

# Geometric Performance of Digital Airborne Camera Systems A User's Perspective

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## MAPS geosystems overview

- High emphasis on automated production procedures
- AT Experience
  - First airborne GPS assisted aerial triangulation project in 1990 (with assistance from TU-Stuttgart)
  - 305 Blocks
  - 300,000 Frames
  - MAPS extensive experience in large block

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# Digital Elevation Models

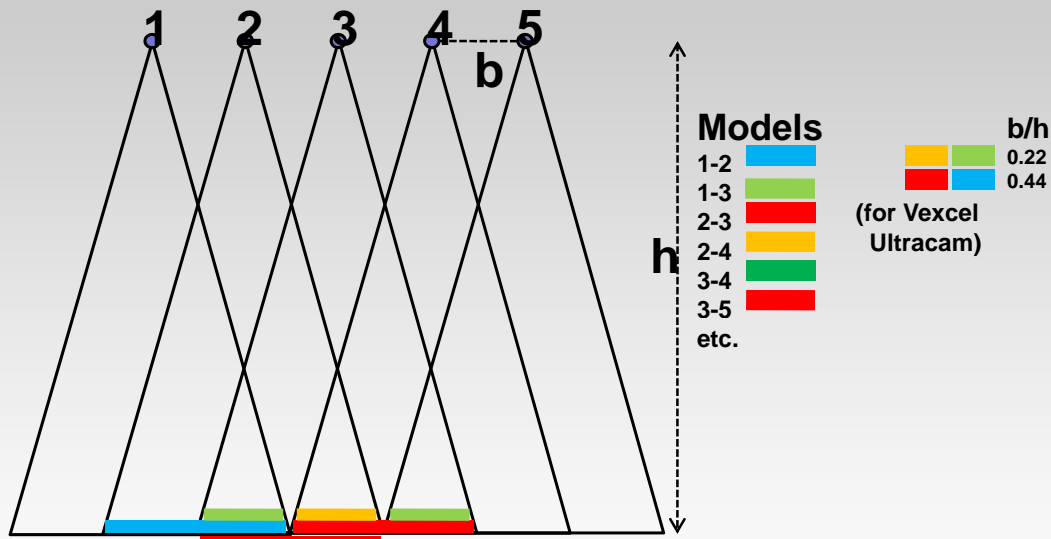
- Products
  - Elevation model
  - Contours
  - For Orthophotos
- Experience
  - Since 15 years not drawn a contour
  - 150,000 models
- I.e. Sudan Project:
  - 70,000 frames
  - 15,000 km<sup>2</sup>
  - 2 m grid
  - +/- 10cm accuracy
  - By Image correlation

# Dense DEMs

- High Density
- By Image correlation
- Suitable terrain in Middle East & Africa
- Used for
  - Automation, Filtering
  - Increased redundancy increases accuracy
- Generally produced from at least two different models

# DEMs for QA / Error Analysis

- Generate DEMs of overlapping models ( $p = 70\%$ )



- Subtract
- Trends = AT , Scan errors
- StdDev indicate relative accuracy of point

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## Application to Digital Cameras

- Further improvements in productivity expected
  - Remove of film
  - Reduced Noise, Scratches, ...
  - Increased overlap
- Preference for frame based Cameras
  - Redundancy
  - Independence of IMU / GPS
  - Same production flow

**What is the geometric accuracy of digital cameras?  
A question the manufactures are reluctant to answer.**

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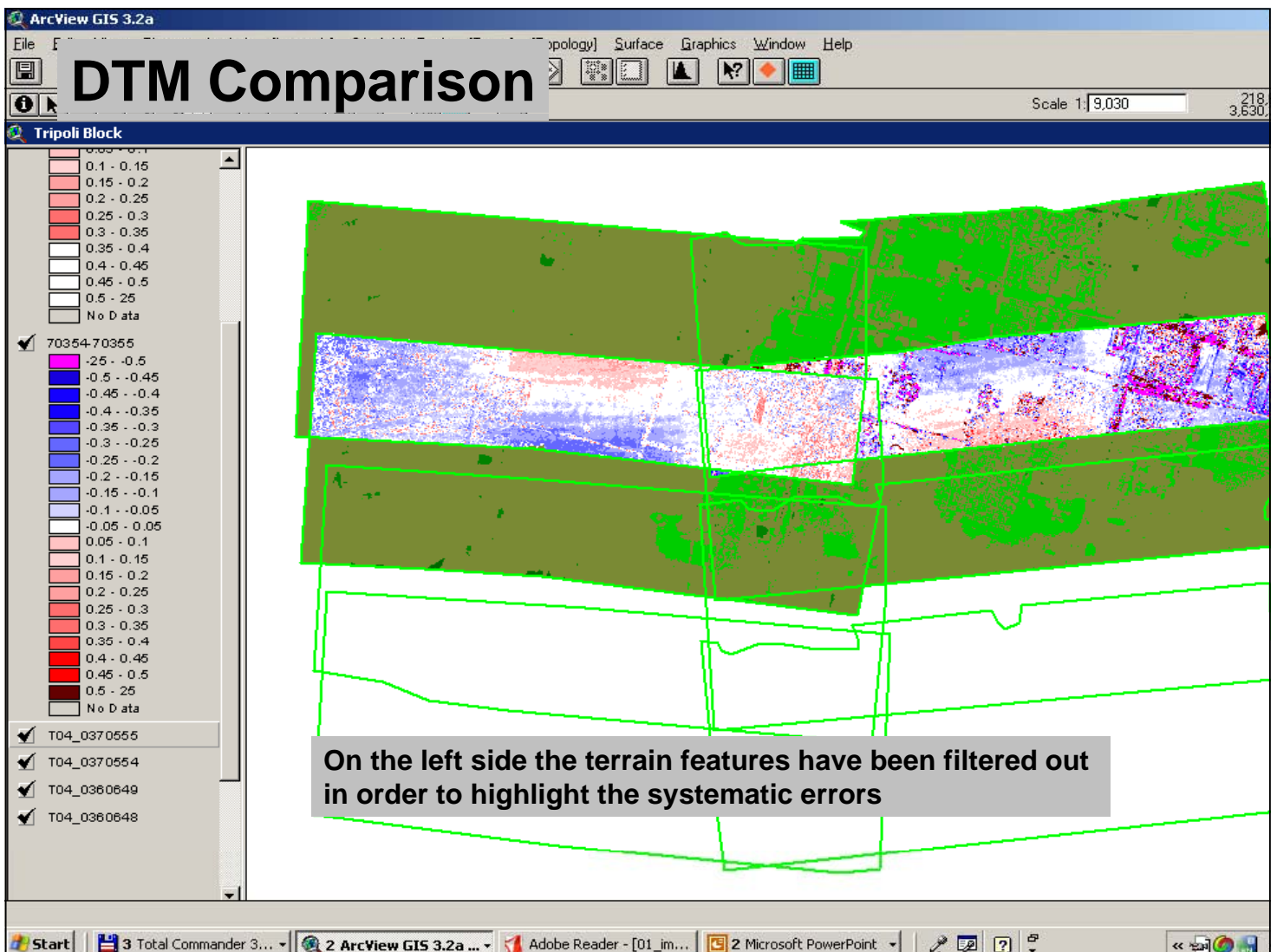
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# UltraCamD Project Block 1

