

PERFORMANCE OF LARGE-FORMAT DIGITAL CAMERAS

Karsten Jacobsen

Leibniz University Hannover, Germany
Institute of Photogrammetry and Geoinformation
jacobsen@ipi.uni-hannover.de



Introduction

2nd generation of Z/I Imaging DMC introduced large format cameras with monolithic large size CCDs, not requiring stitching of sub-images, avoiding possible geometric problems of stitching

Nevertheless CCD may have not a satisfying flatness → systematic image errors, but deviation from plane usually is stable, allowing precise camera calibration

Vexcel Imaging changed the fusion of the sub-images by the so called monolithic stitching in fitting the UltraCam sub-images to the monolithic green image – the geometry of the green image influences the final image geometry and remaining stitching errors may occur

check of image geometry is required – the corresponding systematic image errors should be respected during data acquisition – not all software packages are able to do this, so the model deformation has to be computed to estimate the influence to achieved data



Self-calibration by additional parameters

Different formula sets for self-calibration

Ebner-parameters are eliminating systematic effects in v.-Gruber-points (3X3) – general parameter set not respecting reasons for geometric problems – not satisfying for digital cameras

Grün-parameters = extension of Ebner parameters to 5X5 points in image – during camera test of German Society of Photogrammetry satisfying results, but general parameters respecting not reasons for geometric problems

Parameter set in Hannover bundle adjustment program **BLUH** dominated by additional parameters taking care about source for systematic image errors + few general parameters



Additional parameters in program BLUH

12 additional parameters for standard images – including 3 parameters for radial symmetric distortion

+ special additional parameters

Special additional parameters:

34 – 41 for possible stitching problems of DMC (version 1) 8 parameters

79 common deformation of DMC (version 1) sub-images

42 – 49 scale parameters for UltraCam

50 – 57 shift X parameters for UltraCam

58 – 65 shift Y parameters for UltraCam

66 – 73 UltraCam master images perspective



stitching problems of UltraCam
32 parameters

81-88 parameters for geometry at image corners

(**problem of CCD flatness**) e.g.

81. $x' = x + P81 * |(x^3 * y^3)| * 10^{-9}$ tangential for

$y' = y - P81 * |(x^3 * y^3)| * 10^{-9}$ lower right quarter

85. $x' = x + P85 * x^2 * y^2 * 10^{-6}$ radial for

$y' = y + P85 * x^2 * y^2 * 10^{-6}$ lower right quarter



Remaining systematic image errors

Systematic image errors determined by additional parameters in bundle block adjustment – **only systematic errors determined which can be expressed by used additional parameters**

Systematic image errors may be undetected → **check for remaining systematic image errors** required

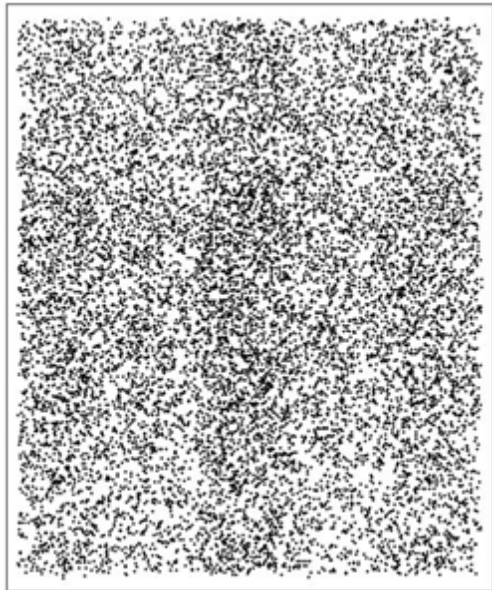
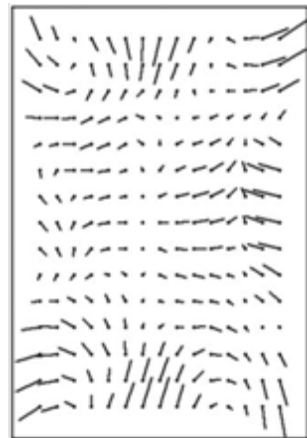


