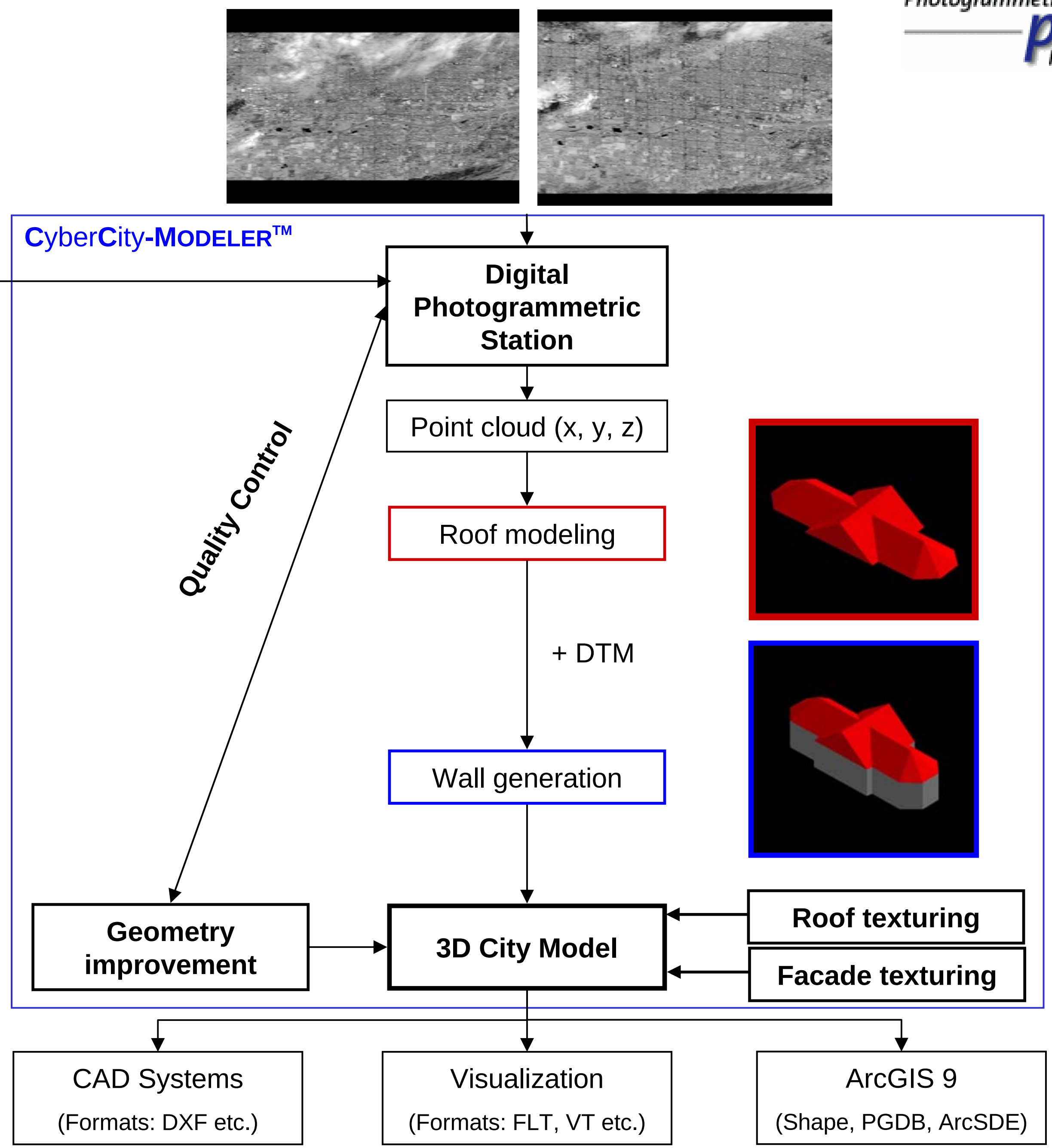






Point Cloud Coding System

- Independence regarding used DPS
- Reduction of manual labour

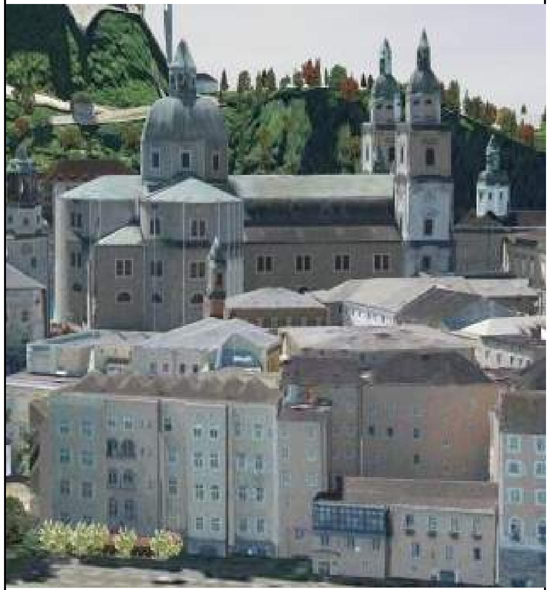


TEXTURING

Generic Texturing

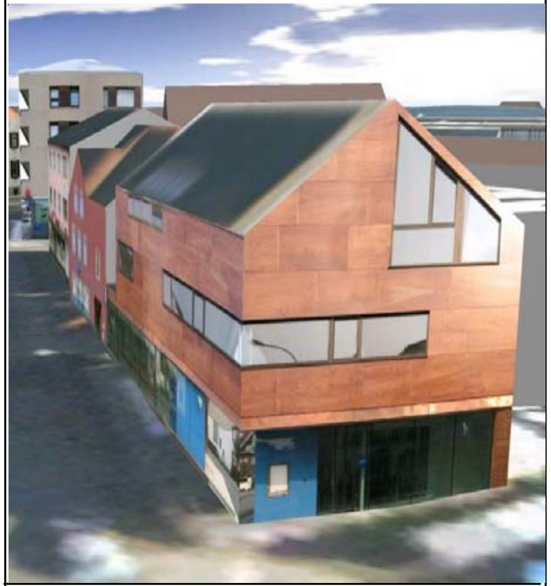
- Texture library
- Not realistic
- Regional texture types
- Automatic

Automatic Texturing



- (Oblique-) Aerial Imagery
- Realistic
