Evaluation of digital surface models generated from high-resolution satellite imagery

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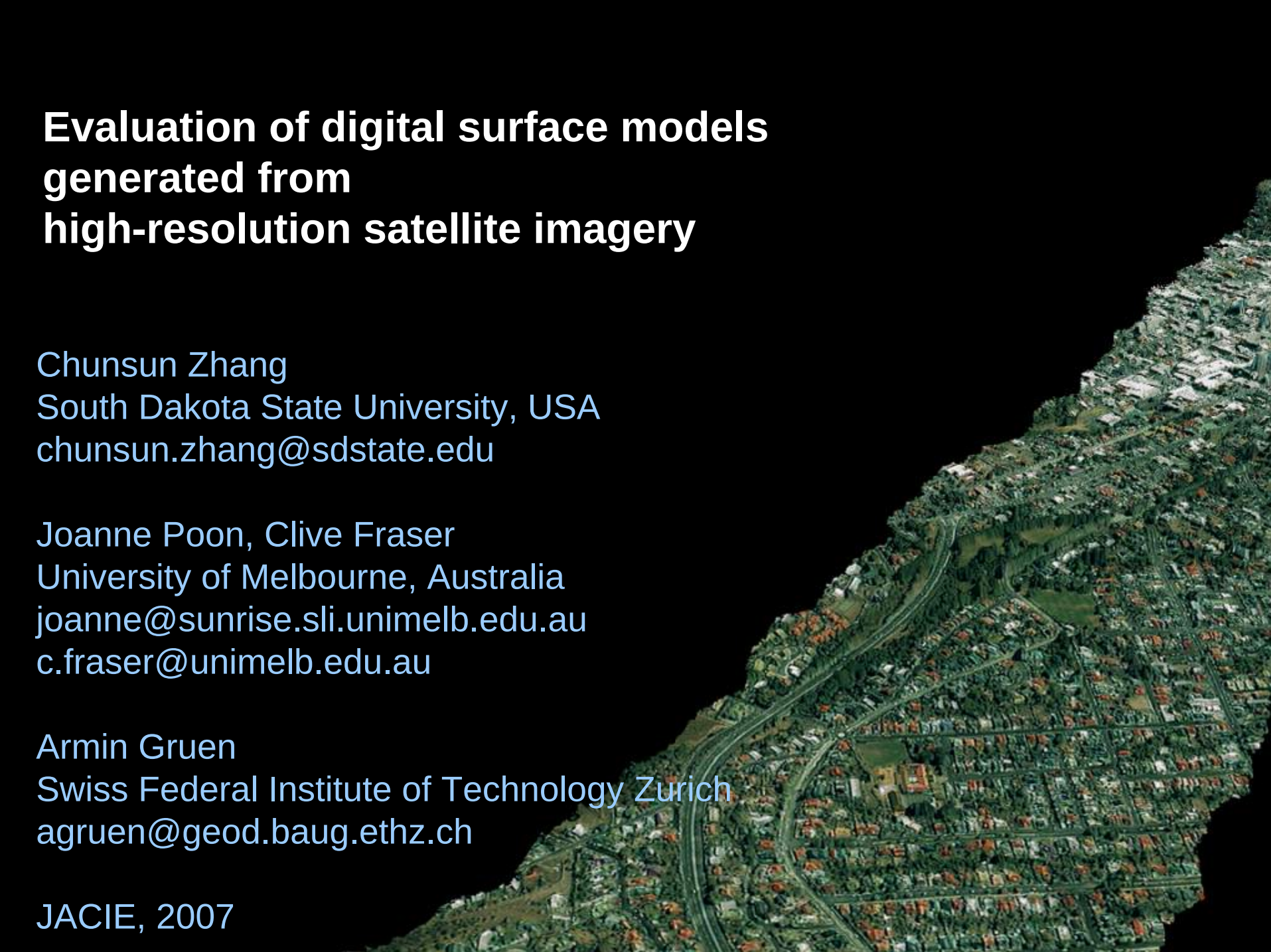
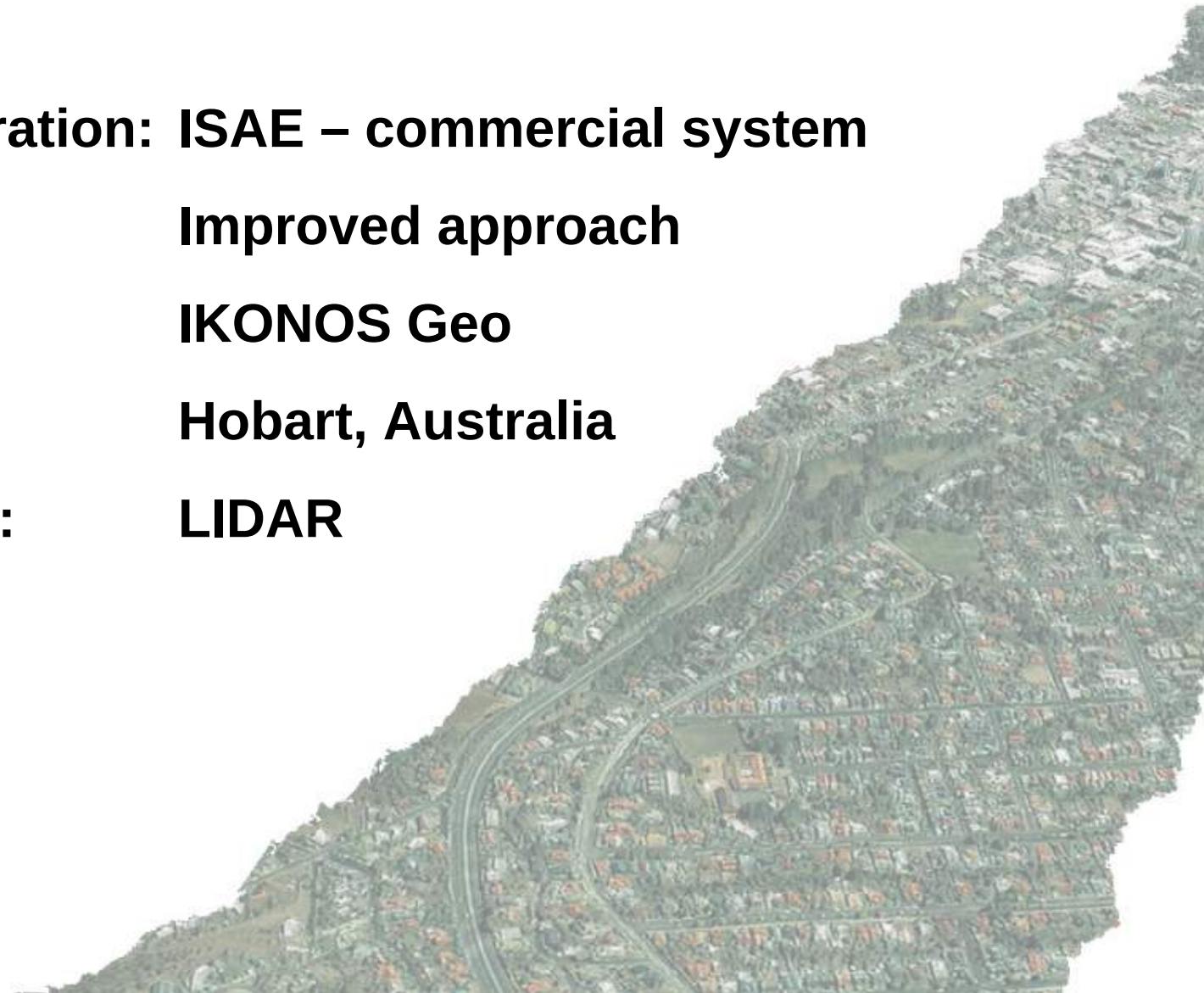
JACIE, 2007