- 70% forward, 30% sidelap
- Airborne GPS Assisted
  - Limited control
  - IMU largely disregarded
  - Standard Airborne AT,  $S_0$  1um
- DEM analysis identified errors
  - Systematic, obviously from CCD
  - Systematic errors up to 0.5 ‰

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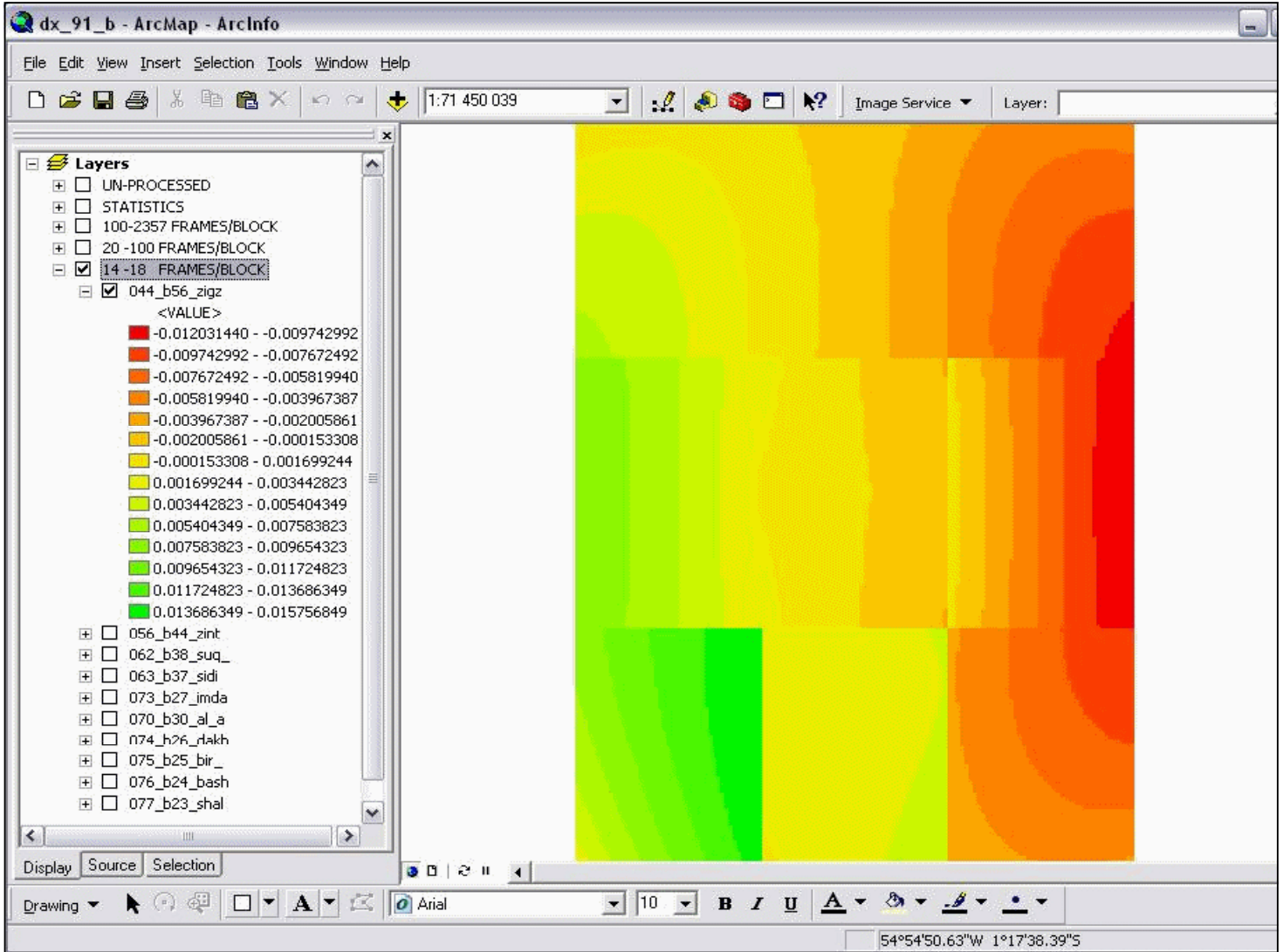
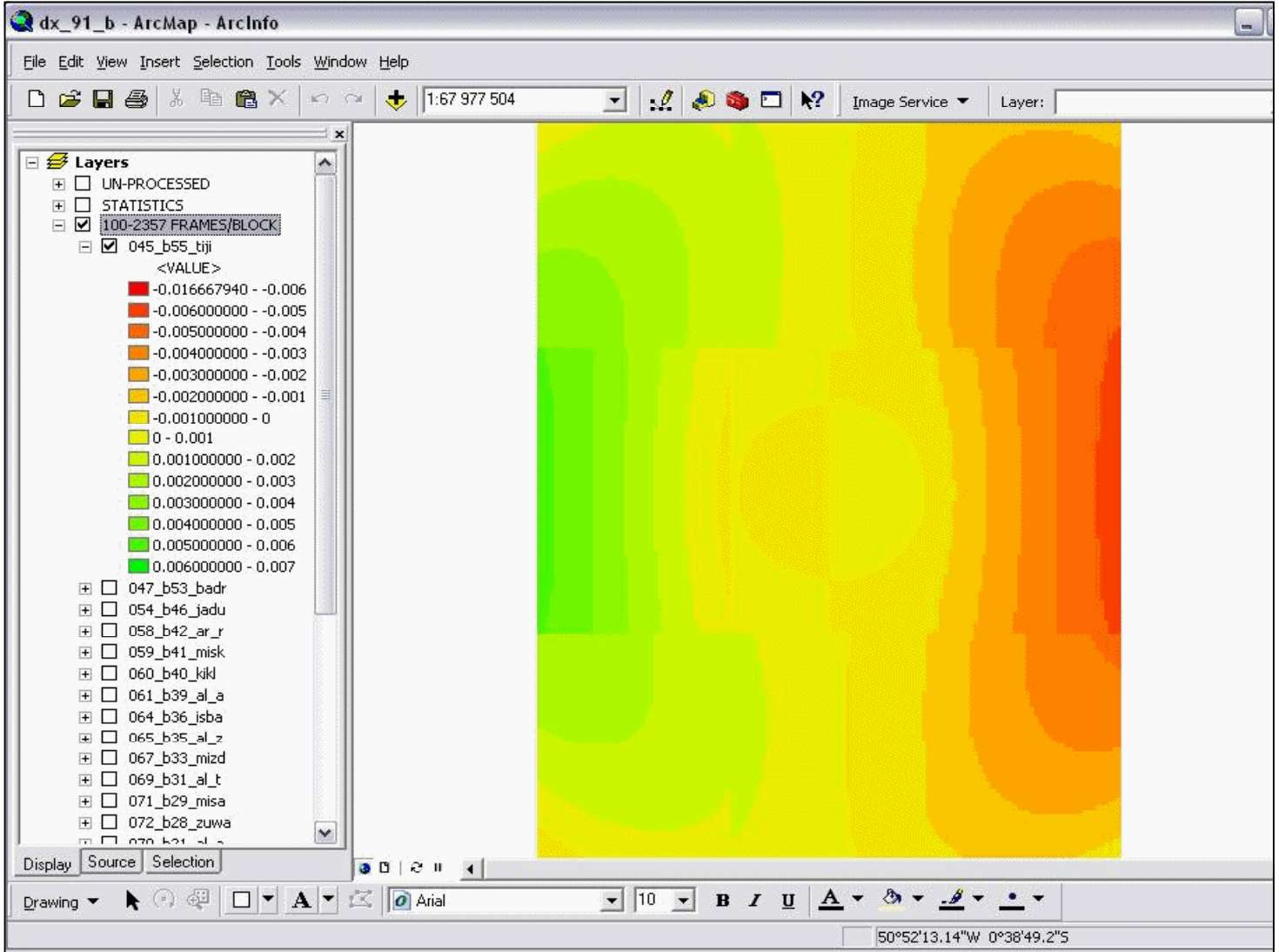
# CCD Based Self Calibration