Image size:
96.4mm x 82.1mm

Overlay of all 14040 image points DMC II-250, 9cm GSD

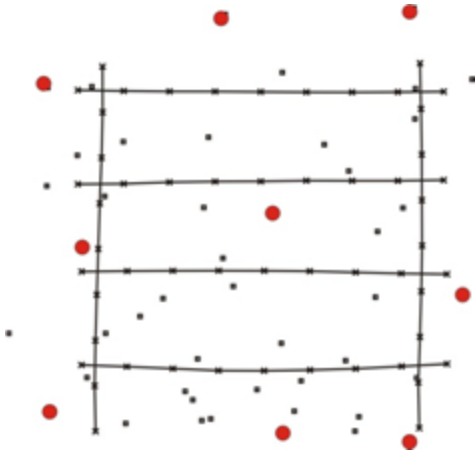
Each image point gets residuals in the bundle block adjustment
Overlay of all image points with their residuals in image space
Averaging of the overlaid residuals in image sub-units →
remaining systematic image errors



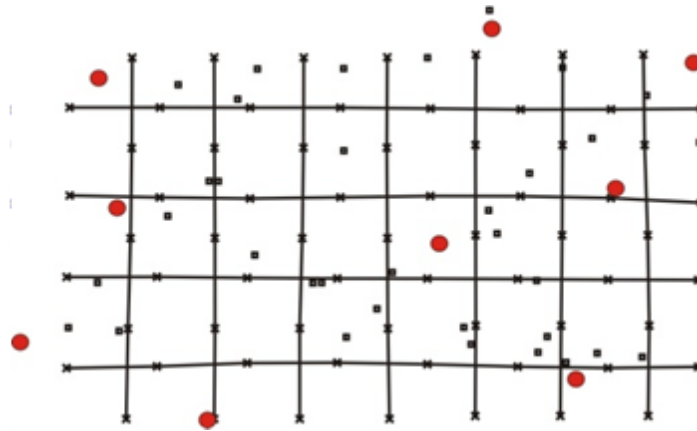
Remaining systematic image errors – UltraCam Eagle without self-calibration
Neighbored vectors computed individually, but floating average filter 3x3



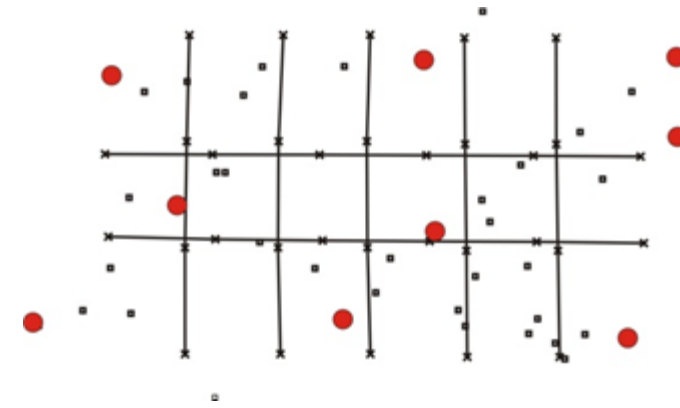
Handled data sets for analysis of image geometry



DMC II-250 5cm GSD

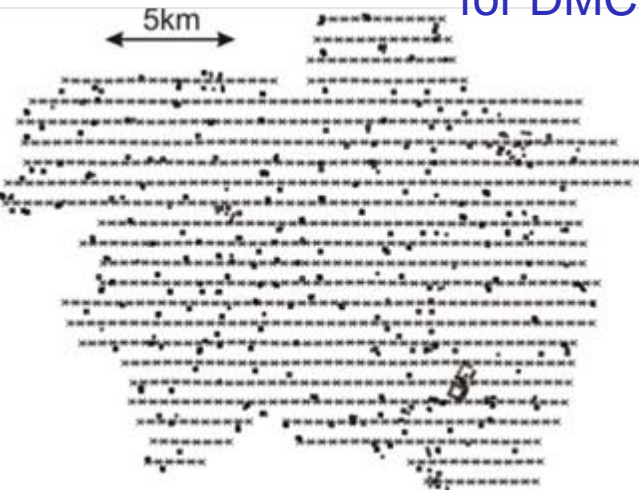


DMC II-250 9cm GSD, 2x(p=q=60%)

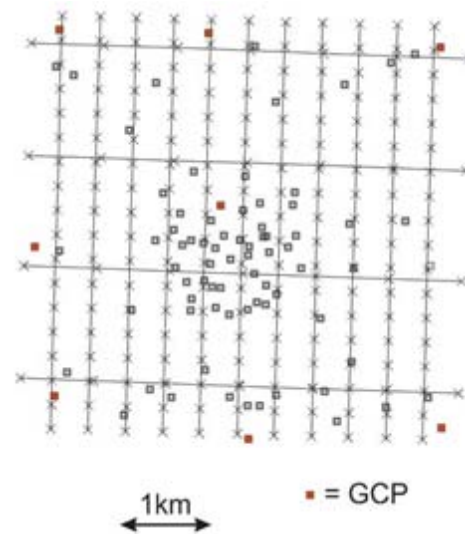


DMC II-250 15cm GSD

for DMC II-140 and DMC II-230 similar configuration 2x(p=q=80%)



