Institut für Photogrammetrie

ifp

DGPF project: Evaluation of digital photogrammetric airborne cameras

Overview and results

Michael Cramer (ifp), Norbert Haala (ifp) & Kirsten Wolff (ETH)

ISPRS Workshop
High Resolution Earth Imaging

Hannover, June 2-5, 09

Universität Stuttgart

Objectives

- Independent and objective evaluation of commercially available digital photogrammetric camera systems (focus on **airborne** and **large format**)
- Follow-up of already done national or international evaluation projects (like **EuroSDR network Digital Camera Calibration**)
- DGPF analysis of data will focus on following topics
  - **Team 1: Geometric accuracy and resolution**
  - **Team 2: Radiometric accuracy**
  - **Team 3: Automatic DSM genereation**
  - **Team 4: Stereoplotting**
- Different institutions are forming **processing teams** for each of the above topics
- Close **exchange within groups** already during processing phase

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Objectives

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- Follow-up of already done nationa… valuation projects (like **EuroSDR netw… bration**)
- DGPF analysis of … g topics
  - **Team 1: … solution**
  - **Te… y**
  - **… genereation**
  - **Te… ting**
- Different institutions are forming **processing teams** for each of the above topics
- Close **exchange within groups** already during processing phase

Major goal:
Evaluation of **sensor specific strengths and potential weaknesses**, **no direct comparison** between performance of different sensors!

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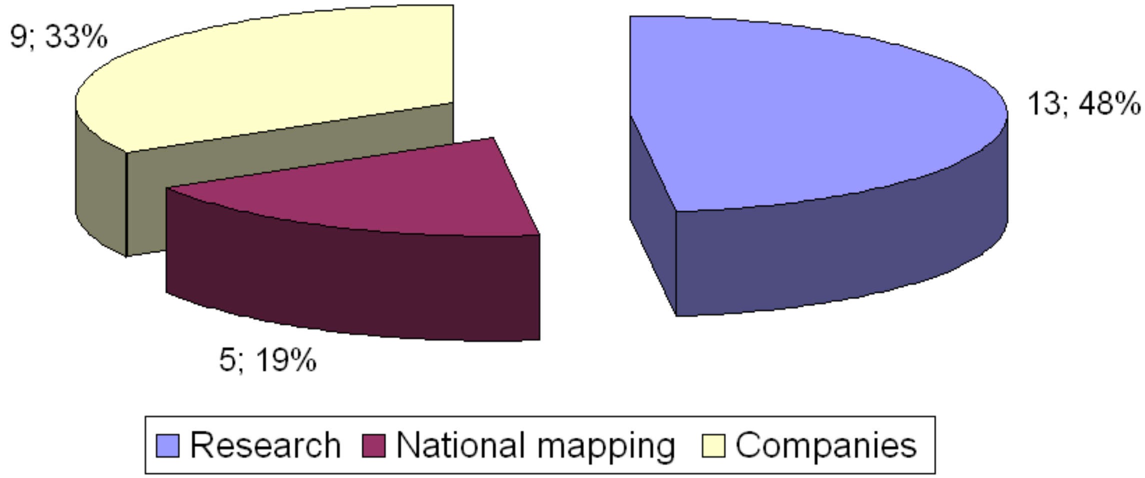
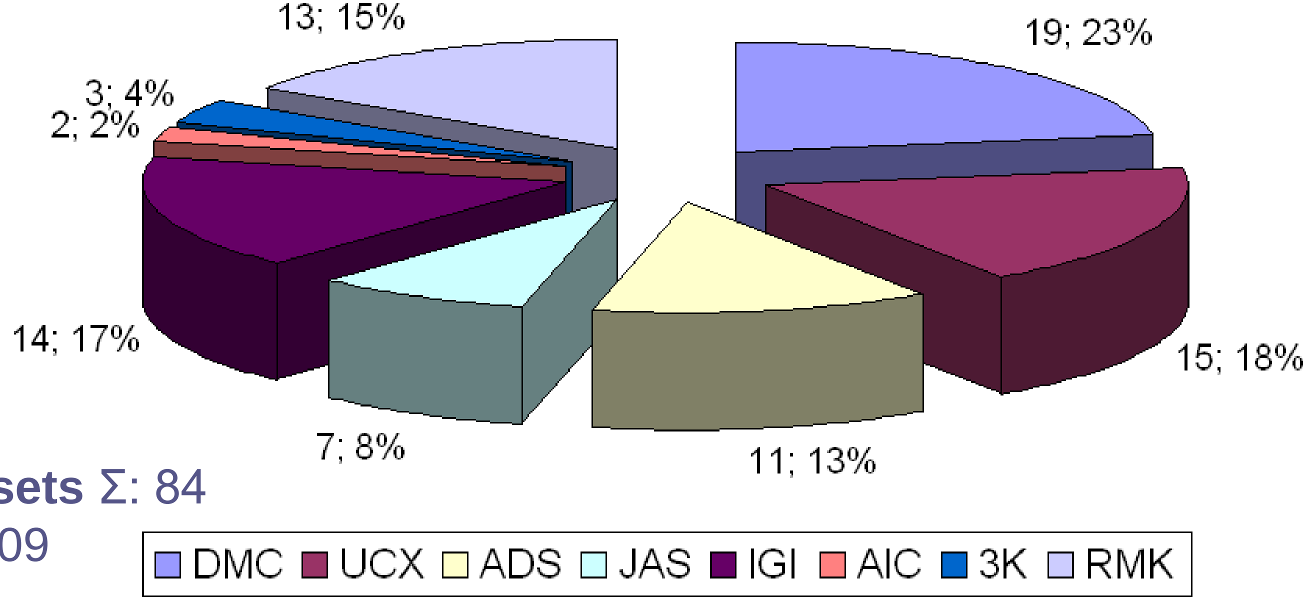
Data Evaluation

Participants and distributed data sets



Active Participants
Σ: 27



Distributed data sets Σ: 84
Status May 20, 2009

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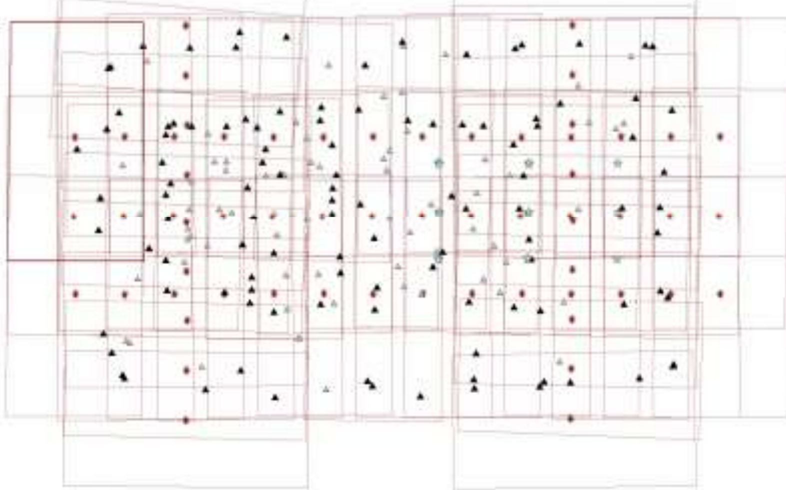
DGPF evaluation test

Vaihingen/Enz test flight data

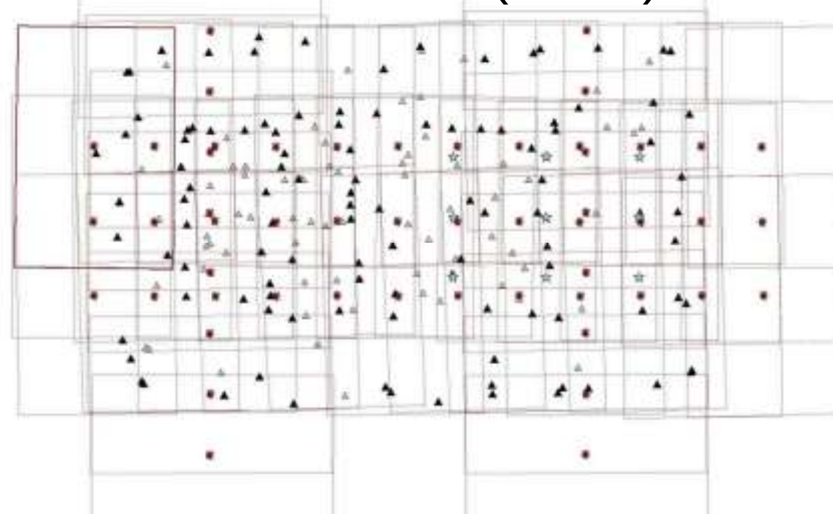
System	System provider	Flyer	Date of flight(s)
DMC	Intergraph/ZI	RWE Power	24.7.08 + 6.8.08
ADS 40, SH52	Leica Geosyst.	Leica Geosyst.	6.8.08
JAS-150	JenaOptronik	RWE Power	9.9.08
Ultracam-X	Vexcel Imaging	bsf Swissphoto	11.9.08
RMK-Top15	Zeiss	RWE Power	24.7.08 + 6.8.08
quattro DigiCAM, 4-Head	IGI	Geoplana	6.8.08
AIC-x1, 1-Head	Rolleimetric	Alpha Luftbild	11.9.08
AIC-x4, 4(3)-Head	Rolleimetric	Vulcan Air	19.9.08
DLR 3K-Camera	DLR Munich	DLR Munich	15.7.08
AISA+ hyper-spectral (with DMC parallel)	Specim/FH Anhalt	RWE Power	2.7.08
ROSIS hyper-spectral	DLR Munich	DLR Munich	15.7.08
ALS 50 LiDAR	Leica Geosyst.	Leica Geosyst.	21.8.08

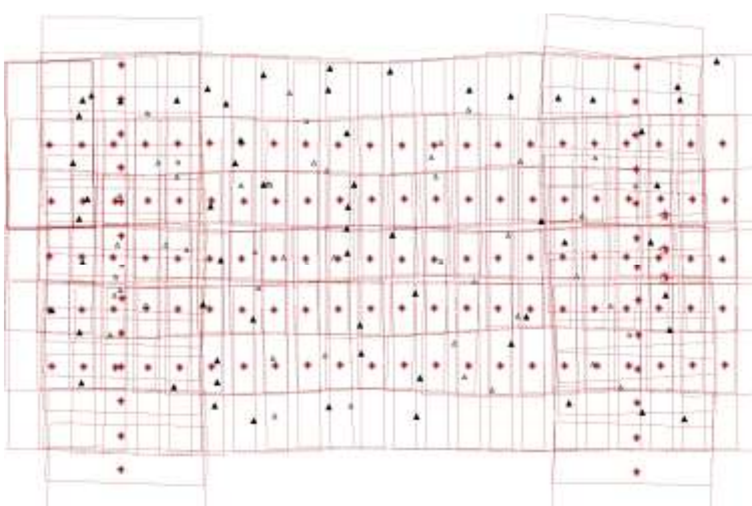
Block design
DMC & UCX GSD 20cm / GSD 8cm

DMC GSD 20cm (60/60)

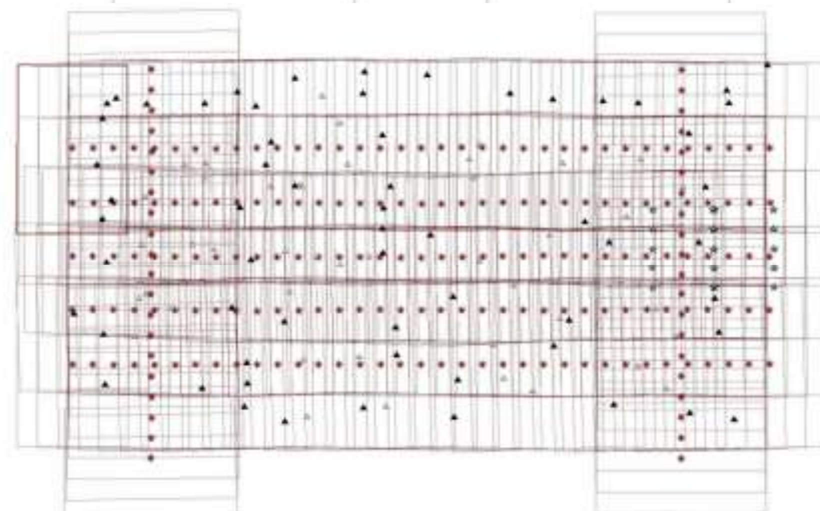


UCX GSD 20cm (60/60)





DMC GSD 8cm (60/63)

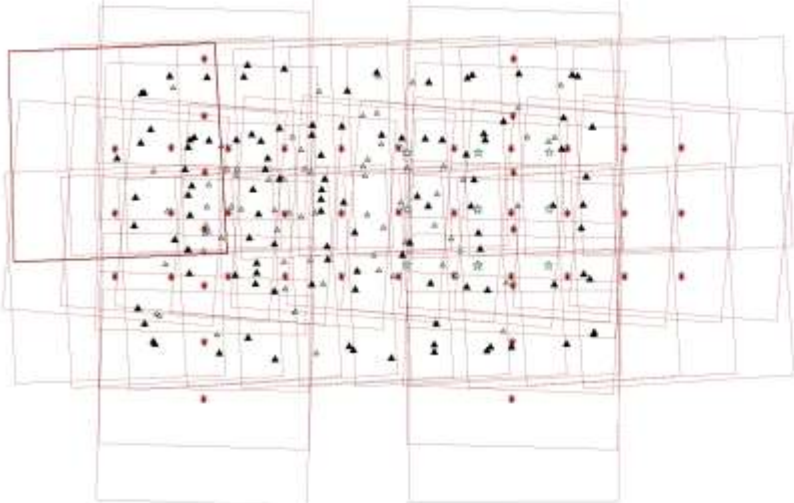


UCX GSD 8cm (75/70)