- Automatic

Terrestrial Texturing



- Digital Photographs
- Realistic / High resolution
- Manually applied

3D Object Extraction From IKONOS Imagery

Input & Data Pre-processing

IKONOS Melbourne Stereopair

7x7 km area

elevation range of less than 100 m

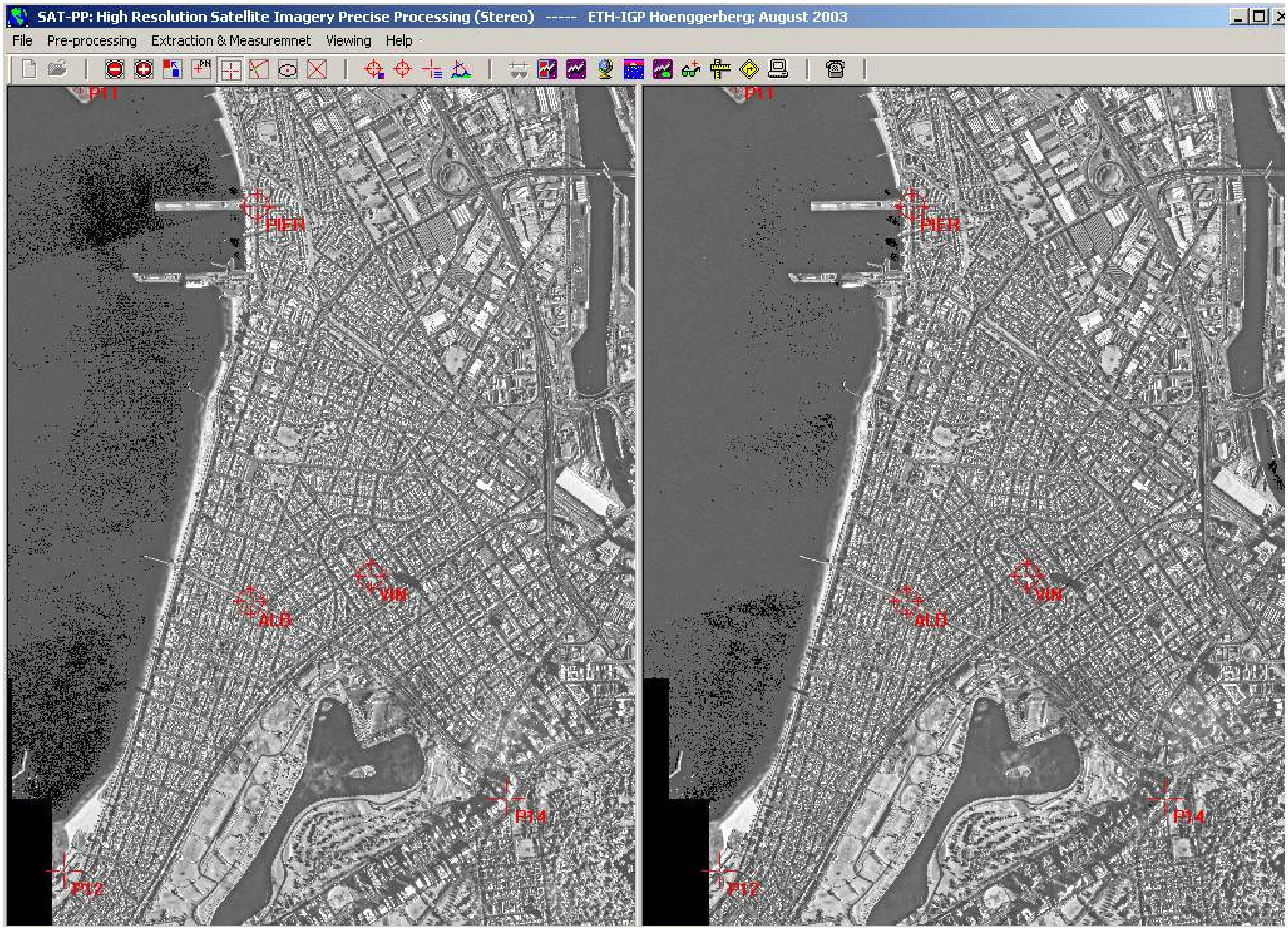
32 GPS-surveyed ground measured semi-automatically by ellipse-fitting method