DMC II-230 7cm GSD
p=60%, q=40%



UltraCam Eagle

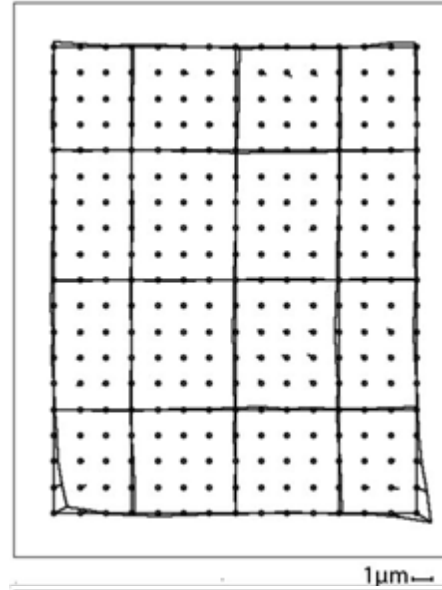
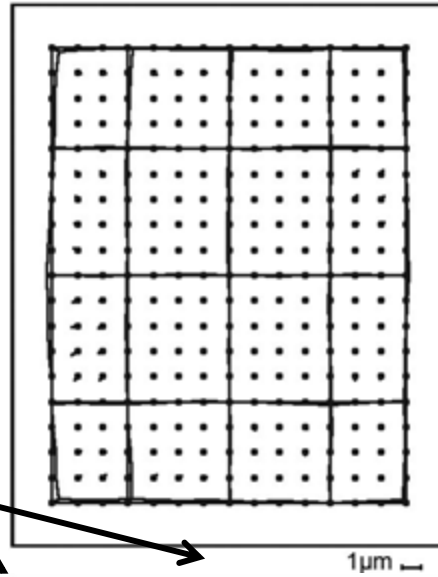
N-S p=q=60% 5cm GSD

E-W p=q=60% 15cm GSD

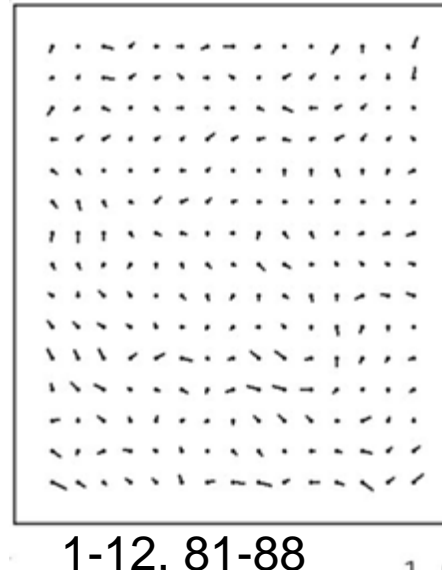
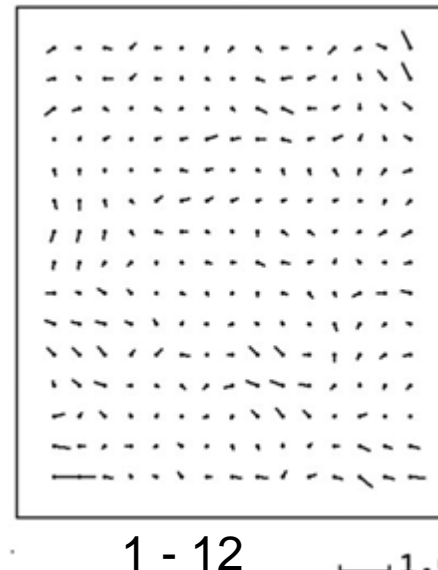
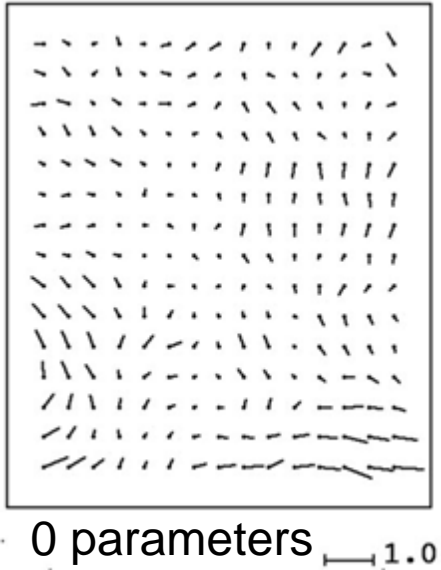