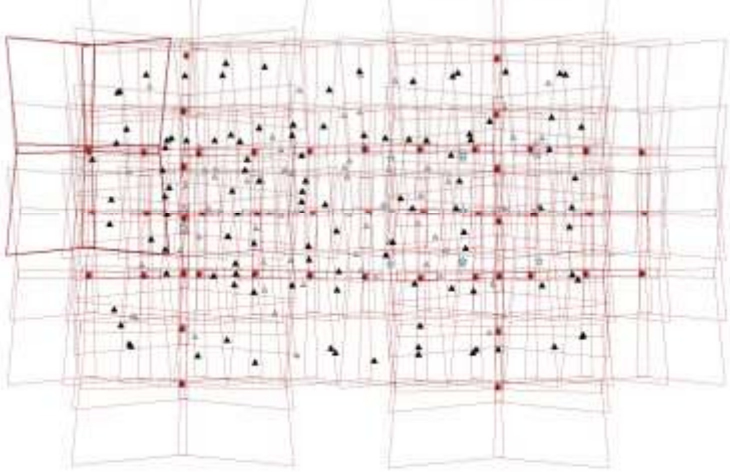
Block design

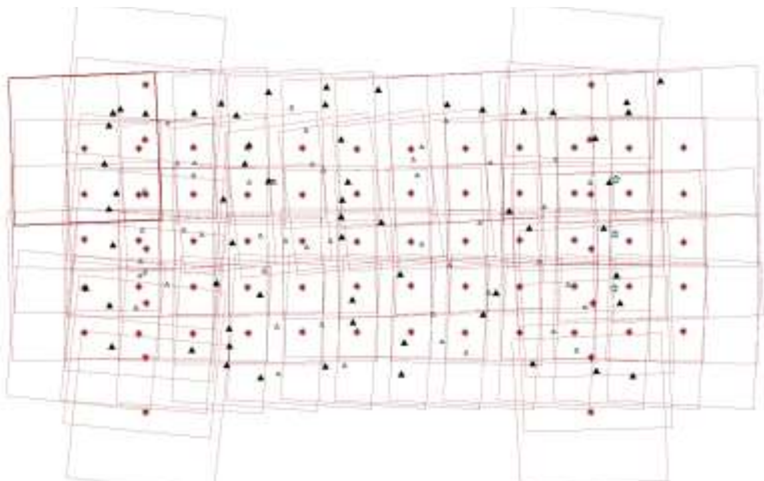
RMK & DigiCAM GSD 20cm / GSD 8cm

RMK GSD 20cm (60/70)

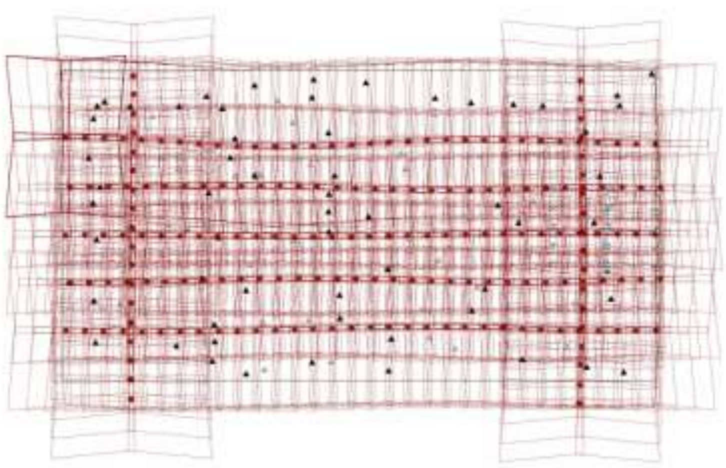


IGI GSD 20cm (62/70)



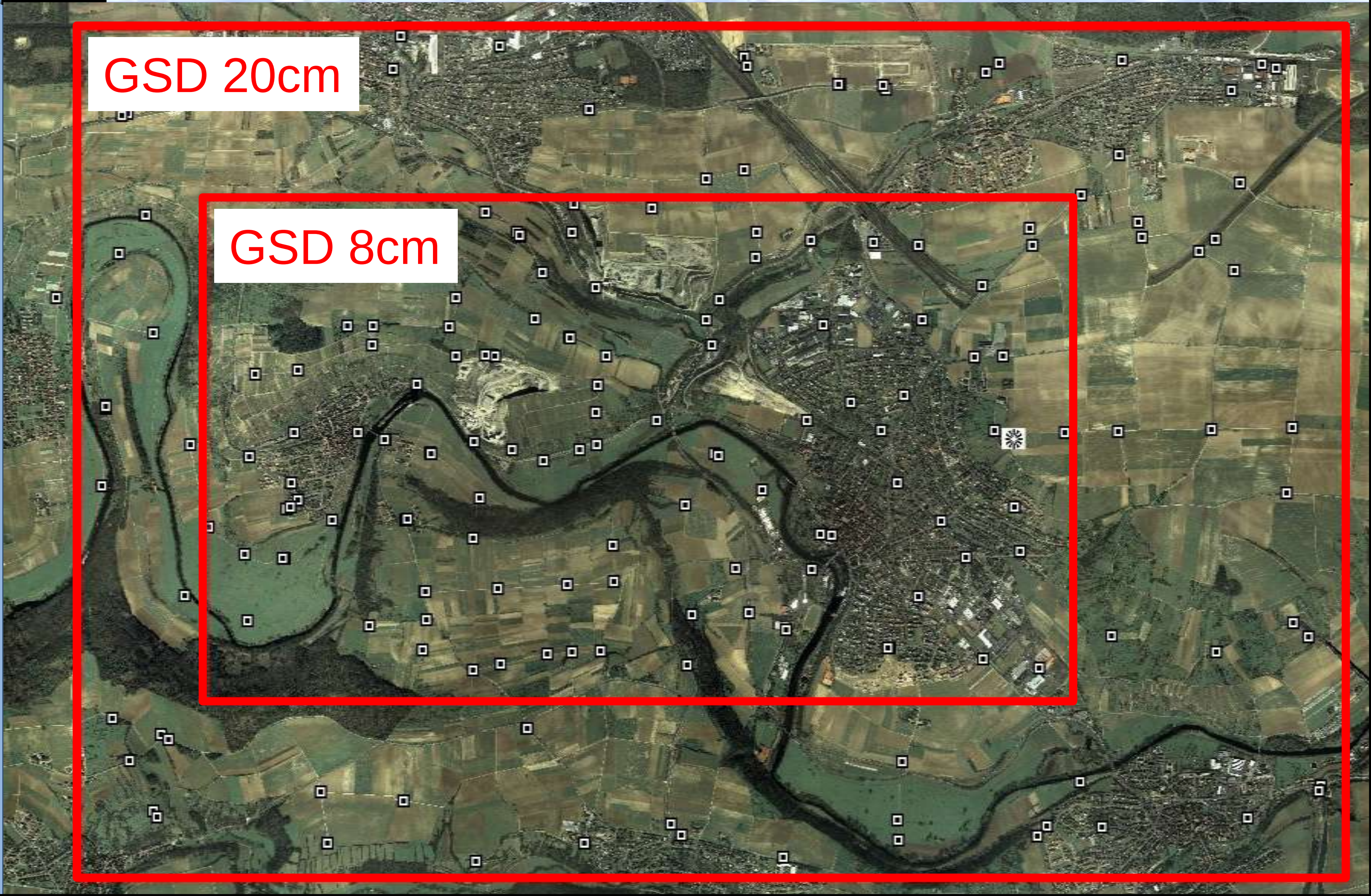


RMK GSD 8cm (60/70)



IGI GSD 8cm (80/70)

Test site Vaihingen/Enz
Institut für Photogrammetrie (ifp)



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Reference data

Test field layout

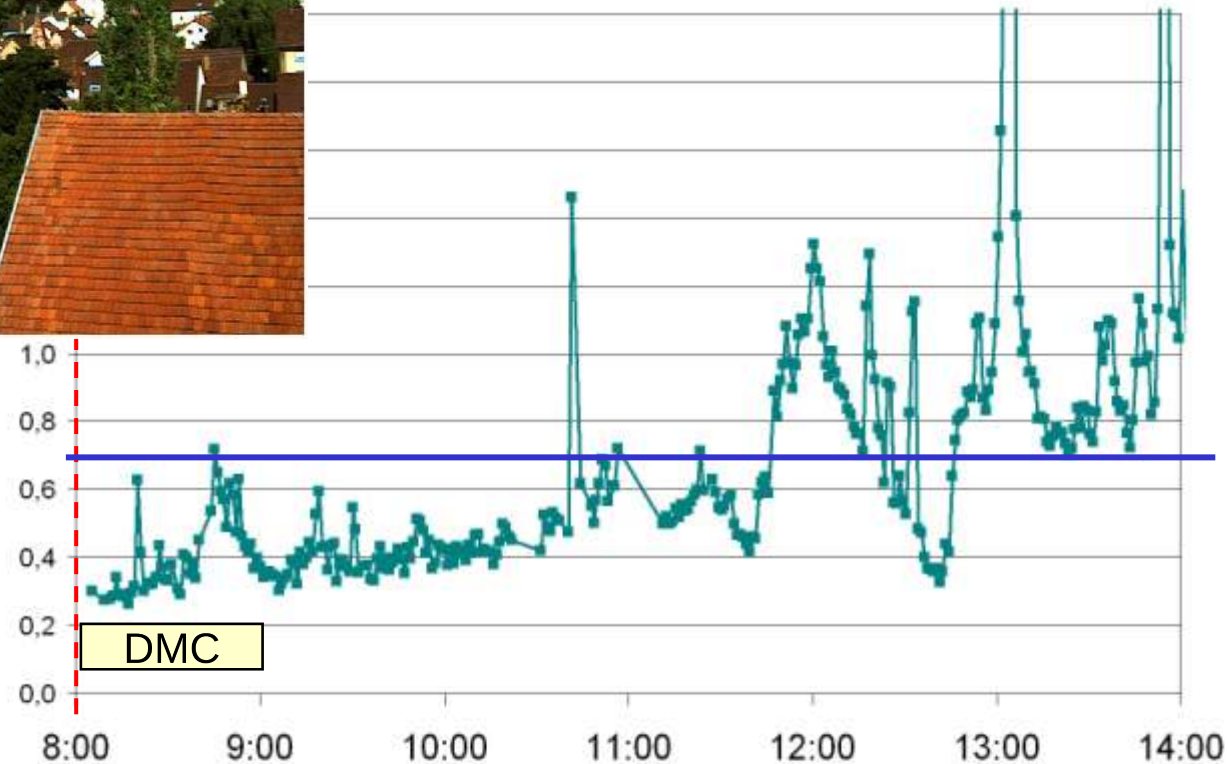
- About 170 signalized and coordinated points (accuracy (STD): 1-2cm),
- Reflectance targets, siemens star
- Spectrometer measurements in field, sunphotometer
- Manual, on-site land use classifications (multiple days)

Sunphotometer & WebCam

Day of flight 6. August 2008

08:00 h UTC

Aerosol optical depth @ 534nm



Time [UTC]

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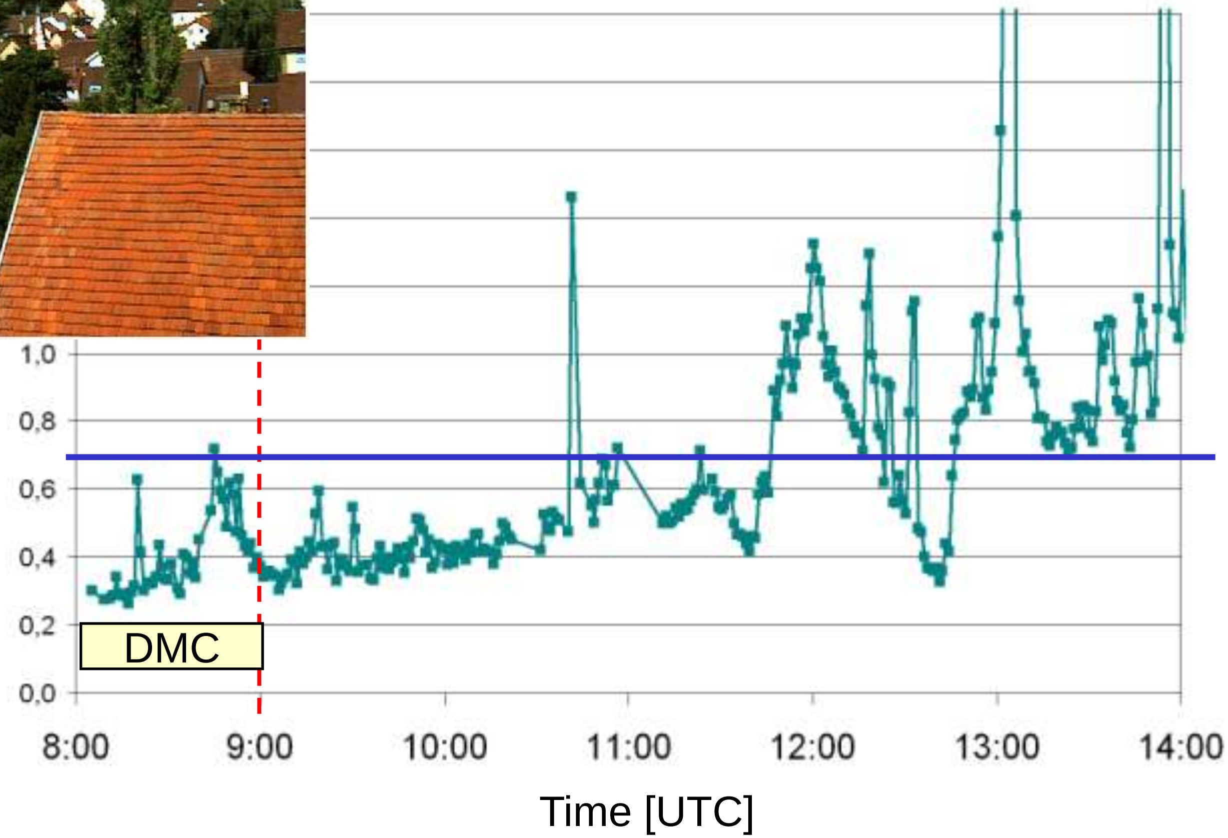
Sunphotometer & WebCam

Day of flight 6. August 2008

09:00 h UTC

Aerosol optical depth @ 534nm



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Sunphotometer & WebCam
Day of flight 6. August 2008