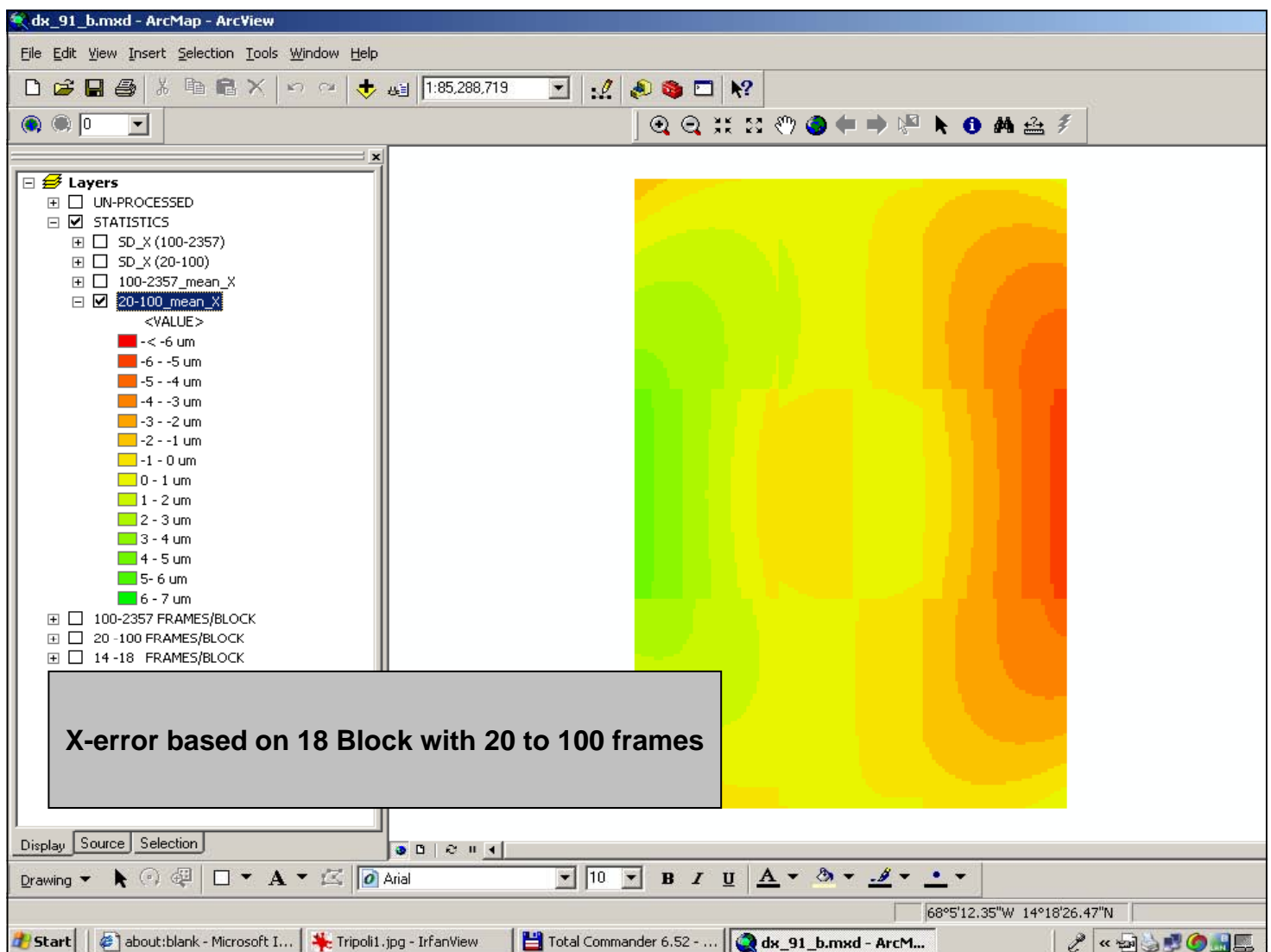
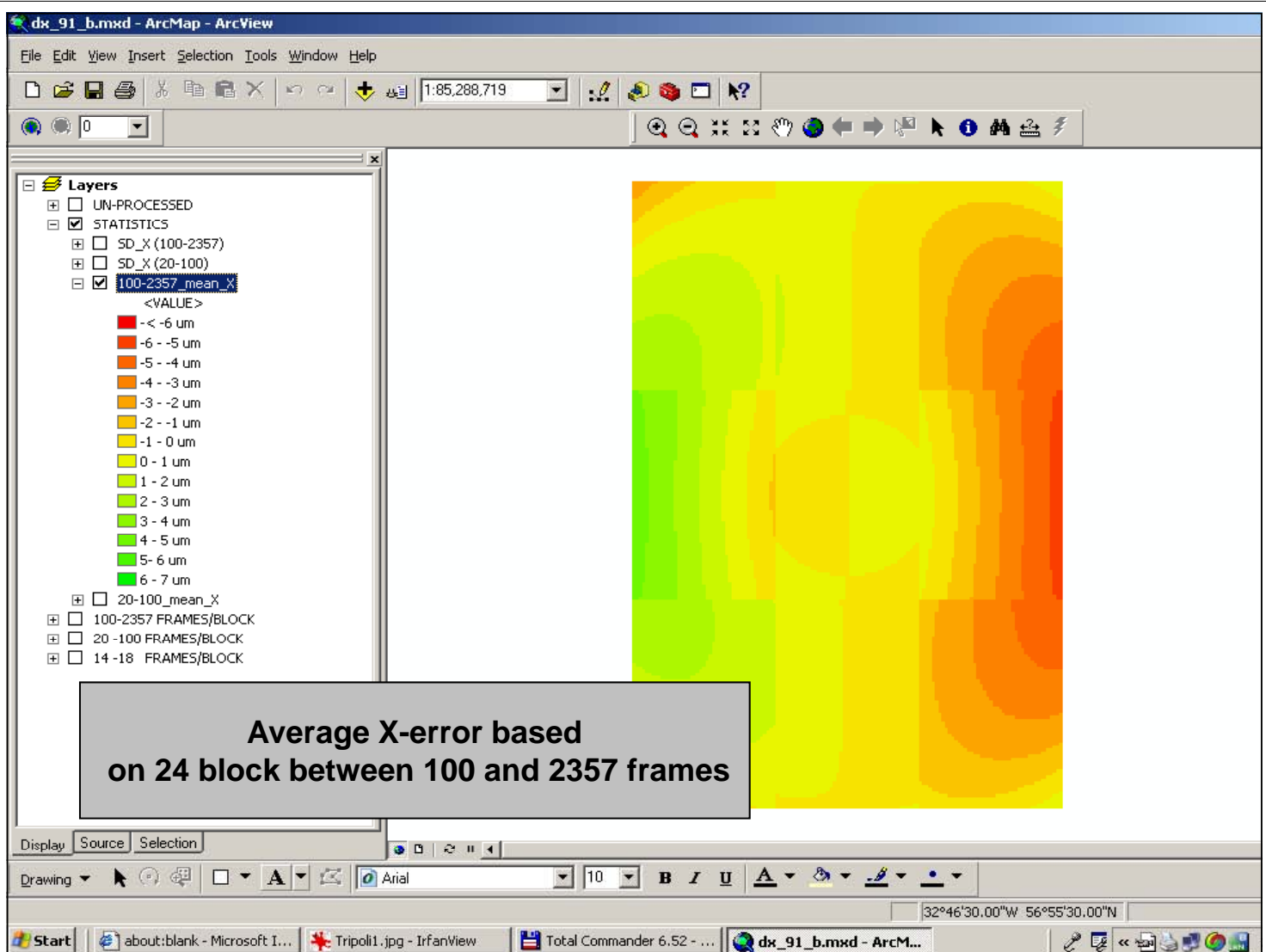
- Block Adjustment with Bingo
  - Utilize CCD specific self calibration
  - AT So 0.8um
  - CCD specific parameters indicated error of up to 6um!
- Feedback of CCD specific parameters
  - Apply correction grid to Image
  - Necessitated re-sampling L2 imagery
- Recreating DEM
  - Error substantially reduced
  - Systematic error < 0.1 ‰
- Indicates need for in situ calibration