	Left stereo	Right stereo
Date, time (local)	16/7/2000, 09:53	16/7/2000, 09:53
Sensor azimuth (°)	136.7	71.9
Sensor elevation (°)	61.4	60.7
Sun azimuth (°)	38.2	38.3
Sun elevation (°)	21.1	21.0

orientation was based on the supplied RPCs parameters (from Space Imaging) plus additional 6 affine transformation parameters in image space.

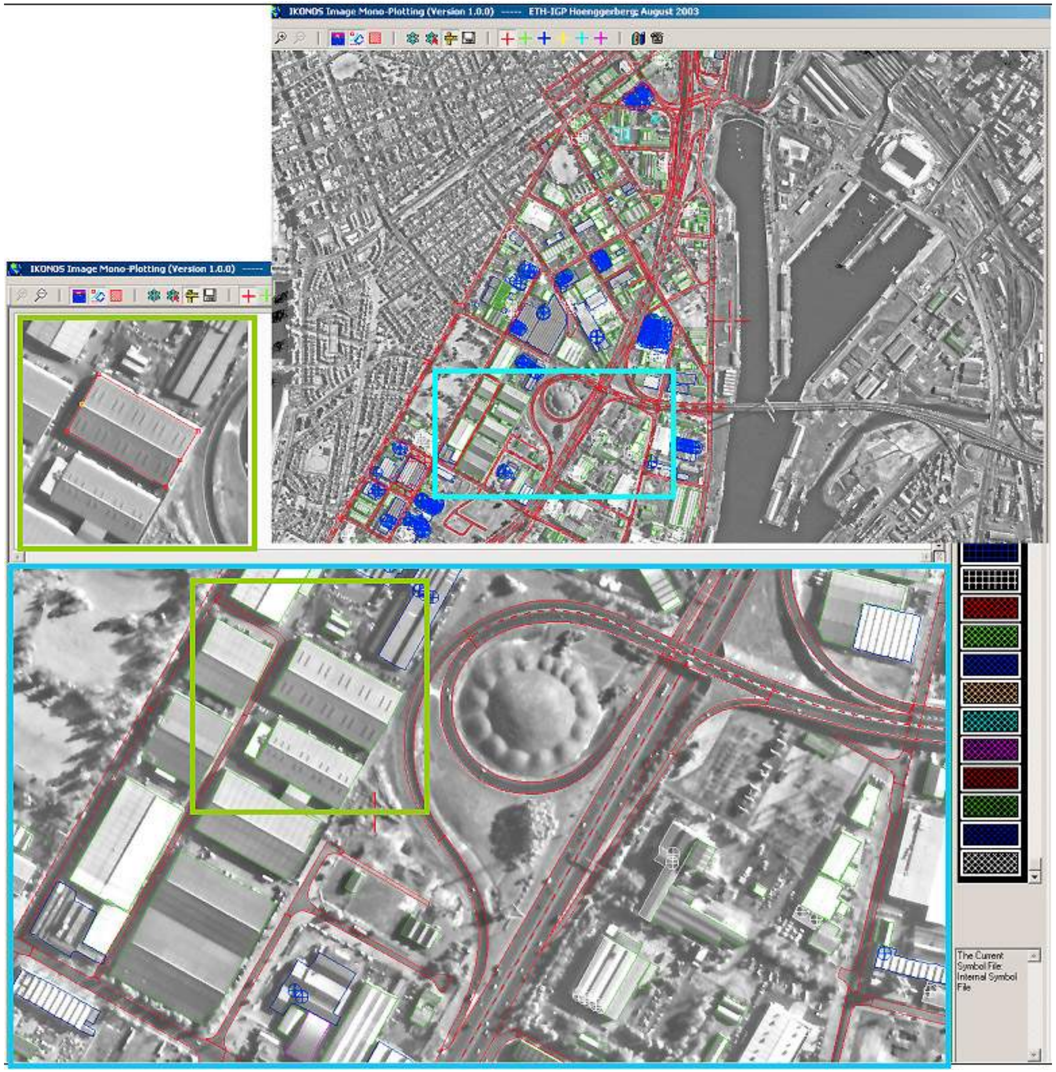
the RMSEs of orientation are 0.4 meters in planimetry and 0.9 meters in height.