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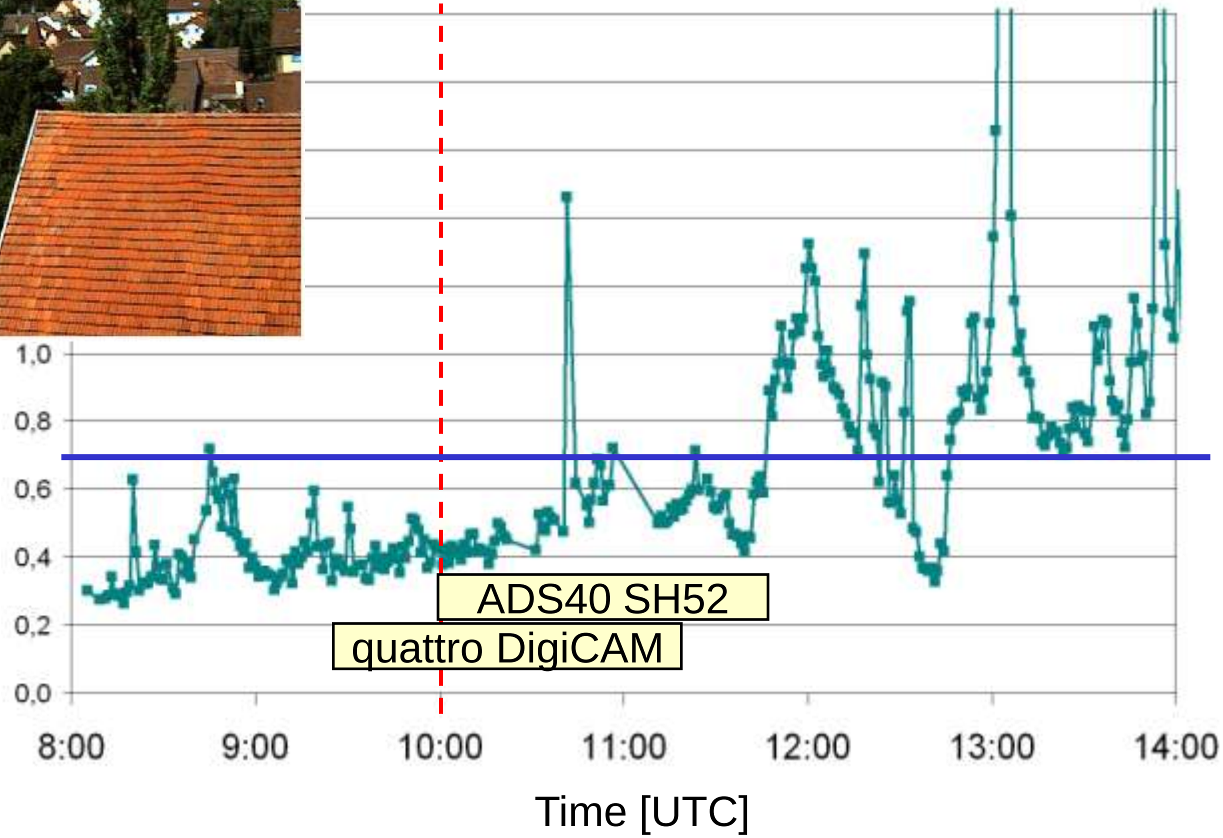
10:00 h UTC

Aerosol optical depth @ 534nm

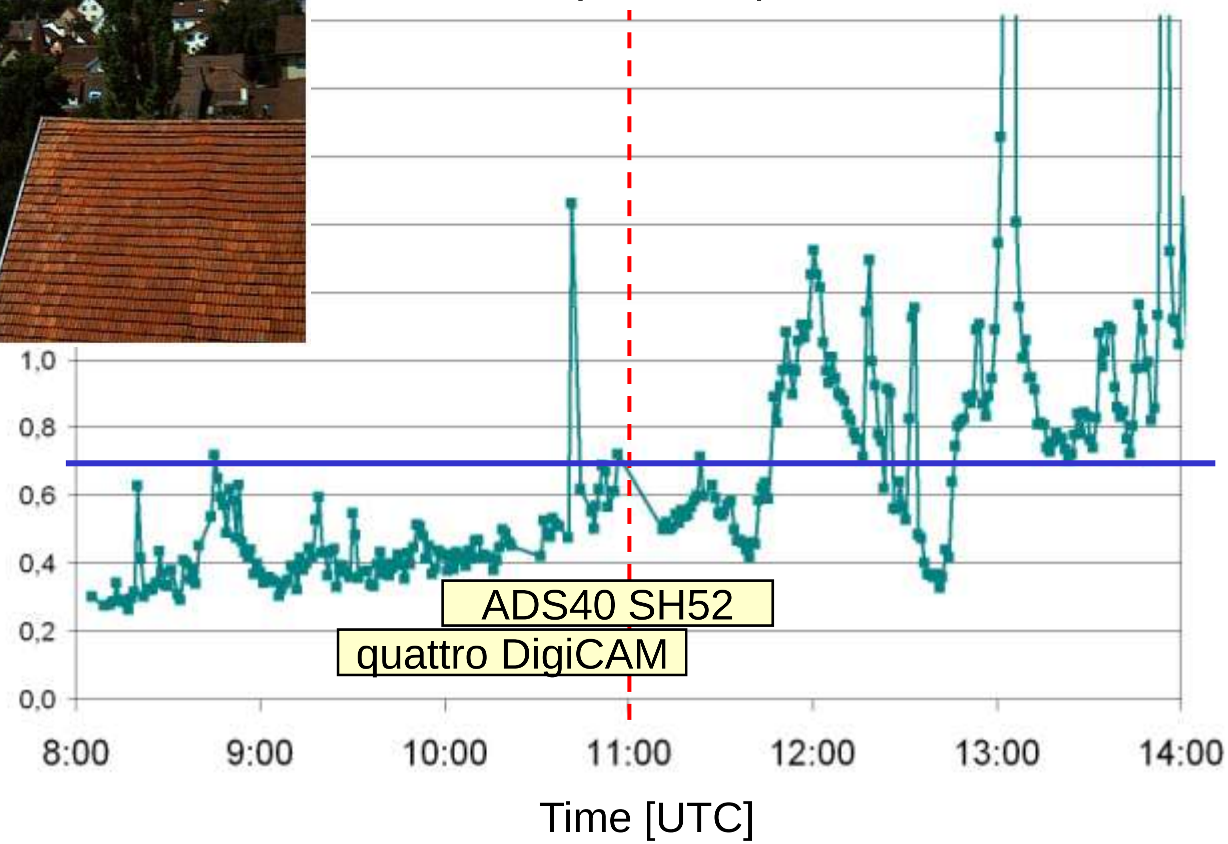


Sunphotometer & WebCam

Day of flight 6. August 2008

11:00 h UTC

Aerosol optical depth @ 534nm



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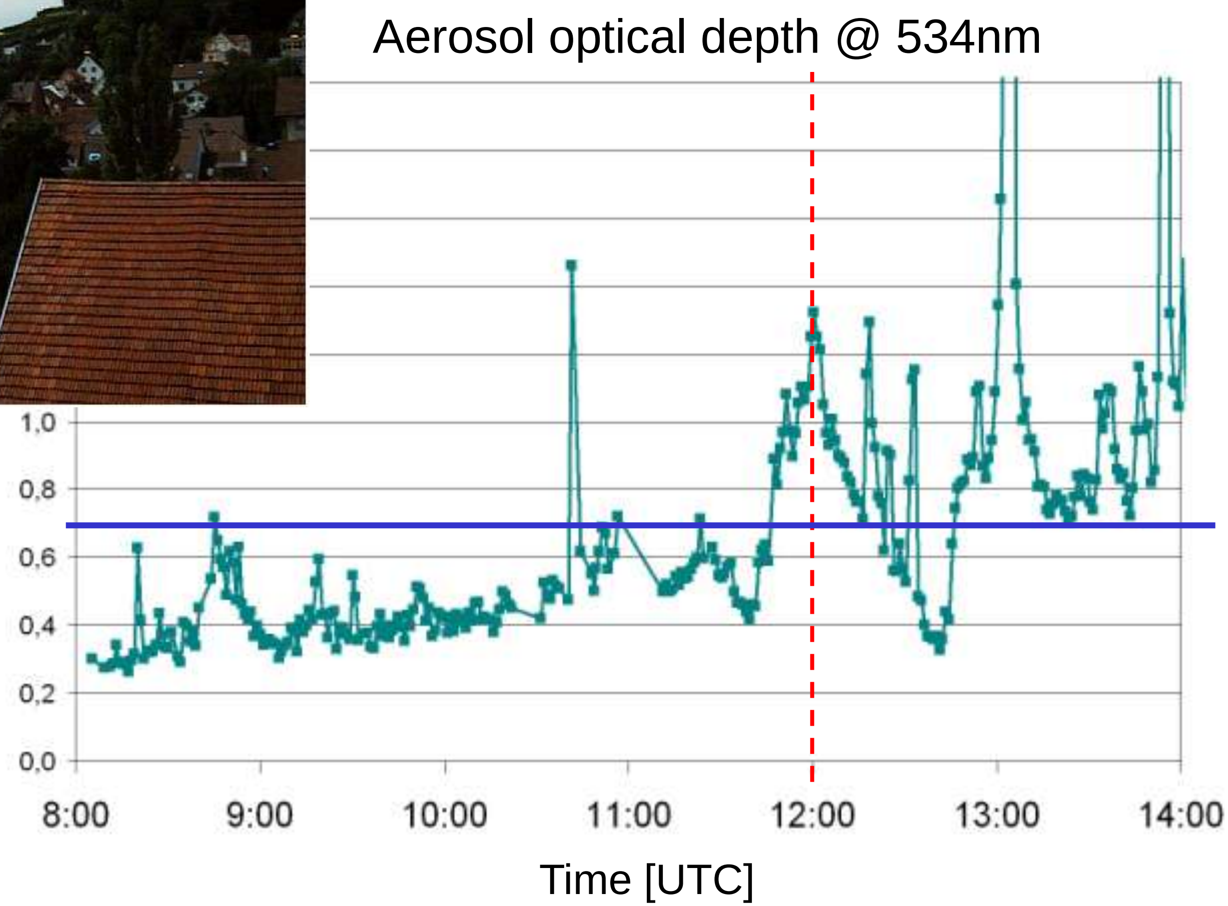
Sunphotometer & WebCam