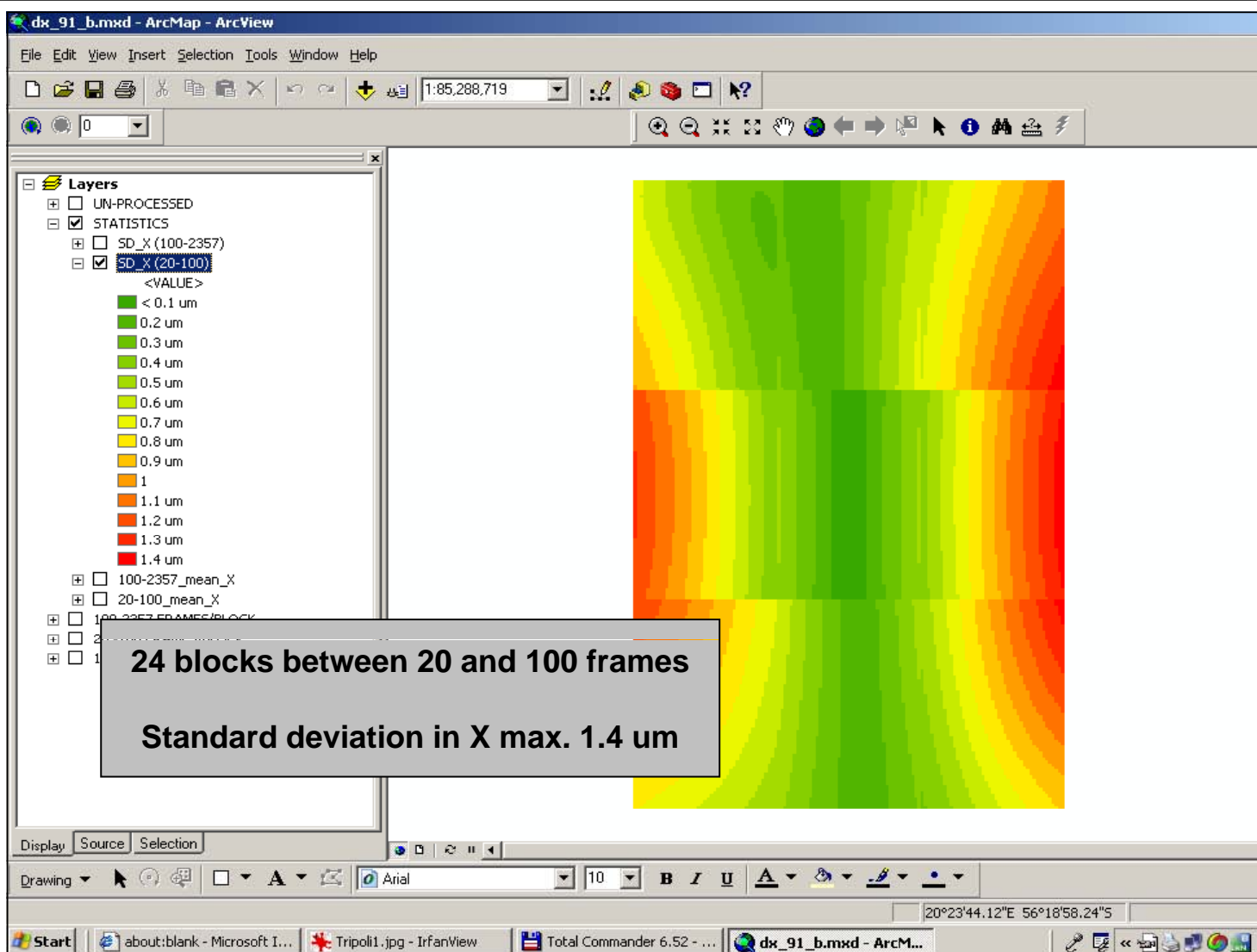
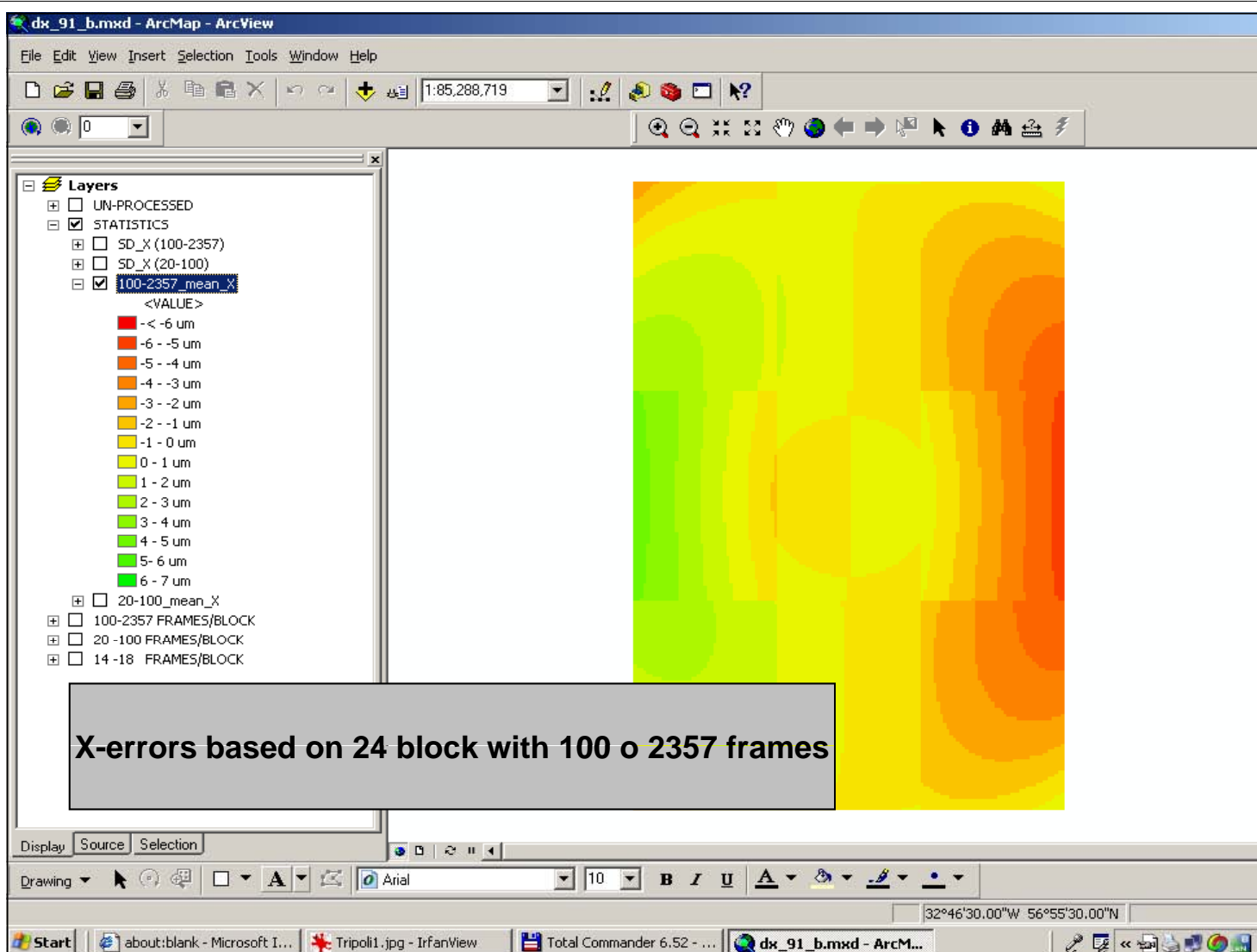
Question: How stable how often need to do *in situ*, how big block