3D Object Extraction From IKONOS Imagery



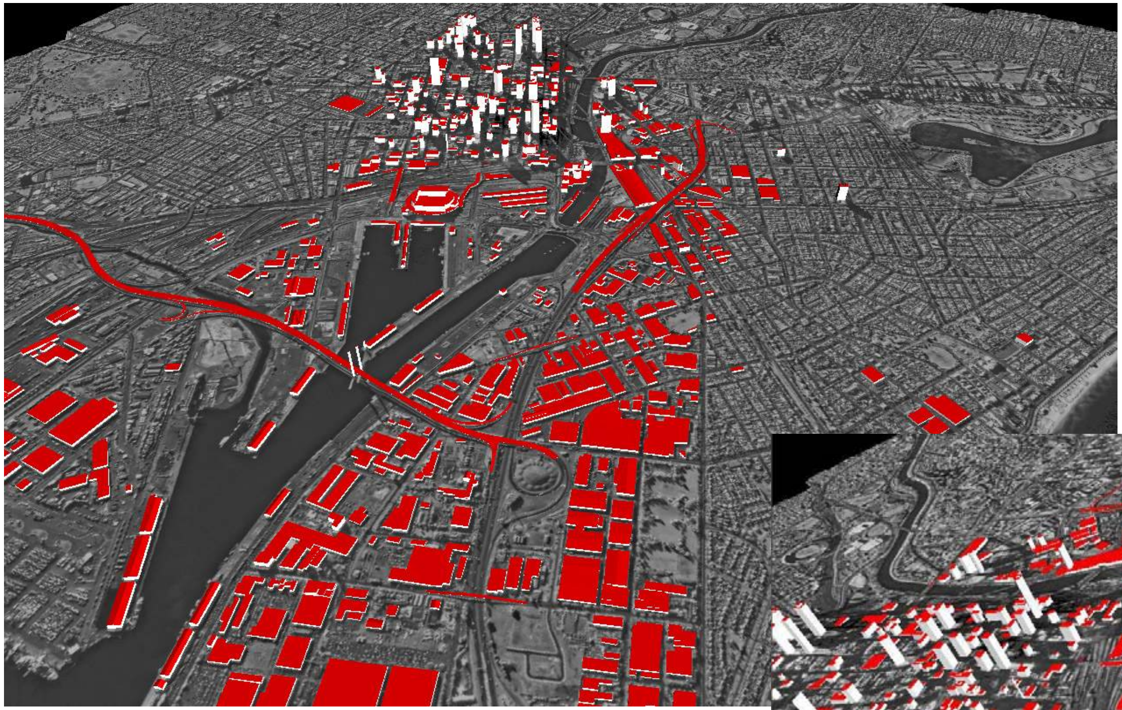
3D Object Extraction From IKONOS Imagery