Day of flight 6. August 2008

12:00 h UTC

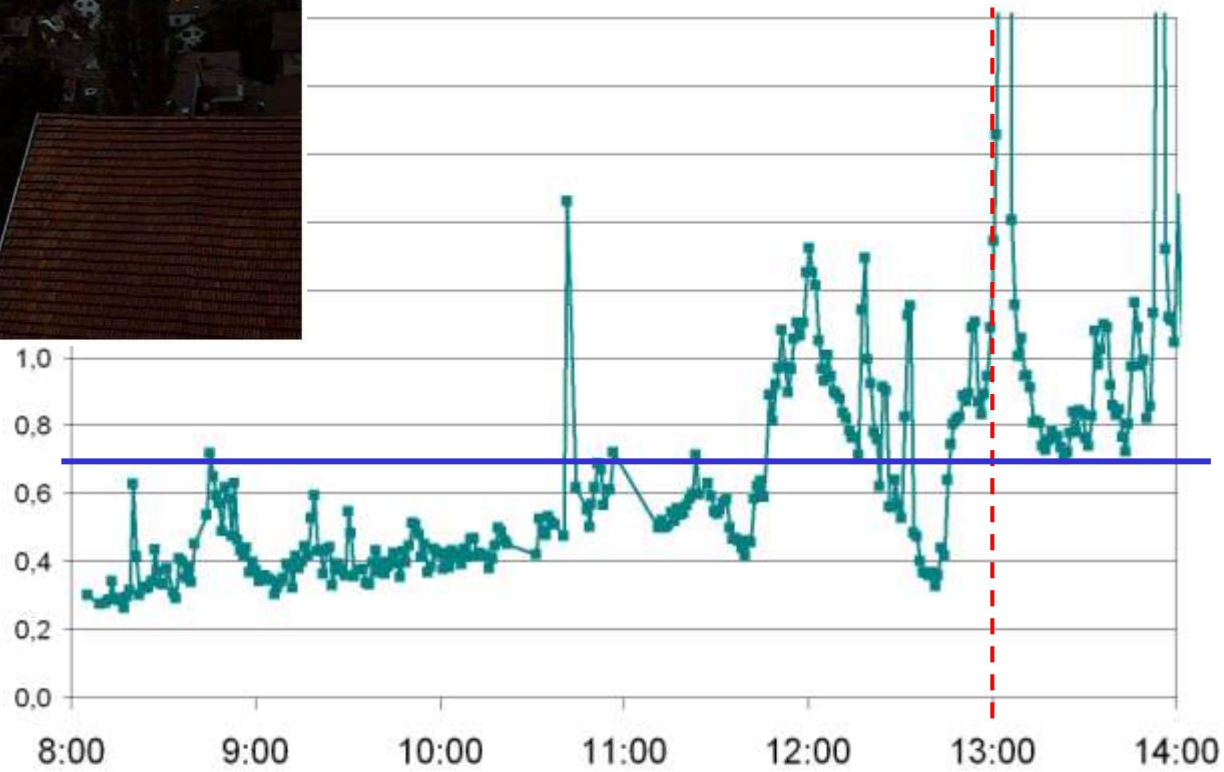


Sunphotometer & WebCam

Day of flight 6. August 2008

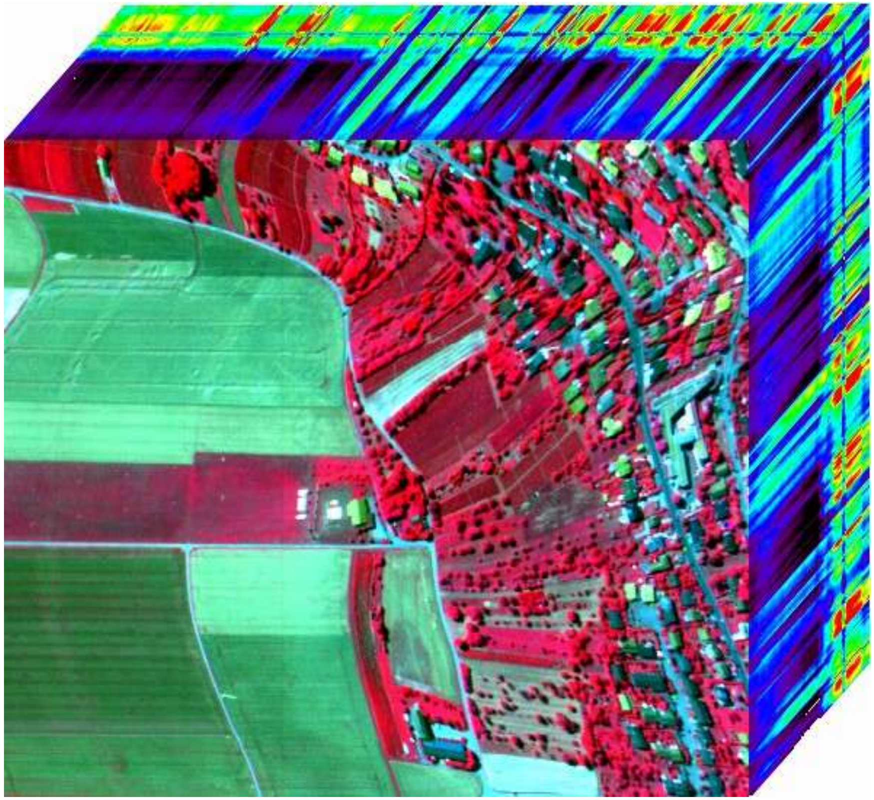
13:00 h UTC

Aerosol optical depth @ 534nm

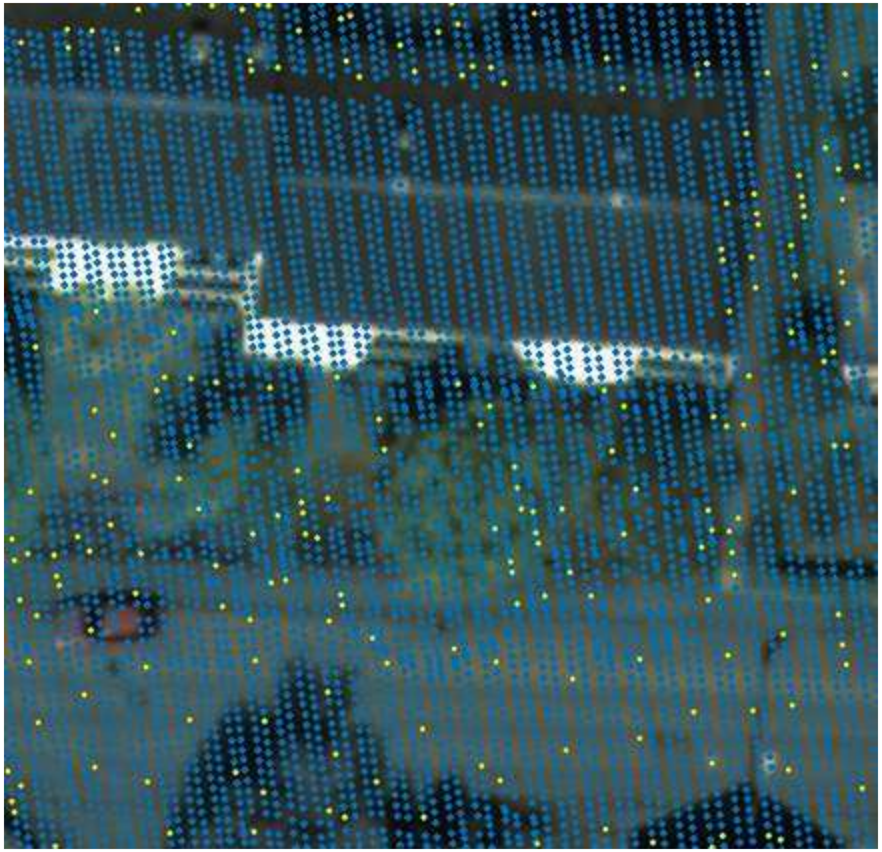


Reference data
Hyper-spectral and LiDAR flights

- **Hyperspectral** data
  - DLR ROSIS (15. July 08)
  - AISA (with DMC, double hole, 2. July 08)



- ALS50 – **LiDAR**
- Flight date 21. August 2008
- Density About 5 pts/sqm



Reference exterior orientation elements

- **one standard set of EO parameters** requested for later DSM generation, should also consider effects from self-calibration
- **Absolute orientation**
  - **self-calibrating AT (44 params)** using all available control points in test-site (i.e. **110 GCP + 77 ChP as control points**) to determine significant add. parameters and object coordinates
  - **correction of image coordinates** by influences estimated from significant additional parameters
  - new AT using **corrected image coordinates** and **all adjusted object points** from self-calibration AT above as fixed observations (absolute orientation)
  - EO parameters from absolute orientation used as reference orientations for product generation (DSM and stereoplotting)
- **external accuracy** checks
  - using sub-set of control points only (but still very dense distribution) and already corrected image coordinates from self-calibrating AT, but no additional parameters

External geometric accuracy

AT based on dense GCP distribution – GSD 8cm

Block	GCP / ChP	σ0	RMS ChP [m]			Std.Dev. [m]		
			ΔX	ΔY	ΔZ	σX	σY	σZ
DMC 8cm 136 photos	60 / 47	1,48	0,02	0,02	0,04	0,01	0,01	0,02
UCX 8cm 215 photos	60 / 50	0,95	0,01	0,02	0,04	0,01	0,01	0,02
IGI 8cm 784 photos	60 / 50	0,99	0,02	0,02	0,03	0,01	0,01	0,02
RMK 8cm 74 photos	60 / 48	4,11	0,02	0,02	0,03	0,01	0,02	0,03

- dense GCP distribution (block borders and 5 GCP chains across the block)
- systematic errors already corrected at image coordinates based on self-calibrating AT (Gruen 44 params) using all available GCPs

very optimistic estimation of maximum accuracy potential

External geometric accuracy

AT based on dense GCP distribution – GSD 20cm

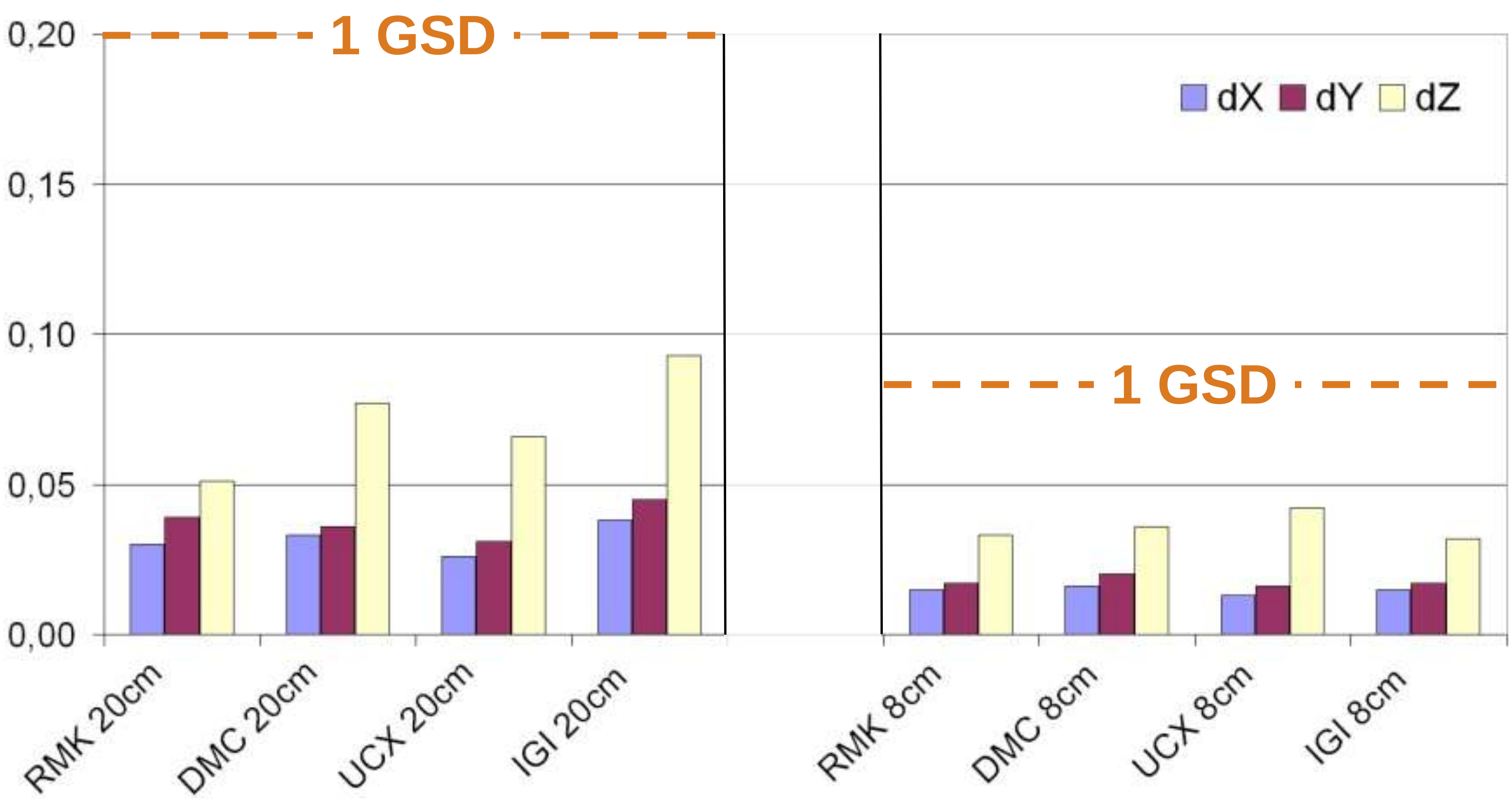
Block	GCP / ChP	σ0	RMS ChP [m]			Std.Dev. [m]		
			ΔX	ΔY	ΔZ	σX	σY	σZ
DMC 20cm 60 photos	70 / 114	1,96	0,03	0,04	0,08	0,02	0,02	0,06
UCX 20cm 52 photos	70 / 112	1,05	0,03	0,03	0,07	0,02	0,02	0,06
IGI 20cm 188 photos	70 / 116	1,28	0,04	0,05	0,09	0,03	0,02	0,09
RMK 20cm 47 photos	70 / 116	4,36	0,03	0,04	0,05	0,03	0,04	0,07

- dense GCP distribution (block borders and 5 GCP chains across the block)
- systematic errors already corrected at image coordinates based on self-calibrating AT (Gruen 44 params) using all available GCPs

very optimistic estimation of maximum accuracy potential

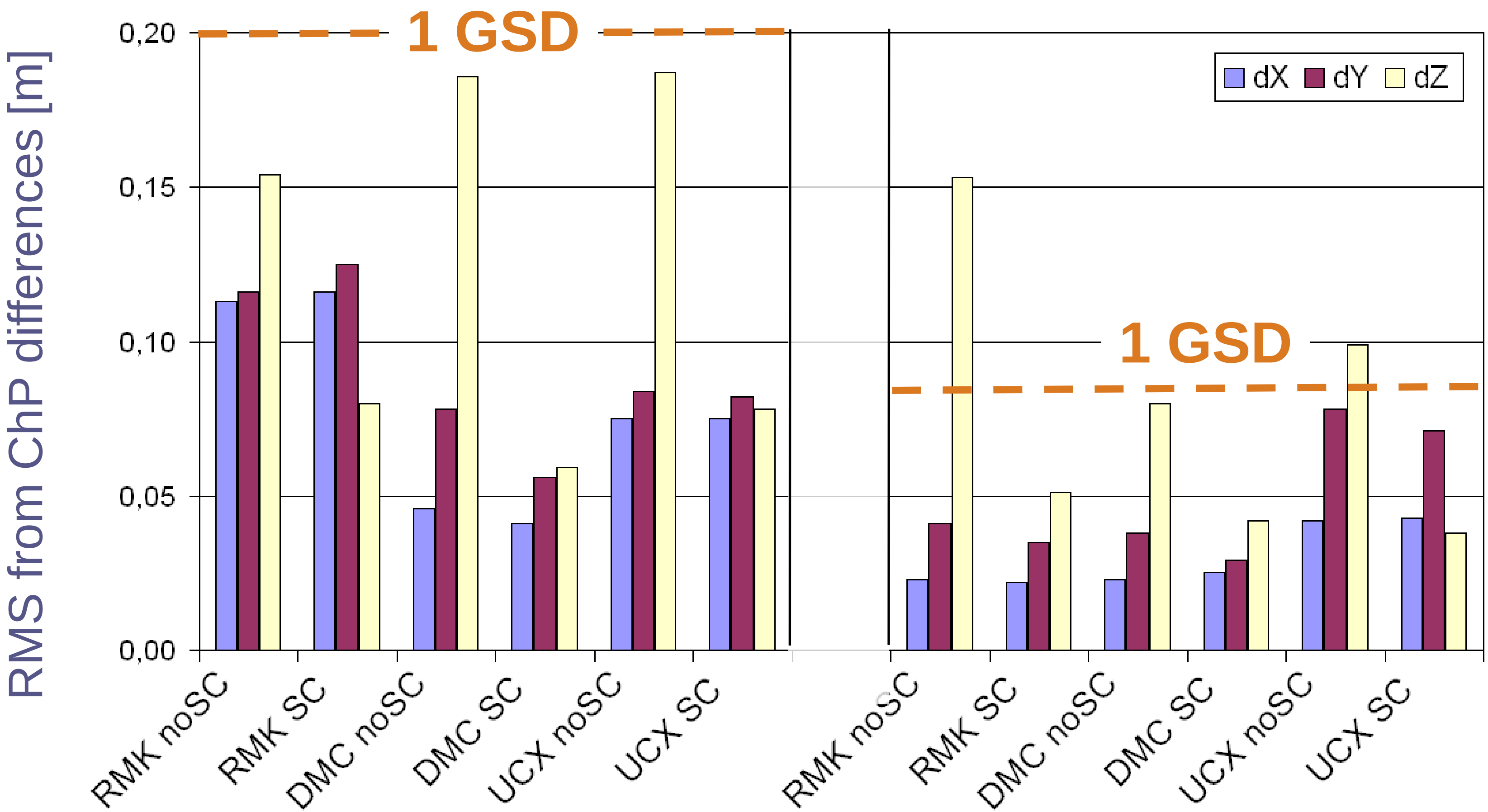
External geometric accuracy
AT based on dense GCP distribution

RMS values from ChP differences [m]



Differences in environmental conditions and block configuration have to be considered!

External geometric accuracy
AT based 9/14 GCP (Jacobsen, 2009)



Differences in environmental conditions and block configuration have to be considered!