# Full UltraCam Project

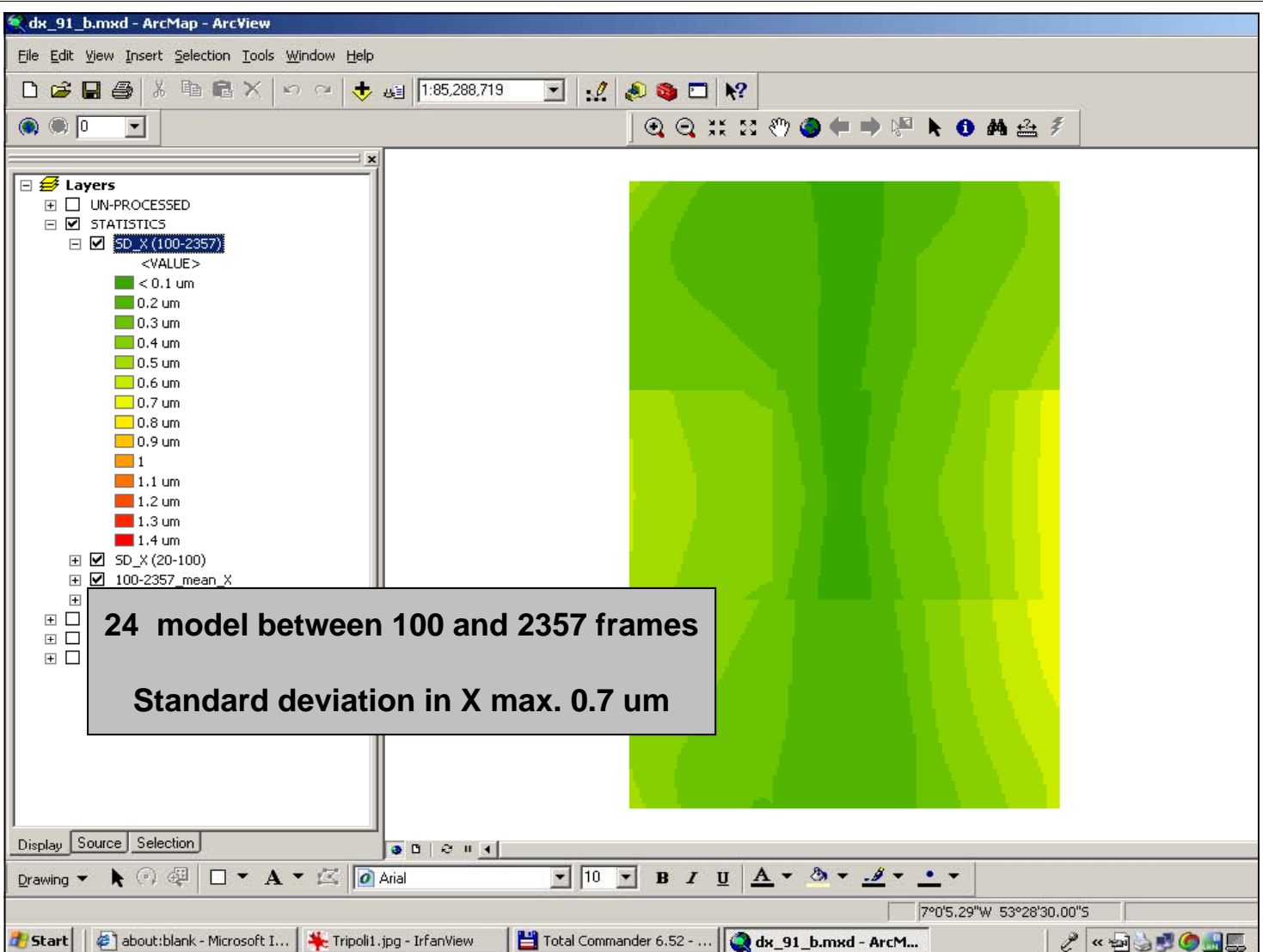
- 56 Blocks to date
- 11321 frames
- Block size range 14-2357 models  
(Airborne GPS Assisted)
- Block Adjustment with CCD specific self calibration
- Analysis of parameters different size blocks