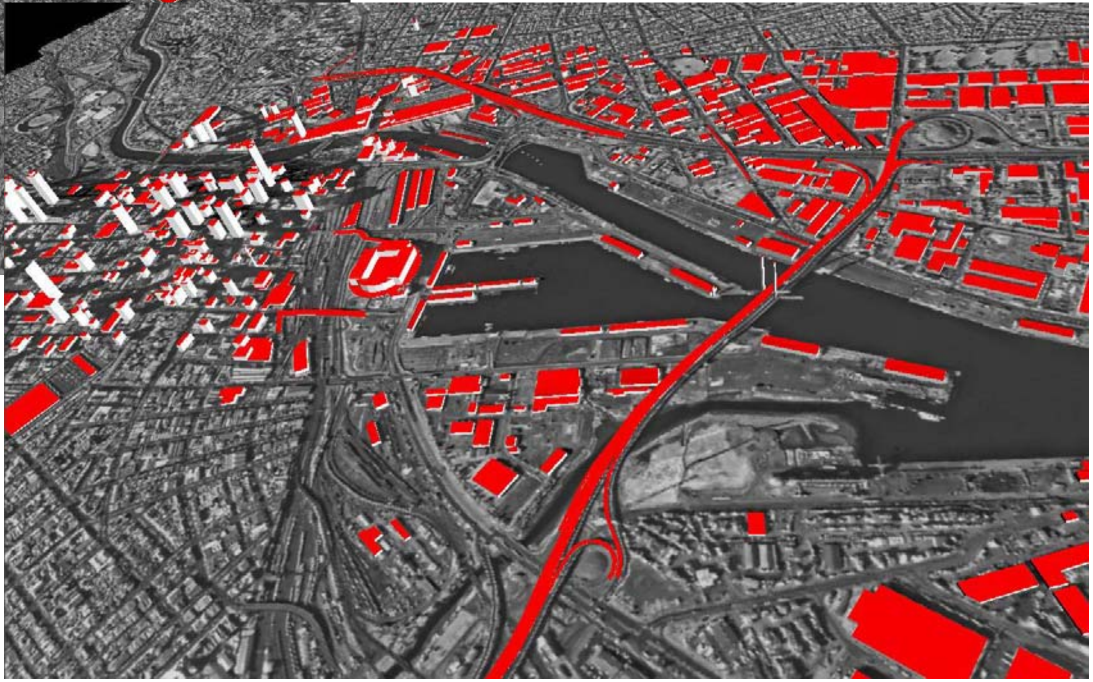
Measurement area overview



3D Object Extraction From IKONOS Imagery

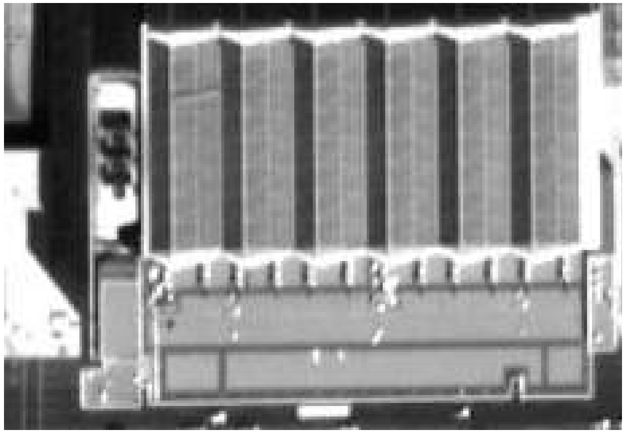
Generated 3D city model



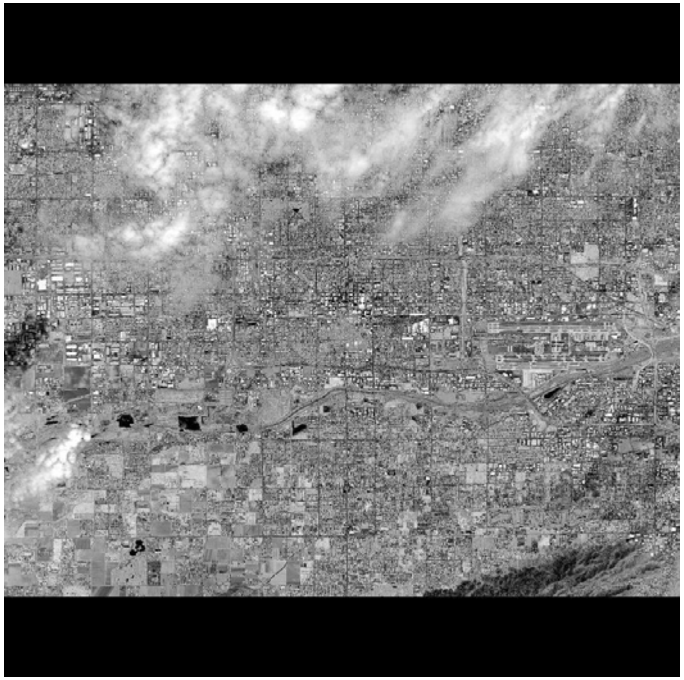


3D City Modeling from Quickbird

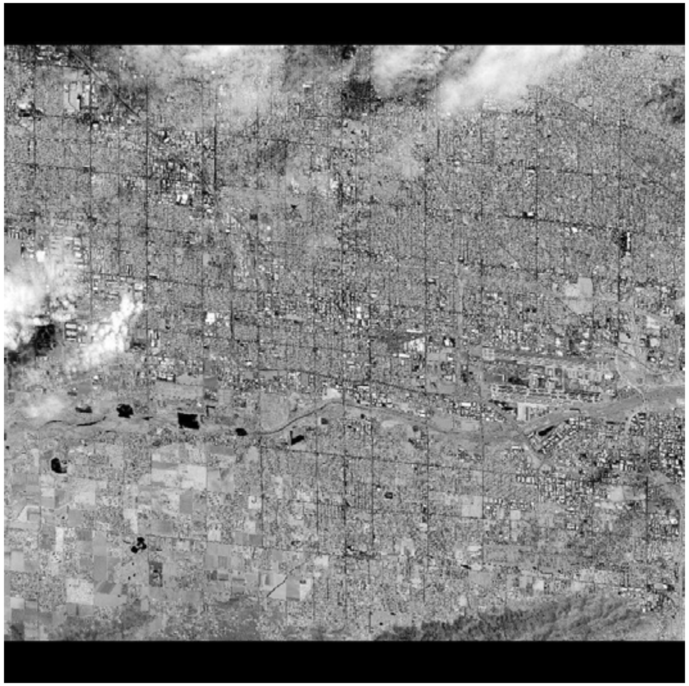
- Quickbird stereo images over Phoenix, USA
  - Acquired on 9 April 2004
  - Along track stereo images
  - GSD: 75cm (mean)
  - Viewing angles: 29º, - 27º



- Detail in Quickbird images



forward



backward

3D City Modeling from Quickbird

Facade textures from library

3D City Modeling from Quickbird

3D City Modeling from Quickbird

Conclusions

SAT-PP: sophisticated image pre-processing algorithms, a set of sensor models, an image matching approach for DSM generation and feature extraction from HRSI.

Sensor modeling and block adjustment:

Basically three types of sensor-model orientation concepts at our disposal:

a) rigorous/physical sensor model

b) Rational Functional Model (RFM) with given RPCs

c) 2D affine model, possibly with added parameters

d) 3D affine and DLT models

Precise (sub-pixel) GCP / tie point collection (LSM) in semi-automatic model

Sub-pixel orientation accuracy can be achieved for all models

Conclusions

Automatic DSM/DTM generation:

Reproduces not only general features, but also detailed features of the terrain relief

Height accuracy of around 1 pixel in cooperative terrain

- RMSE values of 1.3-1.5 m (1.0-2.0 pixels) for IKONOS
- RMSE values of 2.9-4.6 m (0.5-1.0 pixels) for SPOT5 HRS

3D city modeling:

The manual and semi-automatic feature extraction capability of SAT-PP provides a good basis also for 3D city modeling applications with CyberCity-Modeler™ (CCM).

The tools of SAT-PP allowed the stereo-measurements of points on the roofs in order to generate a 3D city model with CCM. Additional features of CCM allow roof and facade texturing.

The results show that building models with main roof structures can be successfully extracted by HRSI. As expected, with Quickbird more details are visible.

Acknowledgements

- Prof. Fraser, Department of Geomatics, University of Melbourne
- Mr. Volpe, Eurimage S.p.A.
- Dr. Poli and Dr. Wang, CyberCity AG
- Space Imaging, U.S.A.
- NPOC (National Point of Contact) - swisstopo, Bern