DMC II-250 9cm GSD

Systematic image errors →



Remaining systematic image errors ↓



Size of additional parameters

0-12		0-12,81-88	
RMS	max.	RMS	max.
0.034	0.083	0.025	0.136

[pixels]

Size of remaining systematic image errors [pixels]

a.p.	0	1-12	1-12 81-88
RMS	0.032	0.027	0.014
max.	0.11 6	0.103	0.041

← additional parameters



UltraCam Eagle

Additional parameters

From left to right

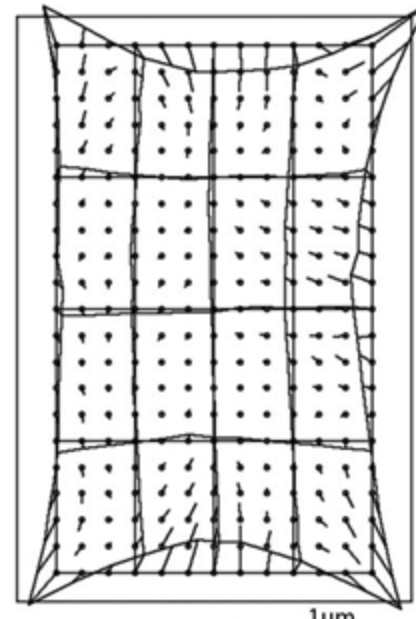
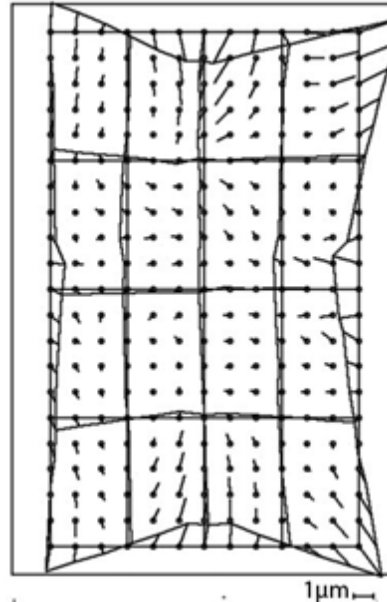
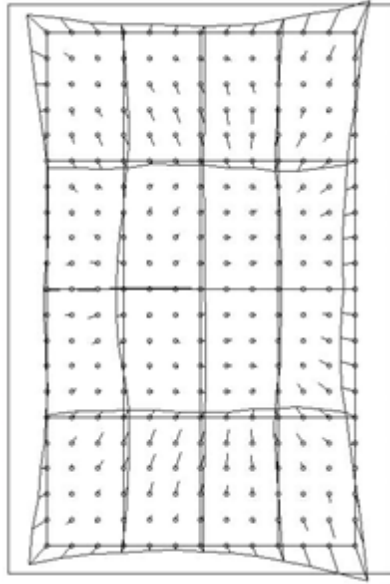
0