Automatic DSM generation
Test site: Sports field Rosswag

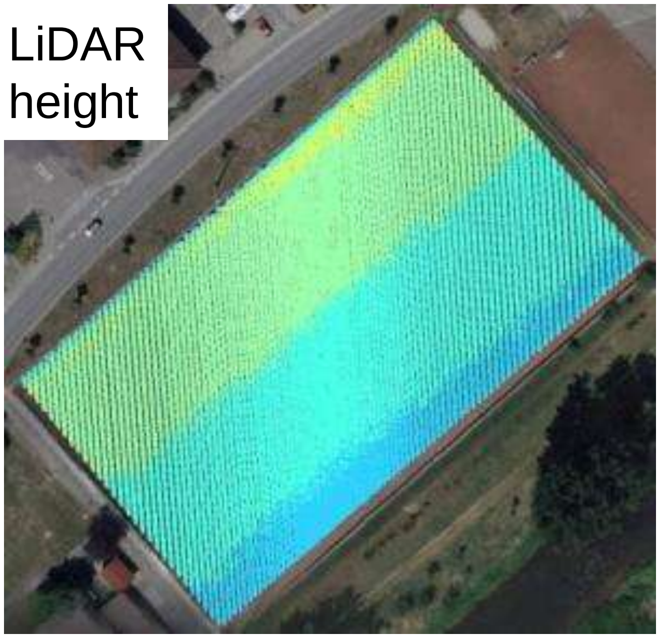
Test site sports field

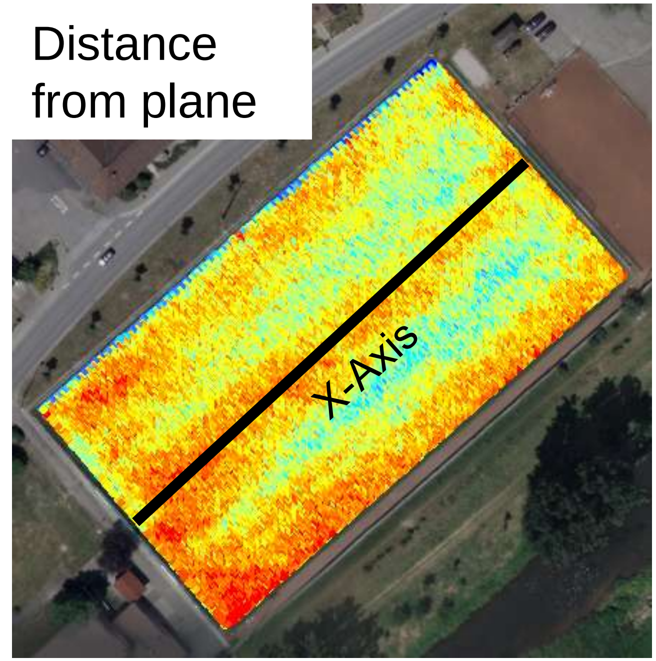
ALS50 LiDAR reference
colour coded height

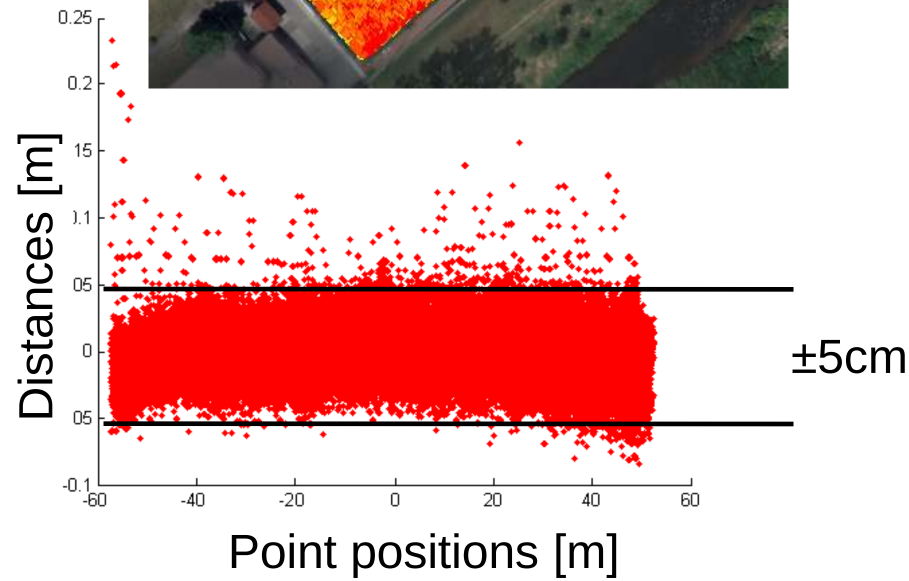
Remark: 3D DSM generation done using inpho Match-T software

Analysis of 3D point clouds in flat areas

Example LiDAR (ALS50) performance







- Adjusted plane from 3D point cloud
- Analysis of distances from plane
  - $Sigma_0$ = 1.92 cm
  - Point density = 8.25 Pts/m^2

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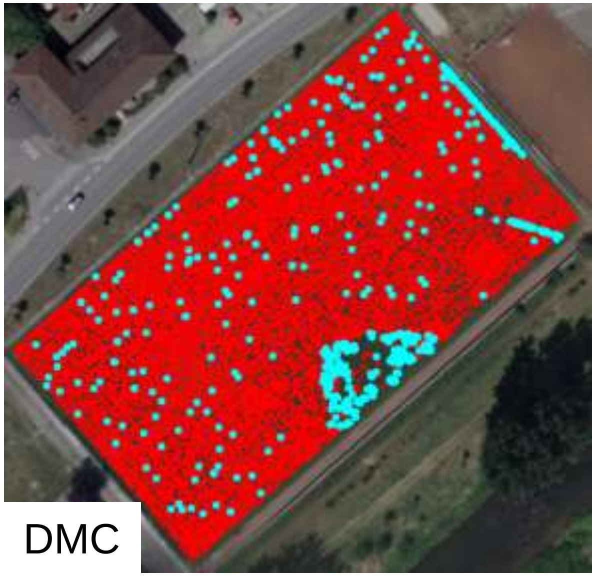
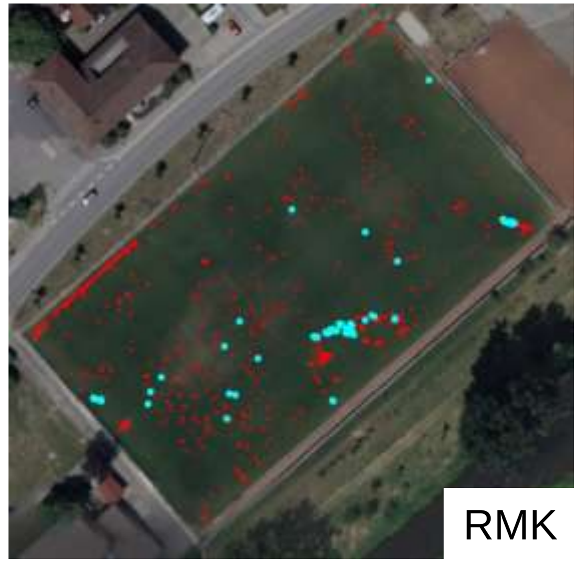
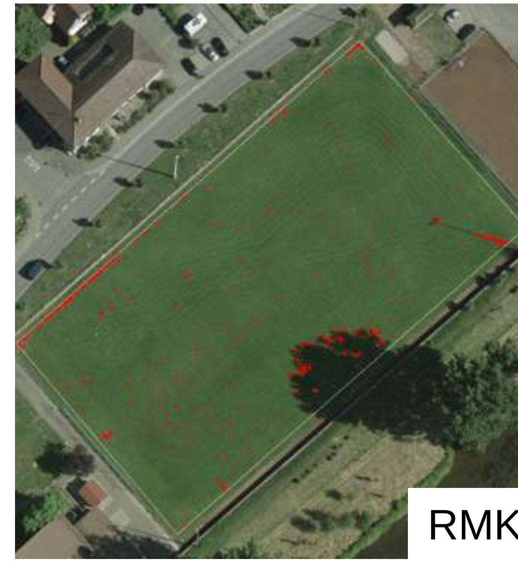
Analysis of 3D point clouds

Sports field Rosswag 8cm GSD







- DMC and RMK images recorded simultaneously, double hole flight allows for direct comparison
  - DMC
    - Sigma_0 = 5.2 cm
    - Point density = 19.7 Pts/m^2
  - RMK
    - Sigma_0 = 17.2 cm
    - Point density = 0.8 Pts/m^2
- Significant quality increase due to digital imagery

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Digital image data

Sports field Rosswag 8cm GSD

DMC

Ultracam-X

DigiCAM

Day of Flight:	July 24	September 11	August 6
Local time:	~10:00h	~12:00h	~12:00h

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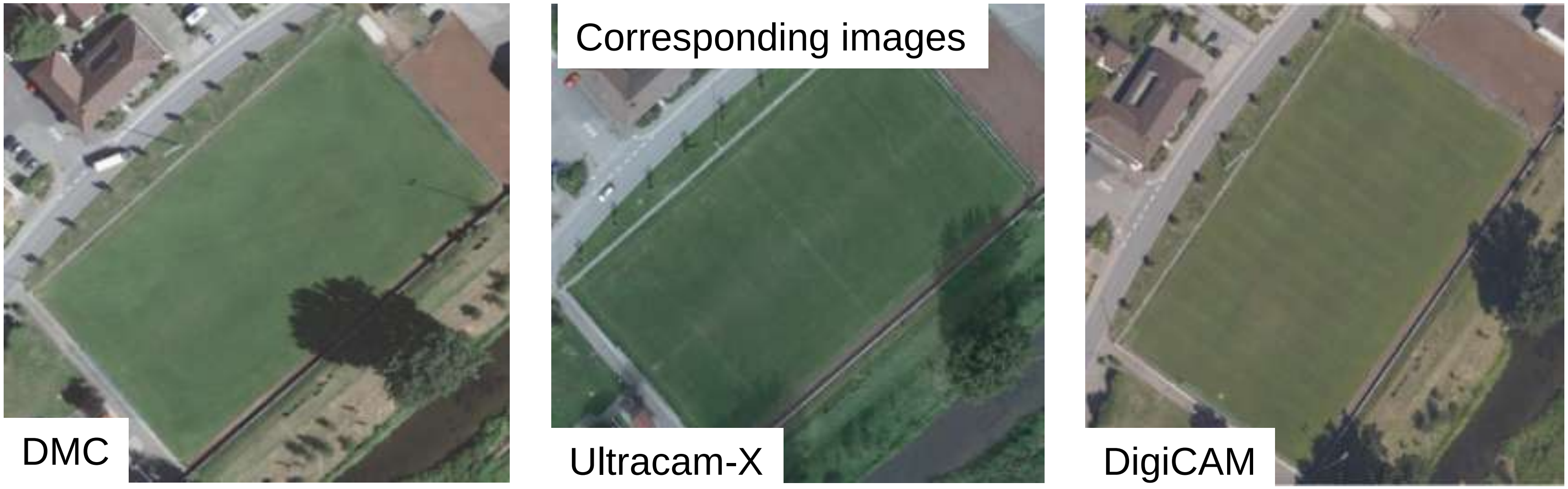
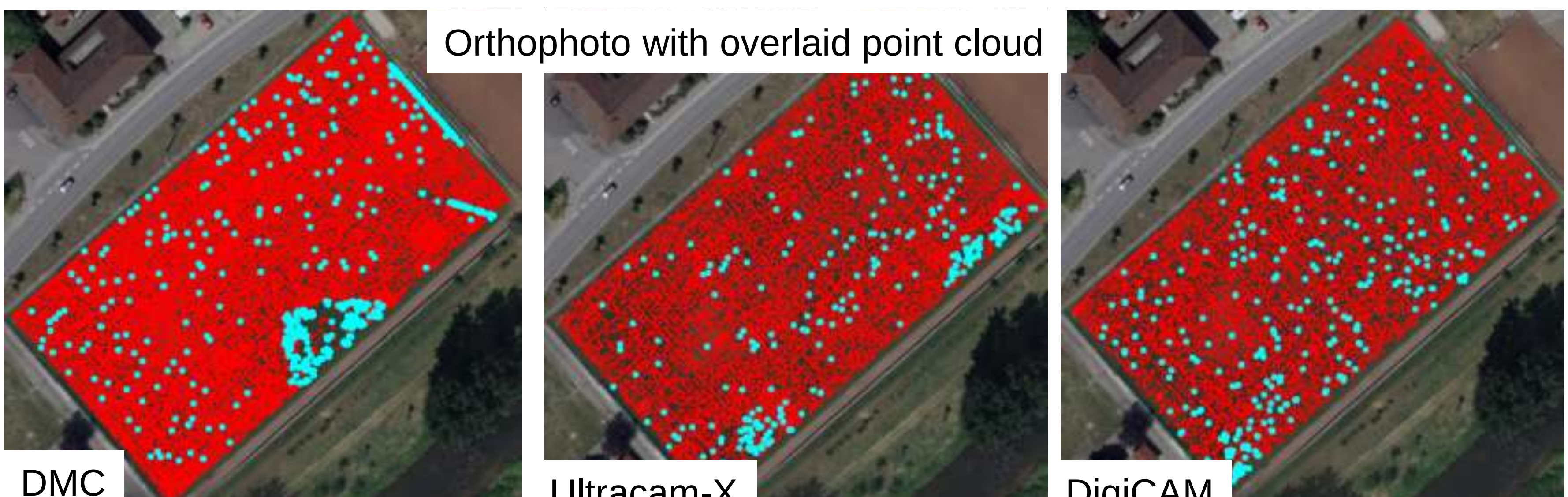
Point clouds (original and filtered)