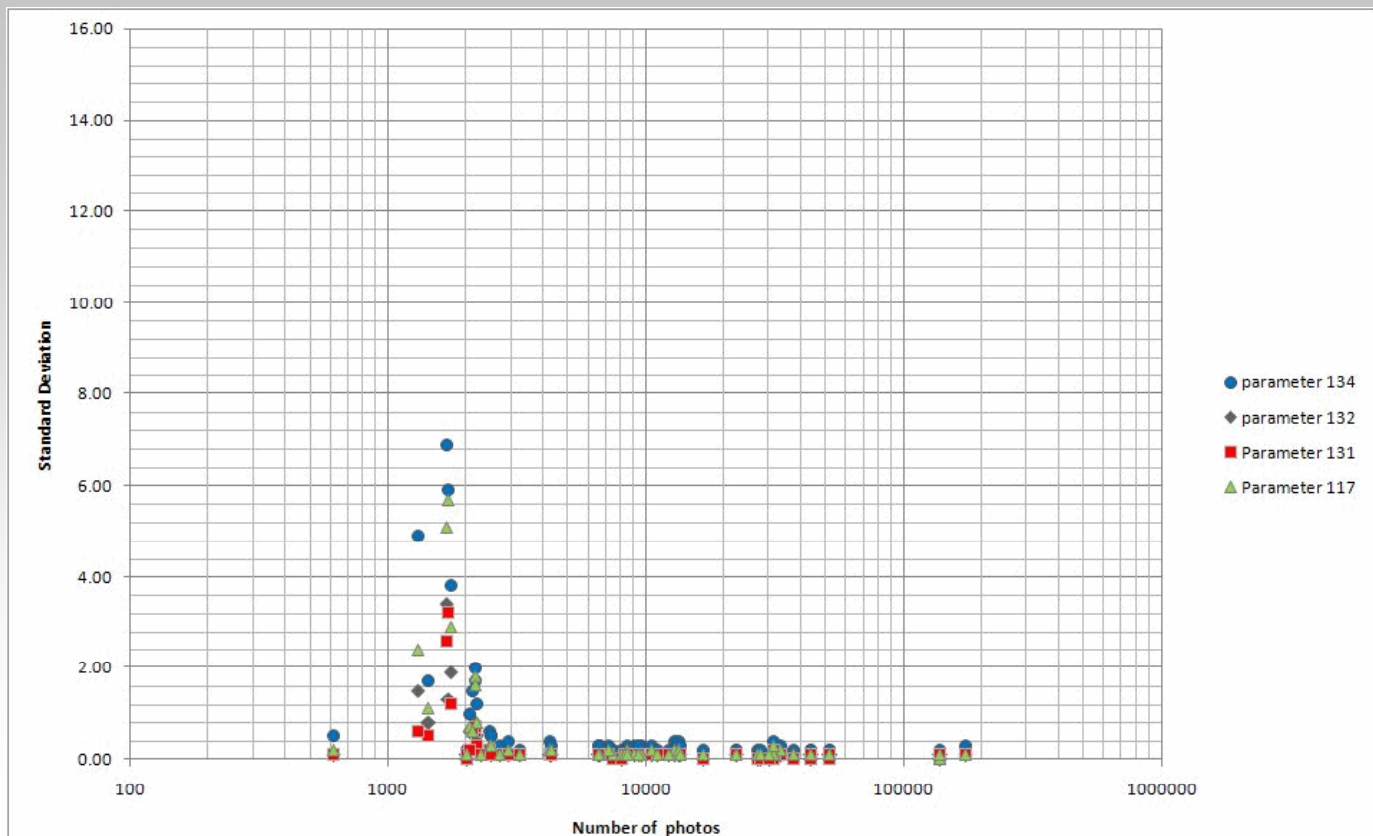








## Standard Deviation of Self-calibration parameters as a function of number of observations



# Summery

The m.s.e of the computed correction of a given image point based on the results the Self-calibration are:

- Based on 18 block with 20 – 100 frames:  
< 1.4 um (in X and Y)
- Based on 24 block with 100 – 2375 frames  
< 0.7 um (in X and Y)

# Investigation Summery

- Self-calibration procedure show a consistent error pattern that matches the array the camera CCDs
- No detectable differences over 8 month  
– (Need to test with different altitude and temp.)
- For parameter determination minimum Block size 200 frames

# Conclusion

- Errors do not significantly affect the accuracy of topographic mapping.
- Accuracy insufficient for highest accuracy requirements
  - Cadastral Applications
  - Engineering surveys
  - High precision terrain modeling.
- For high accuracy In Situ Calibration is required

# Recommendation

- In order to avoid additional image re-sampling, camera manufactures should enable the update the camera calibration parameters used in post processing determined by self calibration

I would like to express my thanks to the staff of both – Z/I and Vexcel – for the frank and open discussion which led us to conduct this investigation.