1-12

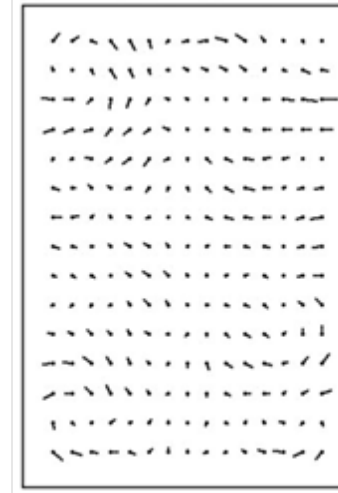
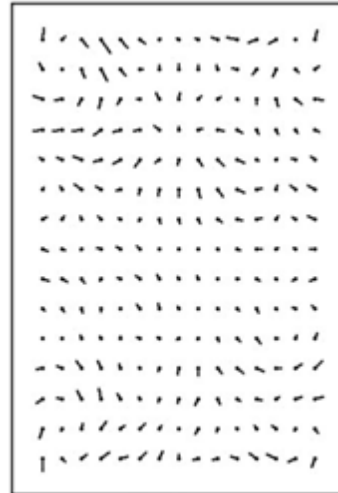
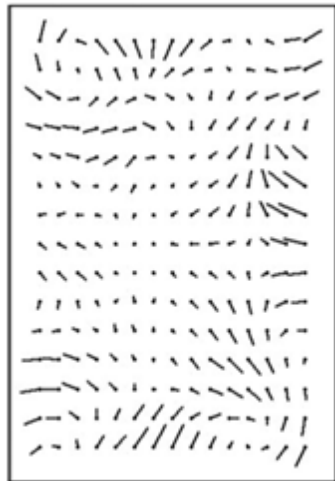
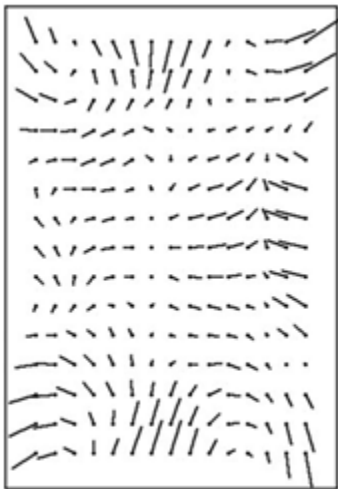
1-12, 42-73

1-12, 42-73, 81-88

Automatic reduction to required parameters



Systematic image errors



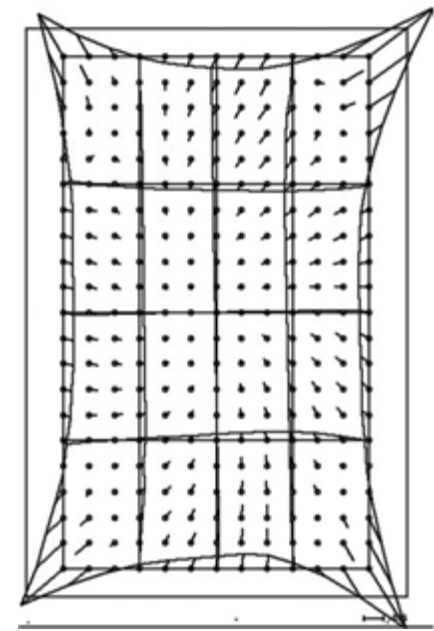
Remaining systematic image errors



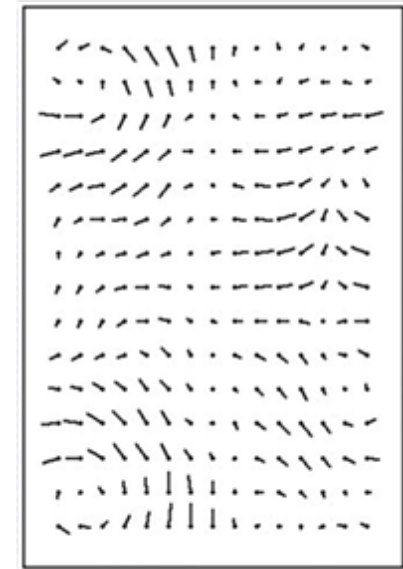
[pixels]

UltraCam Eagle

Add. par.	0	1-12	1-12, 42-73	1-12, 42-73, 81-88	81-88
Systematic image errors					
RMS	-	0.092	0.102	0.092	0.094
max.	-	0.360	0.517	0.517	0.665
Remaining systematic image errors					
RMS	0.056	0.046	0.027	0.029	0.038
max.	0.246	0.173	0.108	0.119	0.133



Syst.
Image
errors
only
add.par
81-88



Remain.
syst.
image
errors

a.p.	0	1-12	1-12 81-88
RMS	-	0.034	0.014
max.	-	0.083	0.041
RMS	0.032	0.027	0.014
max.	0.11 6	0.103	0.041