Sports field Rosswag 8cm GSD





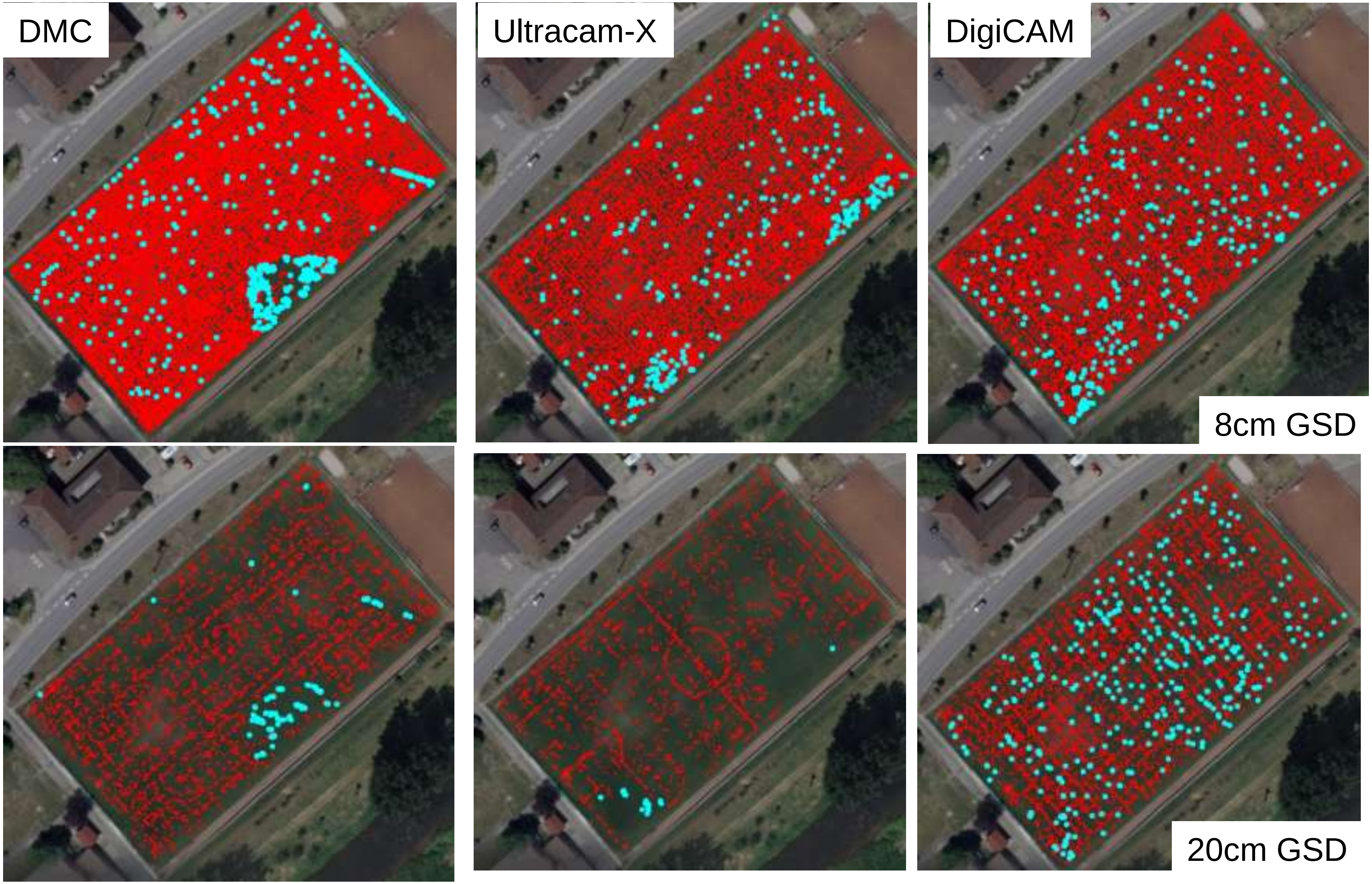
Accuracy of 3D point clouds

Sports field Rosswag - GSD 8cm

Sensor	STD w/o gross errors [cm]	STD [cm]	Elim.Pts. [%]	Density Pts./m²
DMC 8cm	5,2	9,7	1,3	19,67
UCX 8cm	6,8	8,0	0,4	19,04
DigiCAM 8cm	10,2	11,2	0,7	20,83
RMK 8cm	17,2	27,3	3,2	0,77
ALS50	1,8	1,9	0,5	8,25

7,4 cm	**Mean (only from digital cameras)**	**19,85 Pts/m²**

Influence of GSD on DSM generation



Accuracy of 3D point clouds

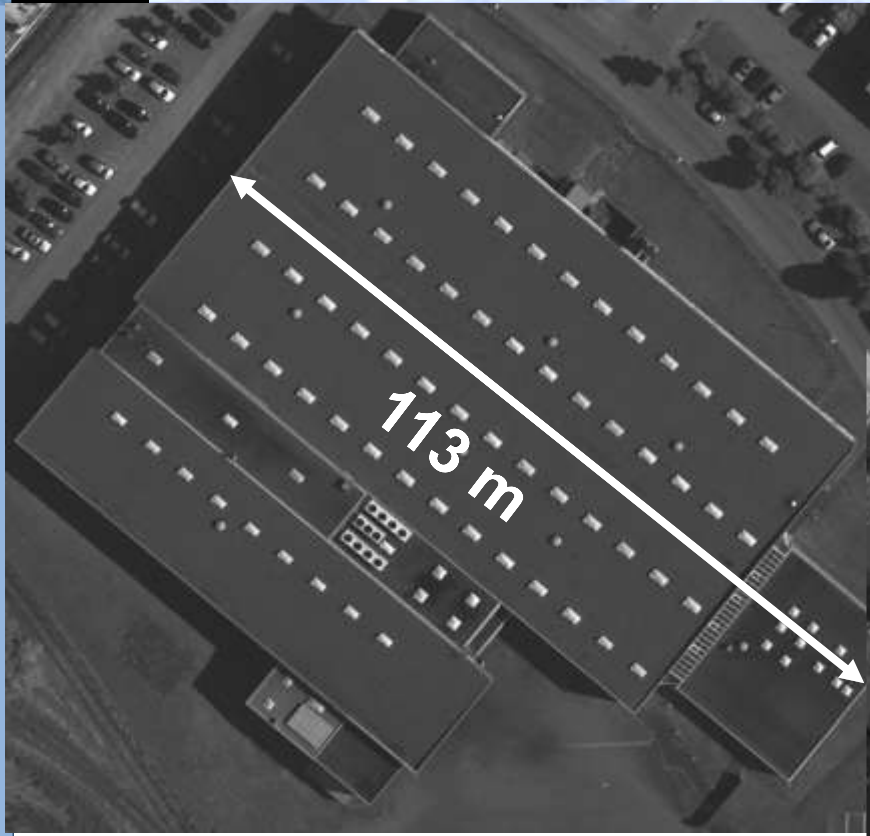
Sports field Rosswag - GSD 20cm

Sensor	STD w/o gross errors [cm]	STD [cm]	Elim.Pts. [%]	Density Pts./m²
DMC 20cm	17,2	25,4	1,1	2,71
UCX 20cm	22,6	34,2	0,4	1,62
DigiCAM 20cm	34,1	48,2	2,5	2,64
RMK 20cm	60,6	66,2	0,7	0,31
ALS50	1,8	1,9	0,5	8,25

24,6 cm	Mean (only from digital cameras)	2,32 Pts./m²

Automatic DSM generation (buildings) (*K. Wolff 2009)*

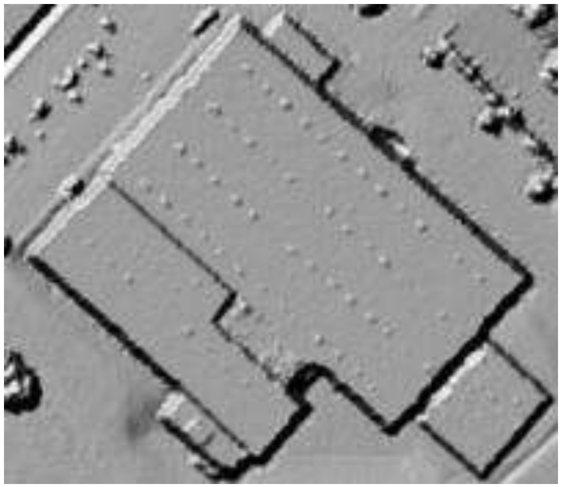
Test object: Industrial building



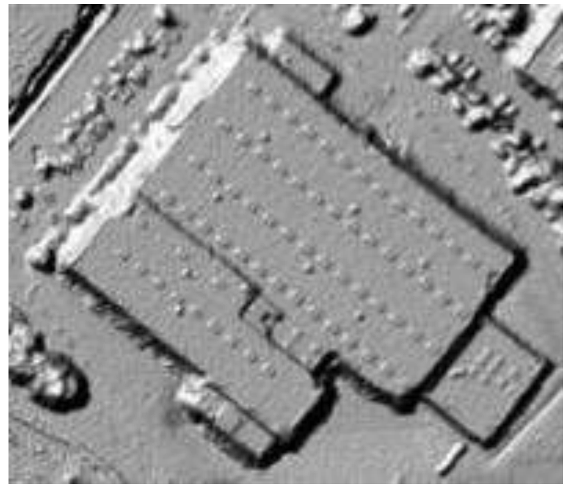
DMC, GSD 8 cm

UC-X, GSD 8 cm

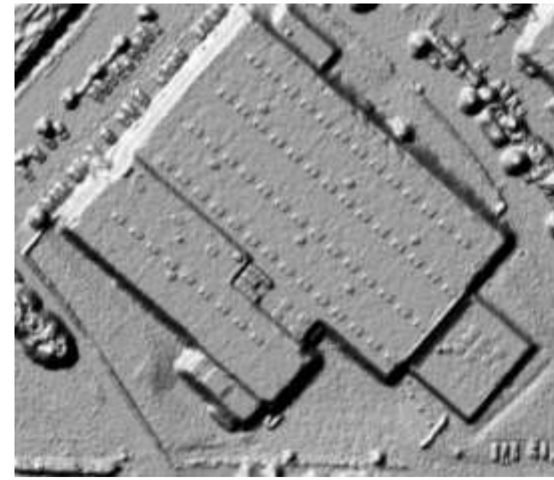
Automatic DSM generation (buildings) (*K. Wolff 2009)*



ALS50 reference
DSM 25cm grid



DMC GSD 8cm
6-folded overlap

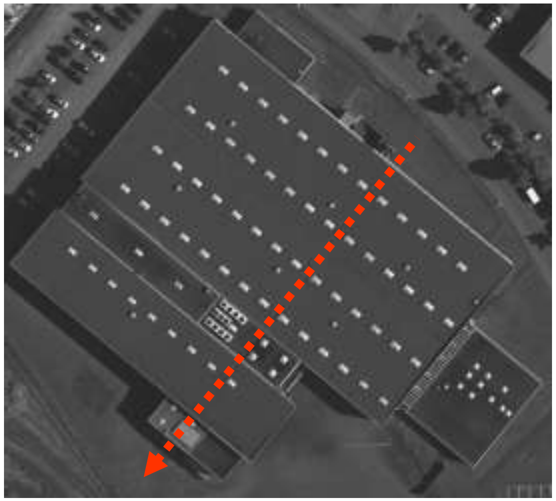


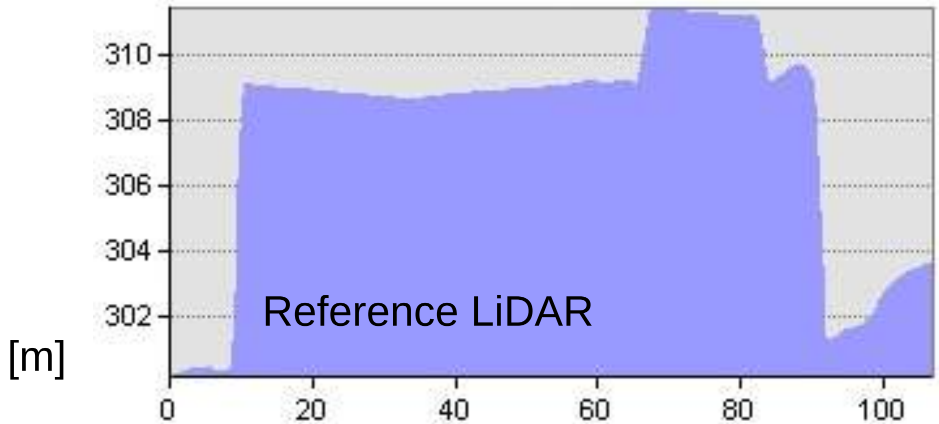
UCX GSD 8cm
10-folded overlap

Results from SAT-PP Software (ETHZ)

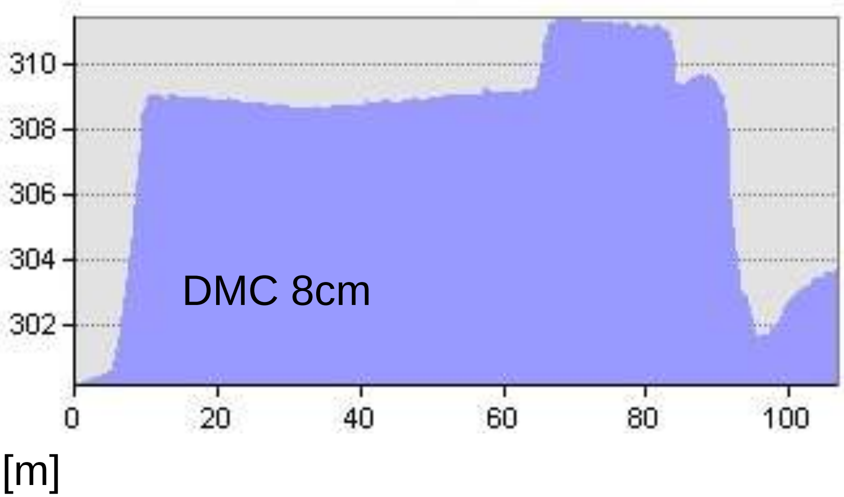
Test site large building

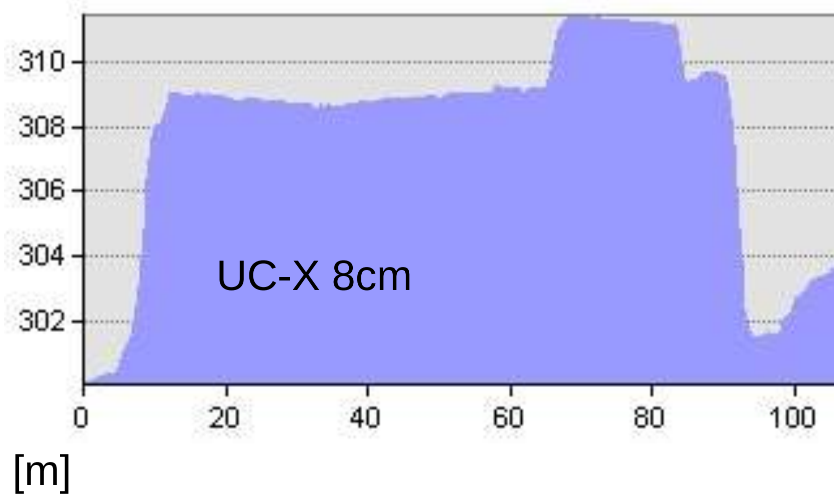
Automatic DSM generation (buildings)
(*K. Wolff 2009*)