Overview

- **DSM generation:** **ISAE – commercial system**
  Improved approach
- **Testfield:** **IKONOS Geo**
  Hobart, Australia
- **Evaluation:** **LIDAR**



Hobart Ikonos Testfield

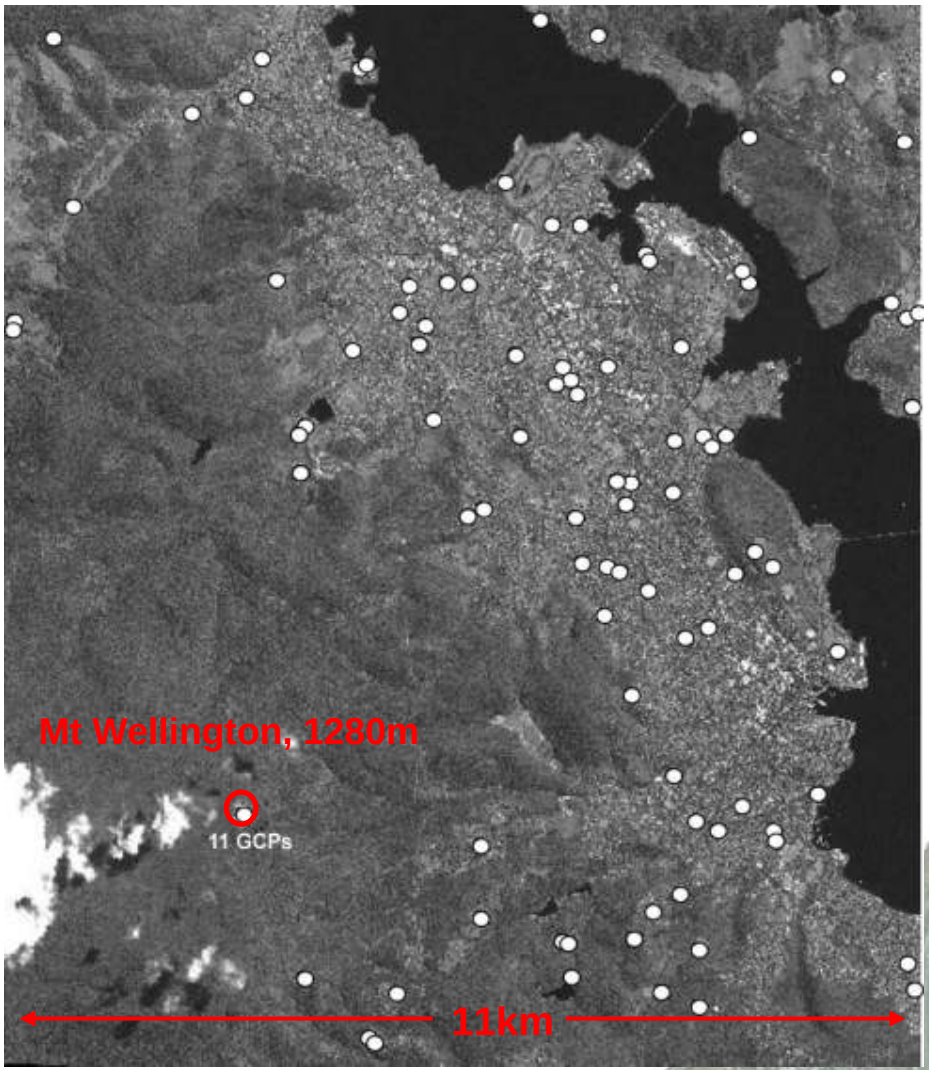
Testfield

- **Hobart, Australia**
  - **Urban areas**
  - **Forest areas**
  - **Mt Wellington, 1280m**
- **IKONOS Geo triplet, B:H = 0.8**
- **Bias-corrected RPCs**
  - **1 pixel level positioning**