DMC II-250 syst. image errors

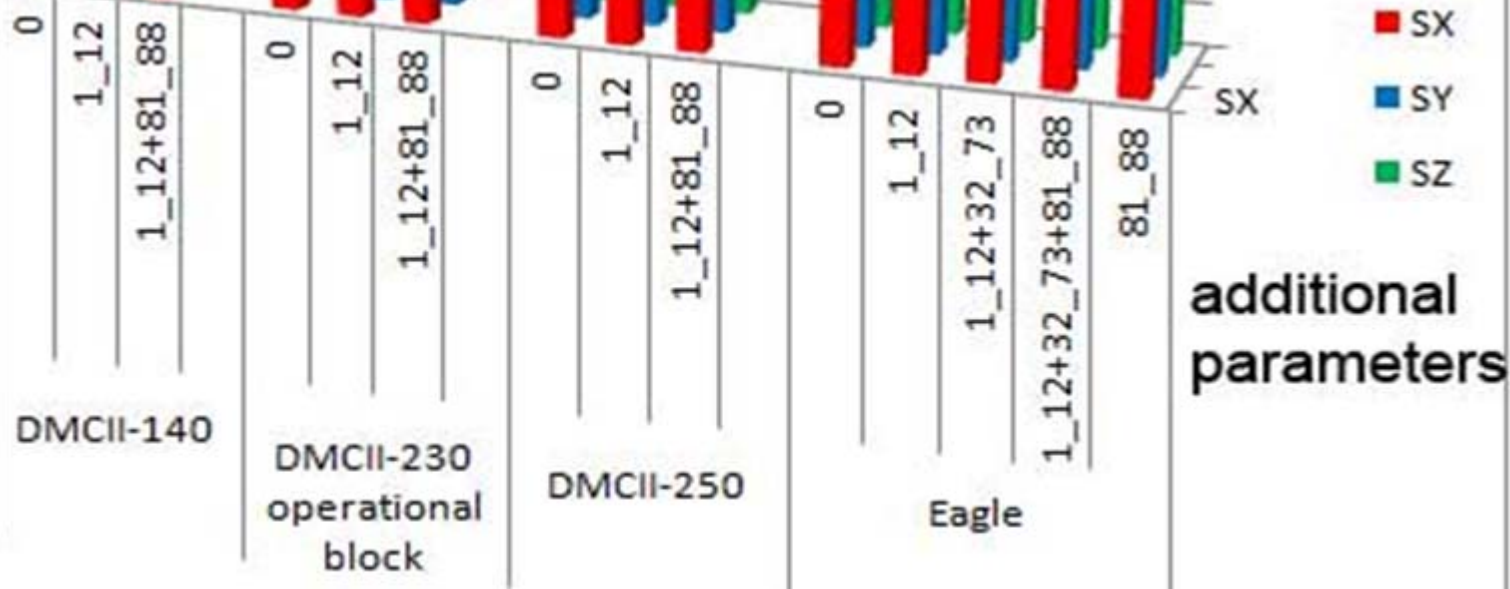
remaining syst. Image errors



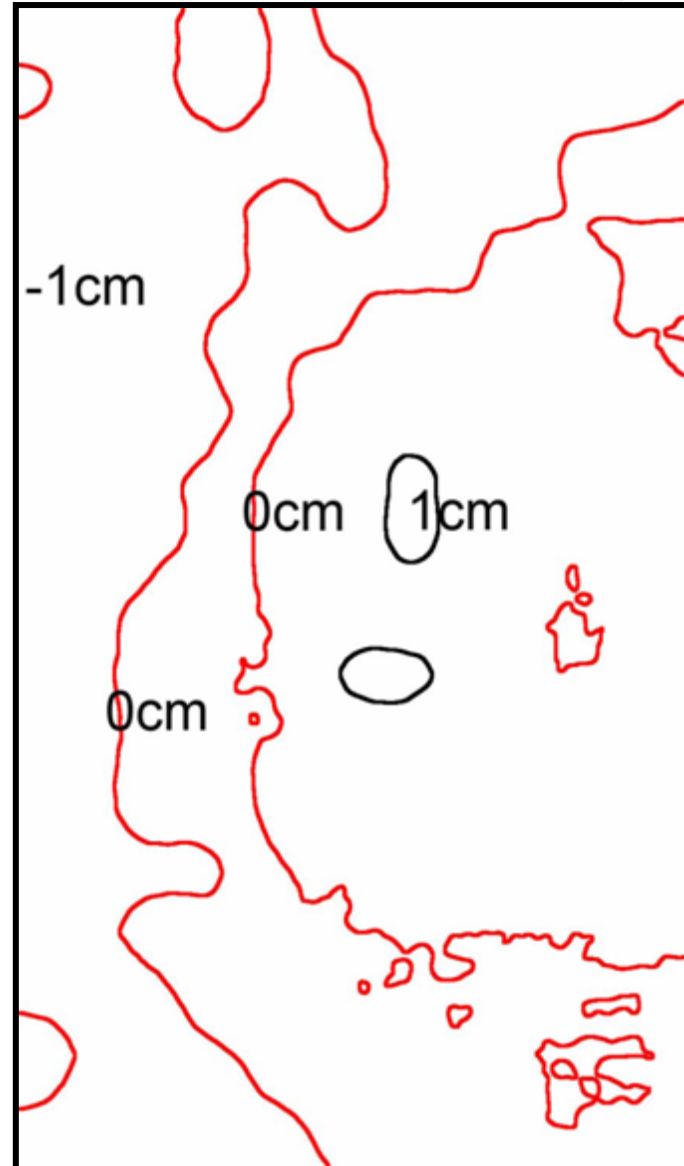
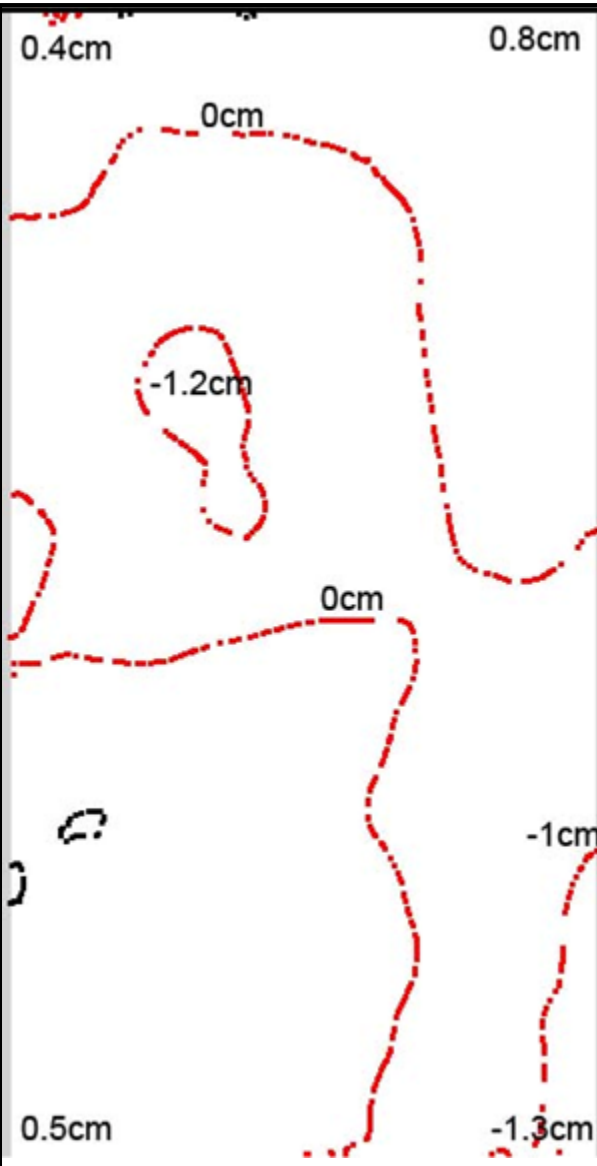
Comparison of accuracy at independent check points

[GSD]

2
1,8
1,6
1,4
1,2
1
0,8
0,6
0,4
0,2
0



Model deformation by systematic image errors DMC II-250



left: model deformation of DMC II-250, 5.4cm GSD,
based on additional
parameters 1-12 + 81-88

right: model deformation of DMC II-250, 9cm GSD,
based on additional
parameters 1-12 + 81-88