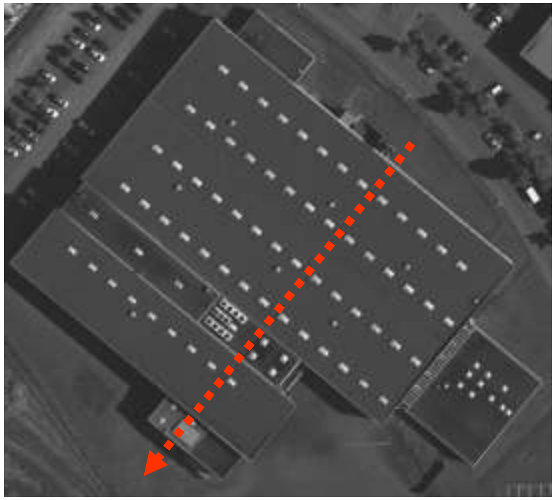


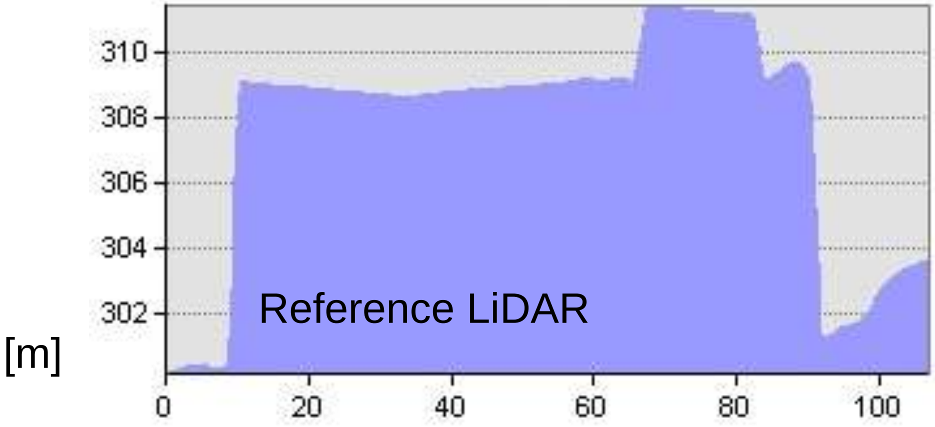
profile



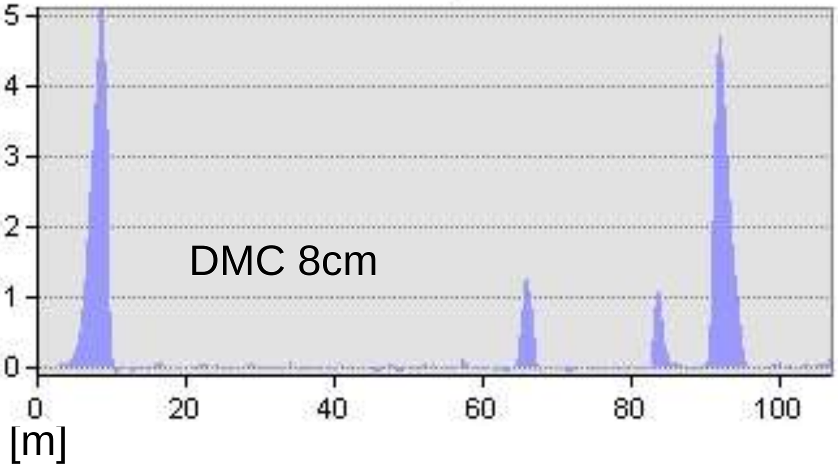


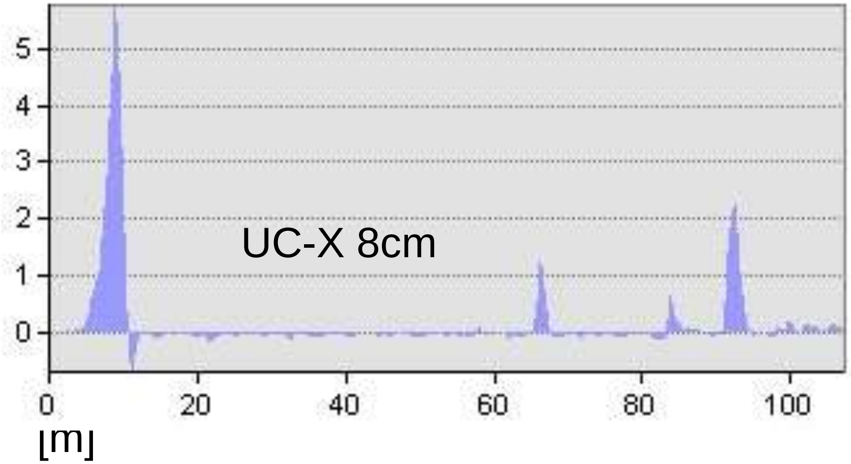
Automatic DSM generation (buildings) (*K. Wolff 2009)*



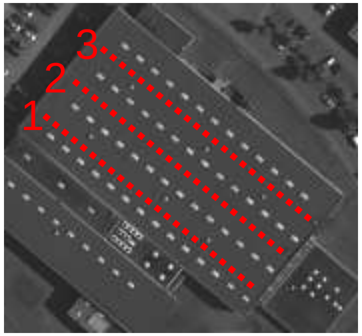


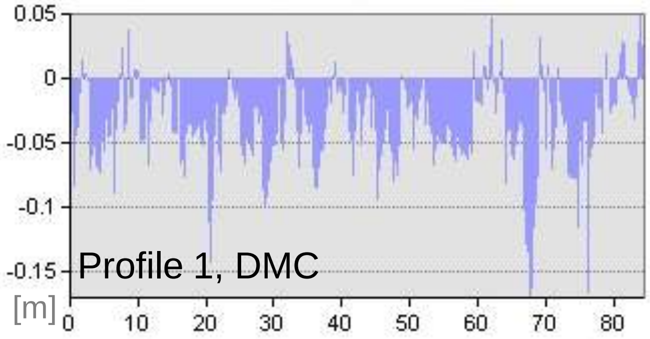
Building profile

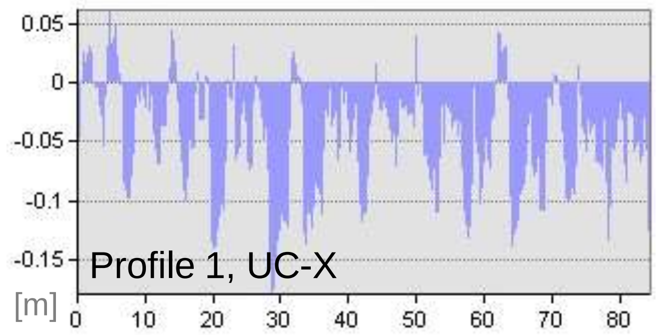




Automatic DSM generation (buildings) (*K. Wolff 2009*)





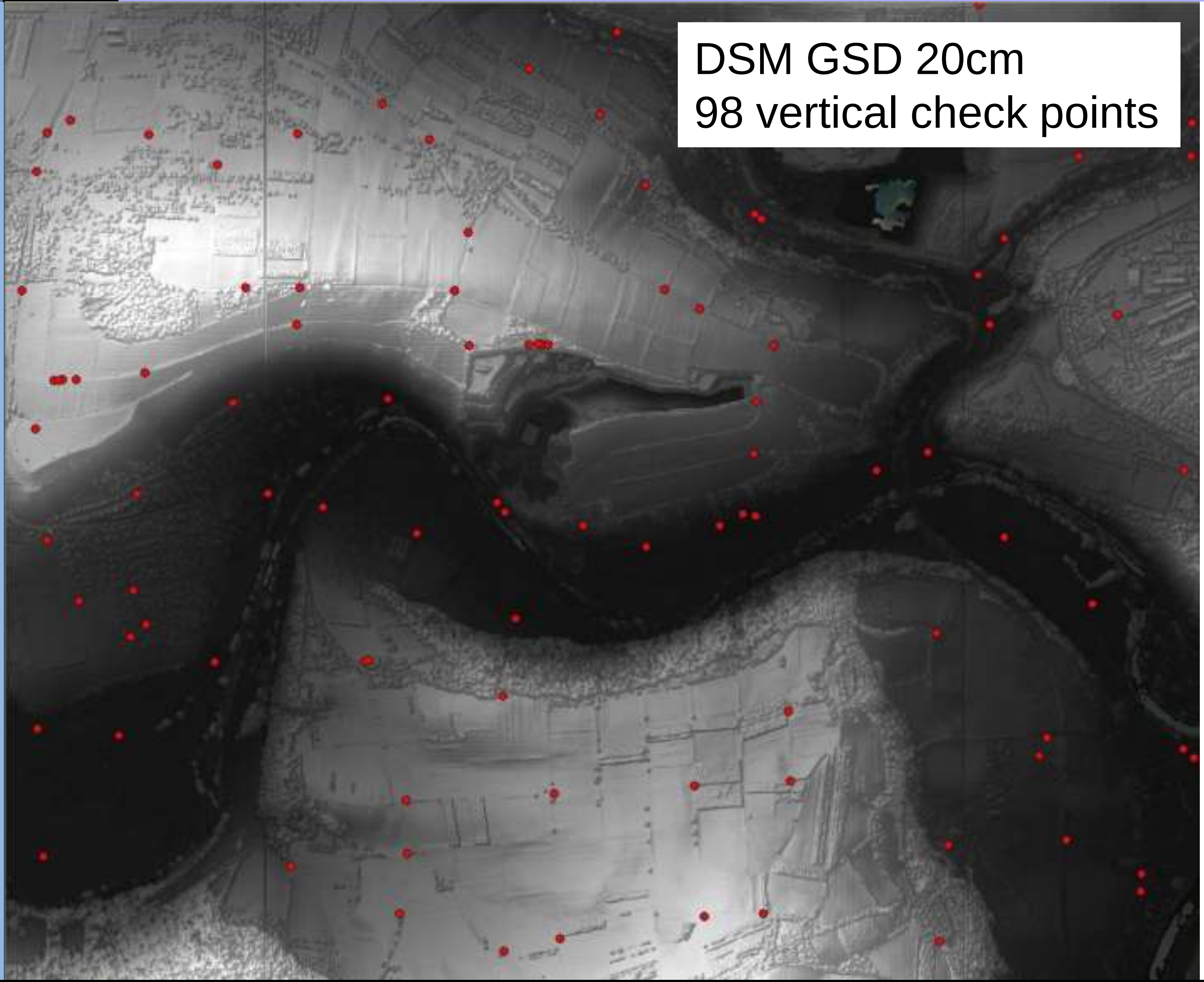


Accuracy from building profiles

profile	RMS [m]	Mean [m]	Min [m]	Max [m]
1 DMC	0.05	-0.04	-0.17	0.05
2 DMC	0.03	-0.02	-0.10	0.07
3 DMC	0.03	-0.06	-0.09	0.05
1 UC-X	0.07	-0.05	-0.18	0.06
2 UC-X	0.06	-0.04	-0.13	0.09
3 UC-X	0.08	-0.06	-0.18	0.06

Absolute DSM accuracy

Height differences at signalised points



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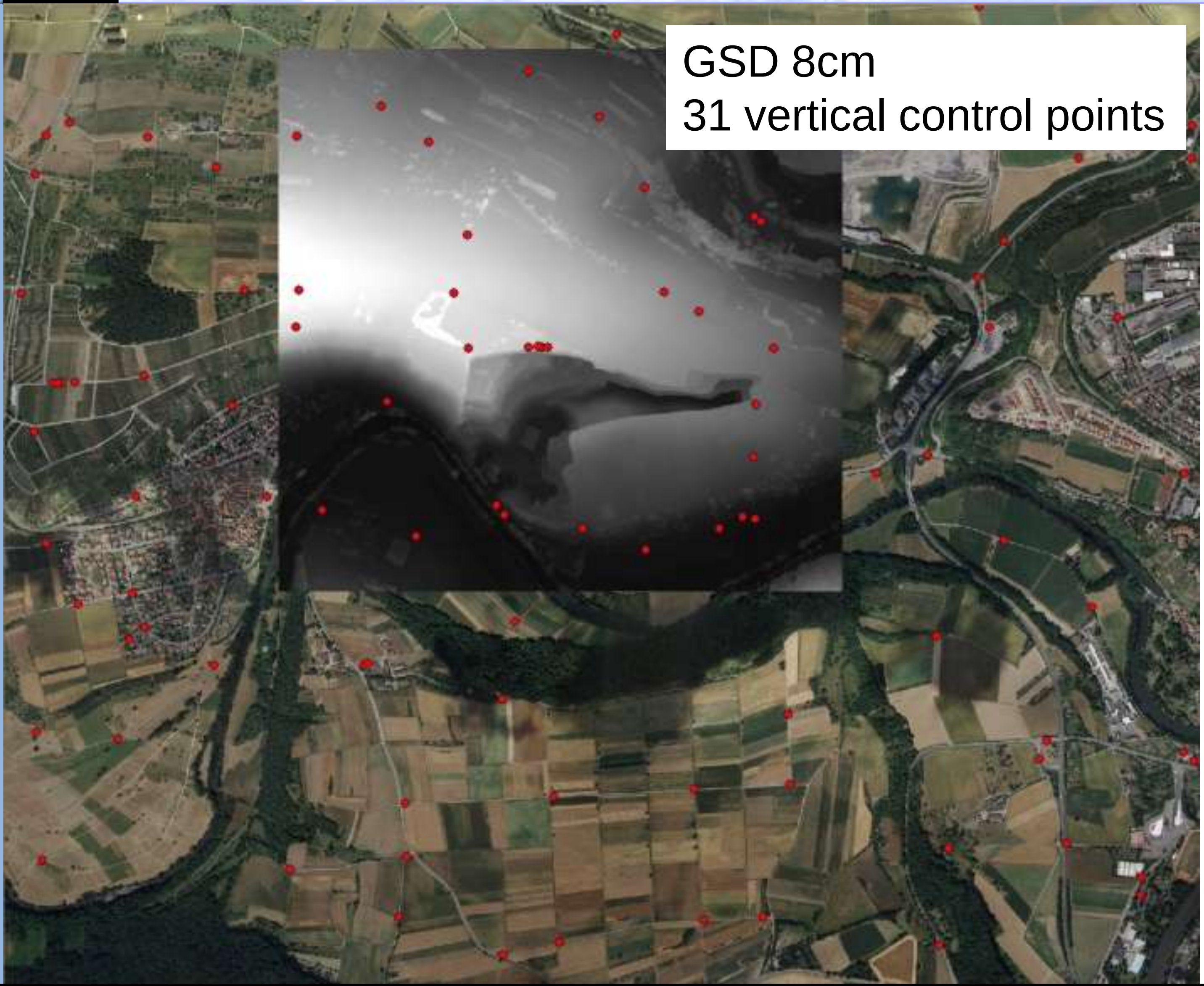
Absolute DSM accuracy
Height differences at signalised points