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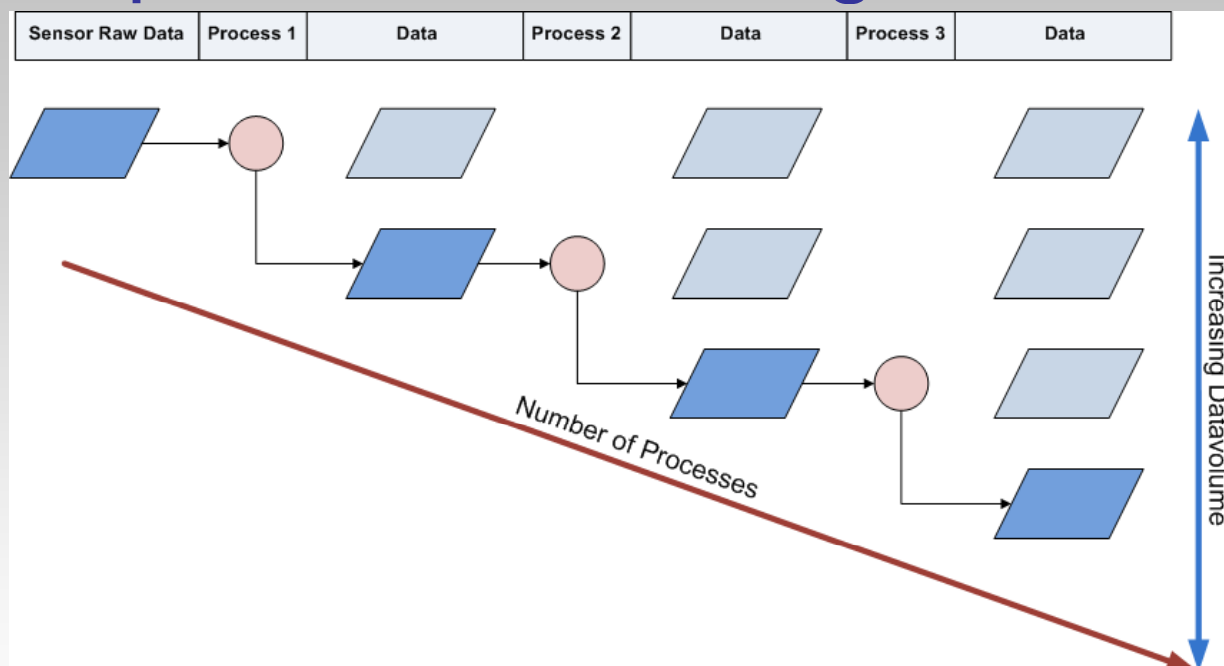
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# The explosion of image data

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## Sequential Processing



- No data duplication/redundancy
- Primary data remains unchanged
- Parameter driven universal process creates final application specific datasets

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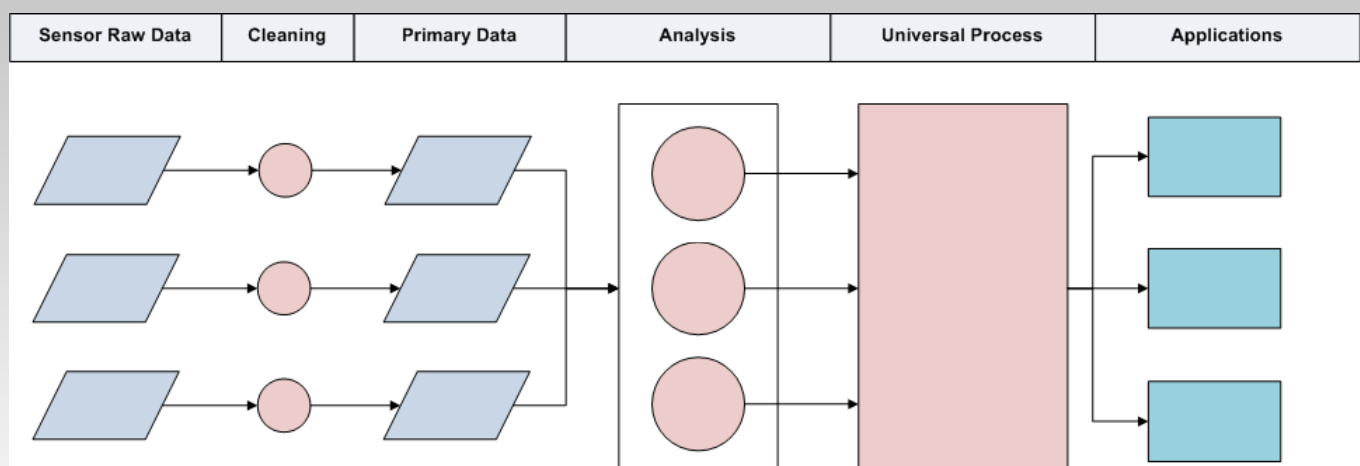
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# Sequential vs 'Holistic' Processing

Separates the photogrammetric procedure into 3 different base components, consisting of:

- sensor(s)
- analysis procedures
- processor

## Holistic Processing



- **No data duplication/redundancy**
- **Primary data remains unchanged**
- **Parameter driven universal process creates final application specific datasets**

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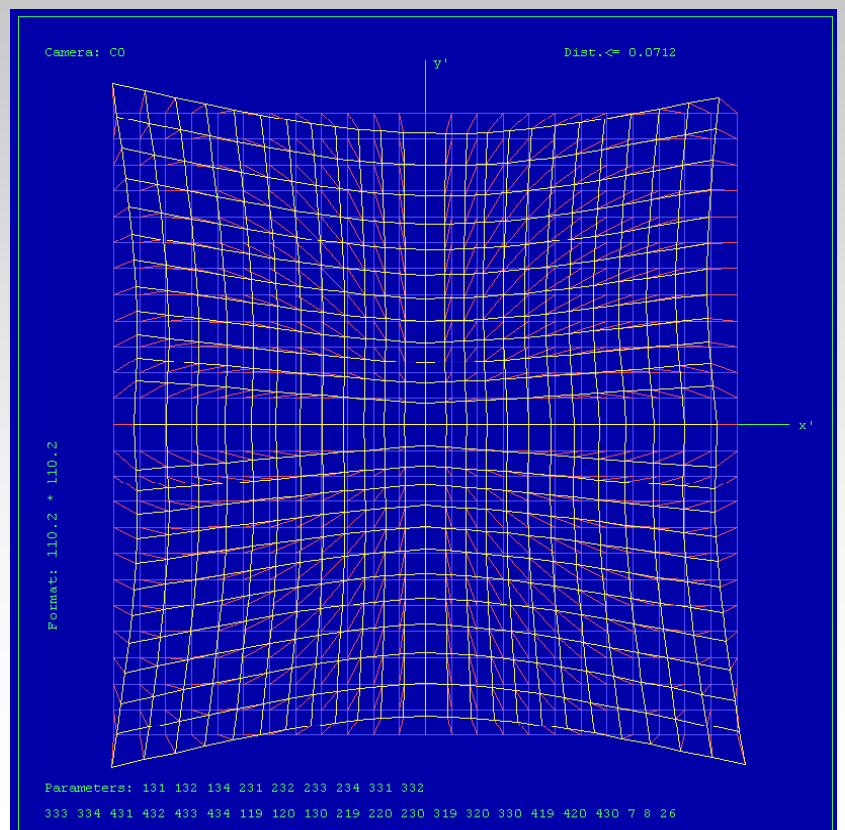
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# Cone 0, Distortion Diagram, Not Effective in Output Image