both maximal 0.22 GSD

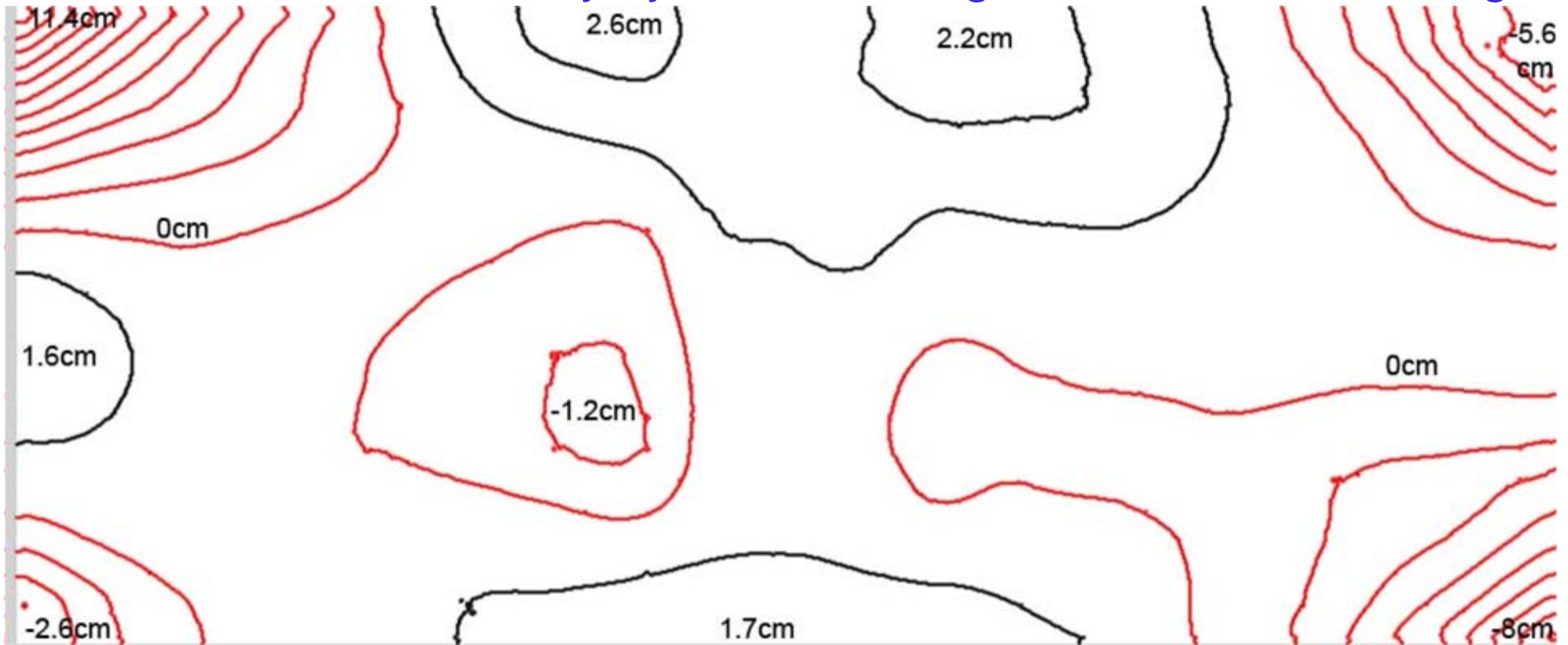
Data acquisition usually
based single stereo pair –
maximal height influence of
0.22 GSD negligible

base / height = 1 : 3.45
(p=60%)

0.22 GSD → $S_{px} = 0.06$ pixels



Model deformation by systematic image errors UltraCam Eagle



5cm GSD, maximal 2.2 GSD height influence

-located in model corner, usually not used because of model overlap

- nevertheless also in usually used area not negligible in relation to achievable pointing accuracy – data acquisition has to respect systematic image errors

$f=80\text{mm}$ base / height = 1: 2.3 2.2 GSD \rightarrow $S_{\text{px}} = 0.96$ pixels



Image quality

camera	blue, pan-sharpened	green, pan-sharpened	red, pan-sharpened
DMC II-140 January	1.01	1.01	1.02
DMC II-230	0.98	0.97	0.98
DMC II-250	0.87	0.88	0.84
UltraCam Eagle January	1.01	1.02	1.03

factor for effective image quality

- can be influenced by edge enhancement, enlarging image noise

camera \ color channel	blue	green	red	blue	green	red
	Mean of 4 groups			Weighted mean		
DMC II-140 January	1.30	1.06	1.20	0.61	0.61	0.61
DMC II-230	1.80	1.40	1.80	0.83	0.61	0.61
DMC II-250	1.80	1.80	1.95	1.04	0.67	0.67
UltraCam Eagle January	2.72	2.48	2.48	3.00	2.54	2.30

Standard deviation of image noise



conclusion

image geometry presented by systematic image errors very important topic for reaching possible high geometric accuracy of photogrammetric products

used set of additional parameters must be able to determine the systematic image errors

remaining systematic image errors should be checked for not respected effects

systematic image errors of all analyzed DMC II images small, only height improved by block adjustment with self-calibration, model deformations small up to negligible

UltraCam Eagle showing larger systematic image errors and model deformations which cannot be neglected for height determination – should be respected by the data acquisition system

Image quality of DMC II and UltraCam Eagle without problem, only the noise of UltraCam larger, influencing object identification in dark areas (signal to noise relation)