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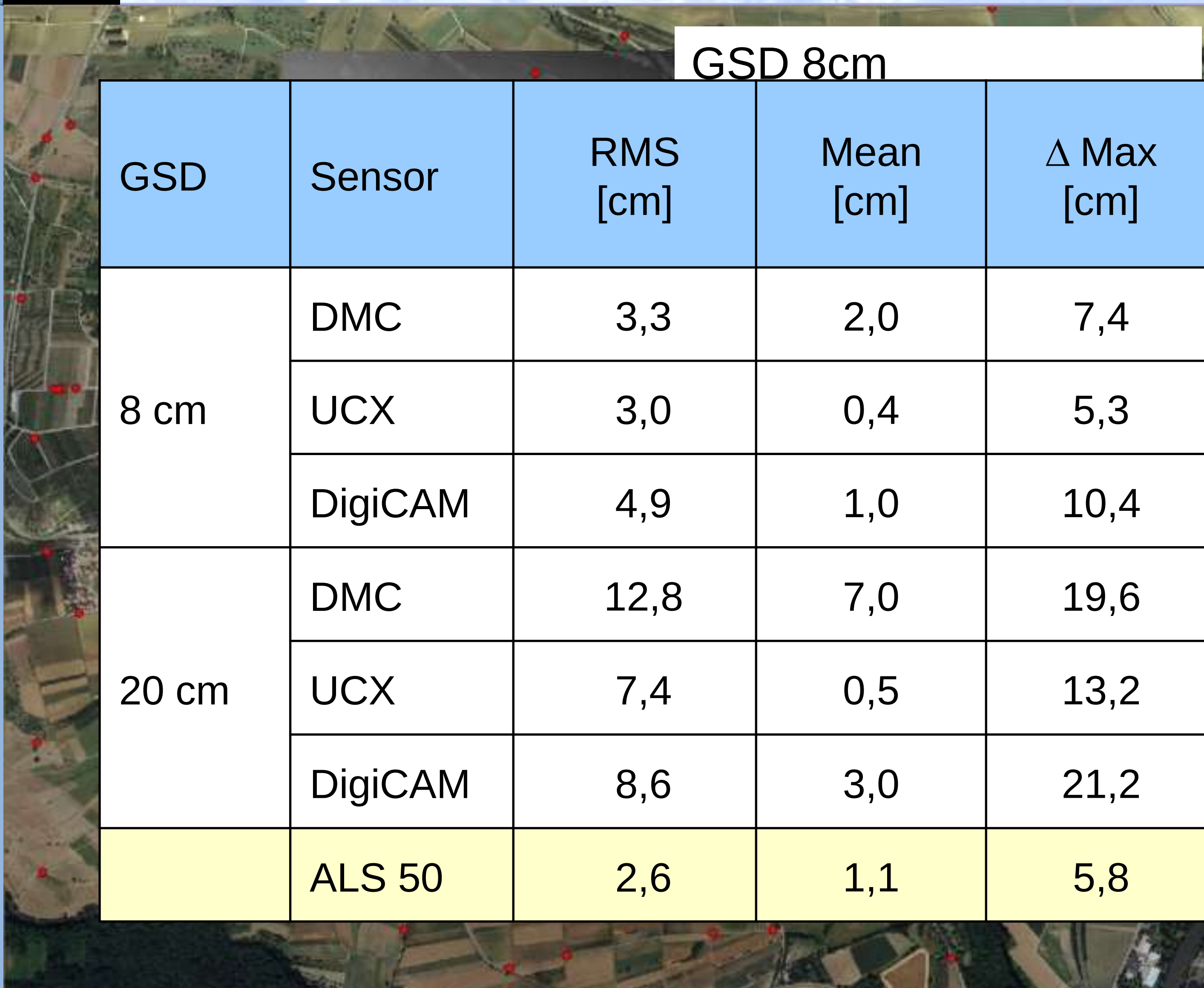
Absolute DSM accuracy

Height differences at signalised points



GSD	Sensor	RMS [cm]	Mean [cm]	∆ Max [cm]	∆ Min [cm]
8 cm	DMC	3,3	2,0	7,4	-3,0
	UCX	3,0	0,4	5,3	-6,9
	DigiCAM	4,9	1,0	10,4	-7,6
20 cm	DMC	12,8	7,0	19,6	-23,4
	UCX	7,4	0,5	13,2	-15,3
	DigiCAM	8,6	3,0	21,2	-11,7
	ALS 50	2,6	1,1	5,8	-5,3

Example – UC-X image, GSD 8cm
(*K. Wolff 2009)*

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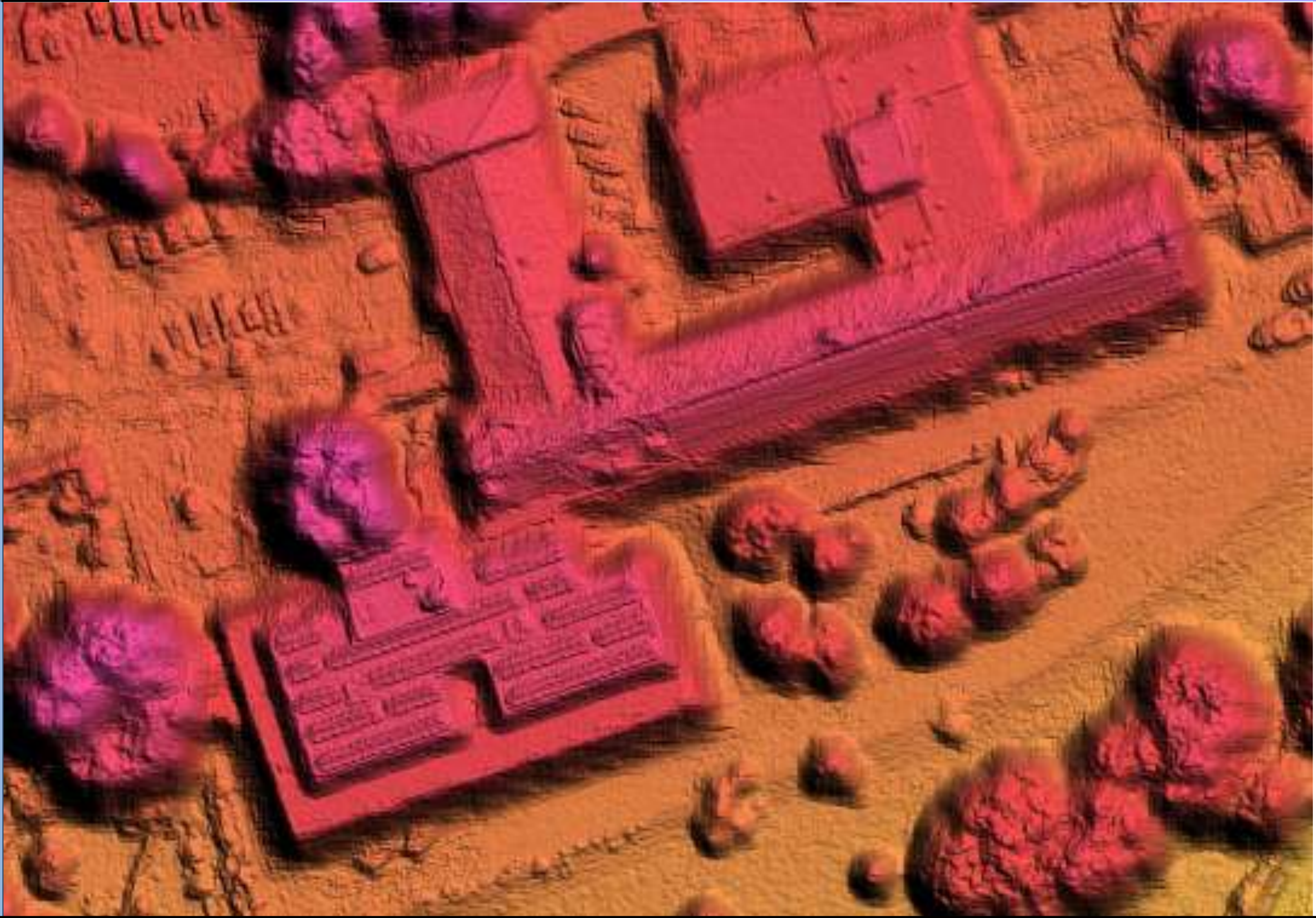
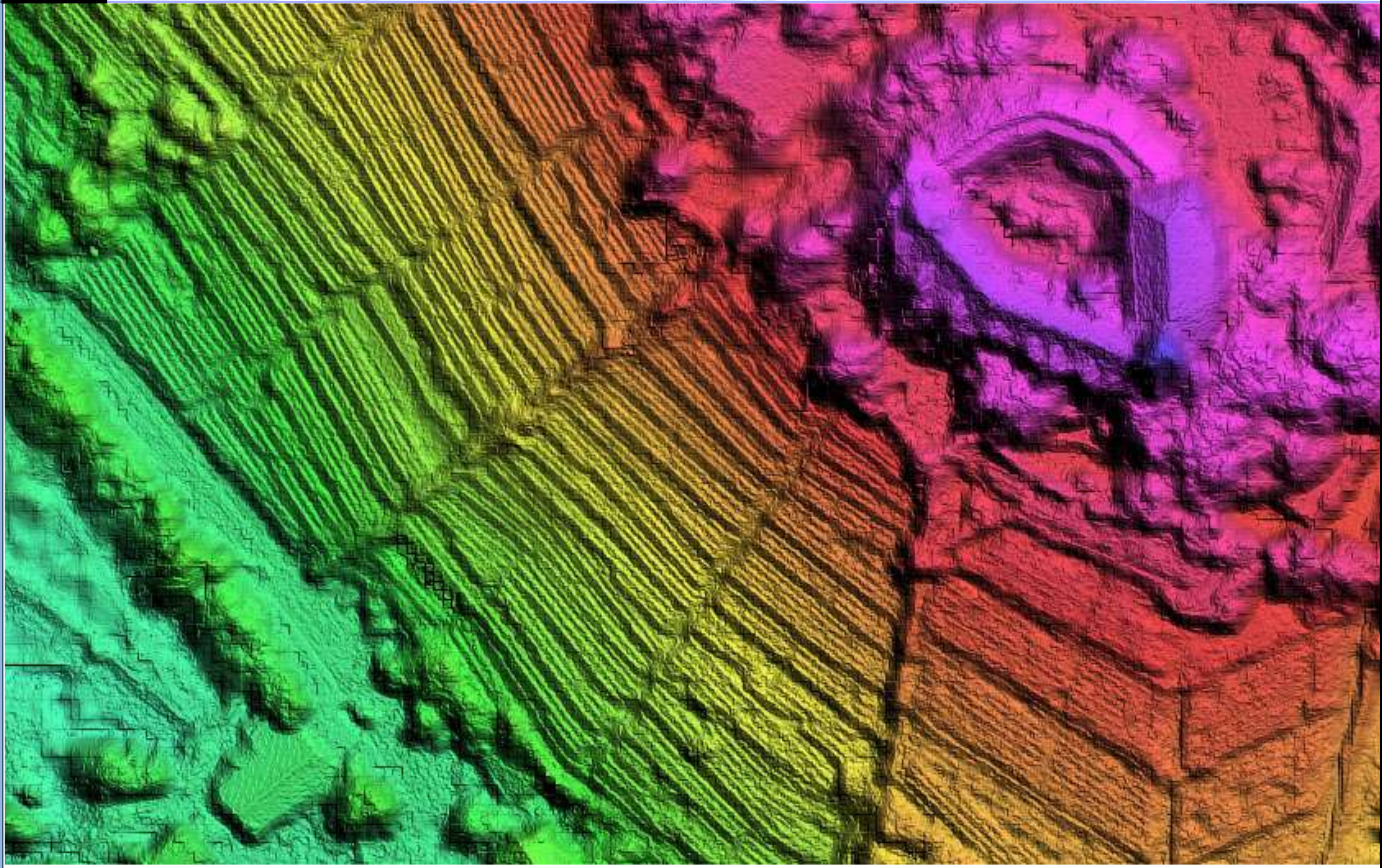
Example – UC-X, 25cm DSM
(*K. Wolff 2009)*



Example – DMC image, GSD 8cm
(*K. Wolff 2009)*

Example – DMC, 25cm DSM (*K. Wolff 2009)*



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Conclusions (1/2)

- Results underline the **high potential of digital image recording, performance of different sensors quite close**

  Abs. Accuracy (RMS) of object point determination

  very dense control ¼ - ½ pix GSD

  more realistic control ~½ pix GSD

  Abs. Accuracy (RMS) of DSM (height)

  from check points about ½ - 1 pix GSD

- Accuracy potential already **close to the accuracy of reference data** (i.e. control points, LiDAR data)
- question whether remaining differences of relevance for later practical operation or only academic discussion?

Conclusions (2/2)

- **Other factors gain in importance** (environmental conditions, choice of reference data) and may have larger impact on final accuracy than choice of sensor system itself
- **Sensor and sensor related software chain** is tightly coupled and has to be considered
- All results rely on (one single) DGPF data set only – **transfer of results to later production environments**?

Upcoming steps

- Structuring of project and increase of coordination between different working groups, for example
  - Pre-defined control point configurations
  - Reference image coordinate data sets
- Next project team meeting scheduled for **October 5-6, 2009** at Universität Stuttgart, Germany
- Project still **open for active participation** (stronger internationalization of project desired)
- Project web site (including all publications and data set descriptions): www.ifp.uni-stuttgart.de/dgpf (in German)
- Project experiences may also serve as input for **future certification strategies**

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