UltraCam D,  
Serial Number  
UCD-SU-1-0015

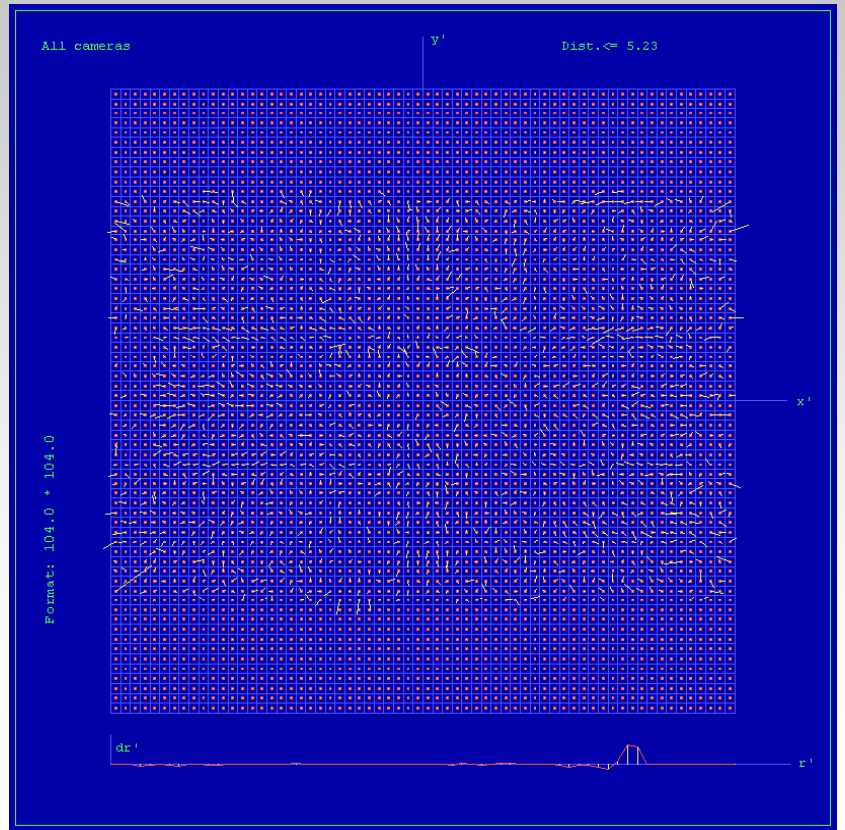


# Full Pan Image, Residual Error Diagram

Residual Error  
(RMS): 0.76 $\mu$ m

UltraCam D,  
Serial Number  
UCD-SU-1-0015

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Seite  
Page 2



9987  
DKD-K-  
05201  
05-07

CAMERA TYPE: RMK TOP 15 SERIAL NO. 142827  
LENS TYPE: PLEDOGN A3 SERIAL NO. 142823  
MAX. APERTURE: F/4 NOM. FOCAL LENGTH: 153 MM

1) CALIBRATED FOCAL LENGTH = 153.401 MM

2) DISTORTION / $\emptyset$ .001 MM, REFERRING TO P.P. OF SYMMETRY PPS

S/MM= 0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150

5	0	0	0	1	1	2	3	4	3	2	1	-1	-2	-2	0	-1
6	0	0	-1	0	1	1	2	1	0	0	-1	-2	-2	0	1	1
7	0	0	0	0	1	2	3	3	2	1	-1	-2	-1	-2	-1	-1
8	0	0	0	1	1	2	2	3	1	0	0	-2	-3	-2	0	-1

AV. 0 0 0 0 1 2 2 3 2 1 0 -1 -2 -1 0 0

3) P.P. OF AUTOCOLLIMATION AND FIDUCIAL CENTRE, REFERRING TO PPS

P.P. OF AUTOCOLLIMATION PPA	X=	-0.004	Y=	-0.004	MM
FIDUCIAL CENTRE FC	X=	-0.010	Y=	-0.008	MM
CORNER FIDUCIAL CENTRE FCC	X=	-0.011	Y=	-0.002	MM

4) FIDUCIAL MARKS, REFERRING TO PPS

X1=	112.984	X2=-	113.011	X3=	-0.008	X4=	-0.012	MM
Y1=	-0.006	Y2=	-0.010	Y3=	112.985	Y4=-	113.001	MM
DISTANCES	1-2=	225.995	3-4=	225.986	MM			
X5=	112.983	X6=-	113.018	X7=-	113.007	X8=	112.988	MM
Y5=	112.986	Y6=-	113.004	Y7=	112.990	Y8=-	112.997	MM

5) PHOTOGRAPHIC RESOLVING POWER, IN CYCLES PER MM  
(AS PER DEFINITION, R. P. IS NOT A CALIBRATED DATUM)  
AREA WEIGHTED AVERAGE RESOLUTION 104

FIELD ANGLE /DEG = 0 7 14 21 28 35 42

RADIAL LINES	145	144	141	136	114	106	86
TANGENTIAL LINES	145	114	109	113	101	87	64

FILM: KODAK PANATOMIC X 3412 SPEED 40 AFS  
DEVELOPED IN AGFA G 74 C AVIPHOT

6) Filter

7) Magazines

8) Measuring uncertainty

Distortion: U = 3  $\mu$ m ; Point of symmetry and collimation: U = 3  $\mu$ m ; Image center: U = 5  $\mu$ m ; Camera constant: U = 5  $\mu$ m

The specification indicates the upgraded measuring uncertainty resulting from the multiplication of the standard measuring uncertainty by the factor k = 2. It was determined in conformity with DKD-3. The values of the measurement parameter lie within the specified range with a probability of 95%.

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# Text

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Seite  
Page 3



9987
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RMK TOP 15 NO. 142827  
PLEOGON A3 4/153 NO. 142823  
CFL=153.401 MM

DISTORTION /0.001 MM, REFERRING TO PPS