Testfield

Land cover

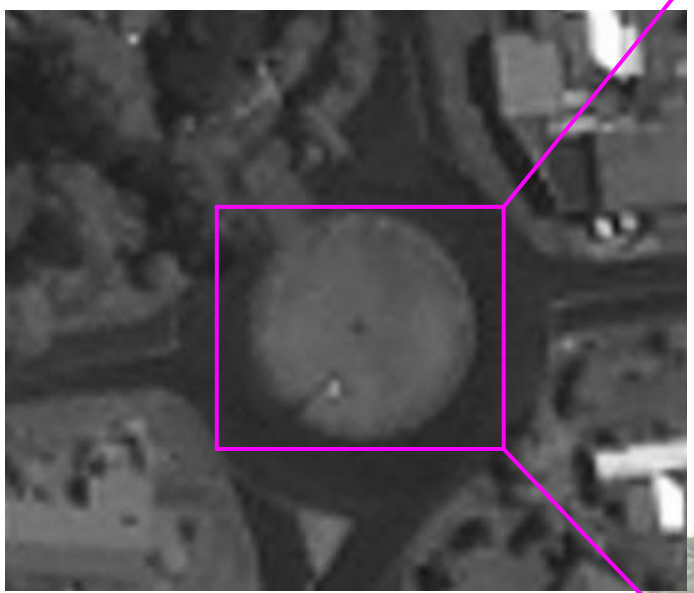
Hobart Ikonos Testfield

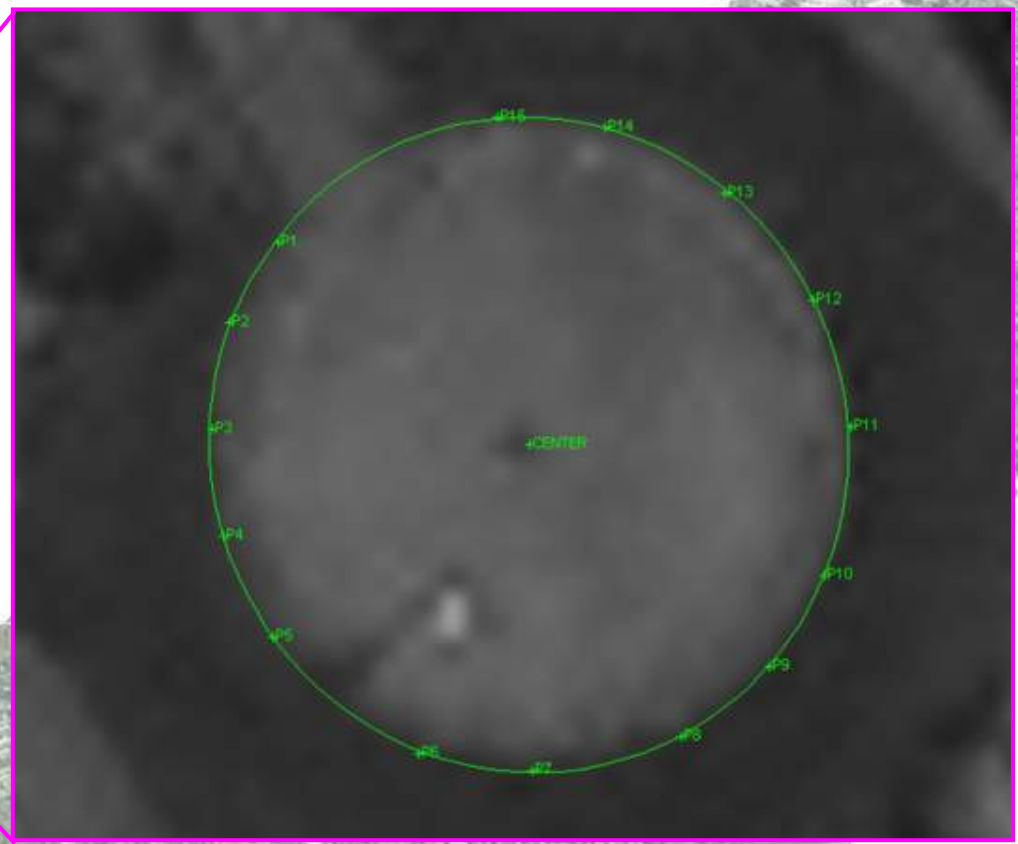


- A height variation of 1280m over 8km
- 115 GCPs to 10cm accuracy

Hobart Ikonos Testfield

GCP and measurement





Sensor orientation model

Rational Polynomial Coefficients (RPCs)

$$F_x = x_{ij} = \frac{P_{i1}(X,Y,Z)_j}{P_{i2}(X,Y,Z)_j}$$

$$F_y = y_{ij} = \frac{P_{i3}(X,Y,Z)_j}{P_{i4}(X,Y,Z)_j}$$

where

$$P_{i1}(X,Y,Z)_j = a_1 + a_2 \cdot Y + a_3 \cdot X + a_4 \cdot Z + a_5 \cdot Y \cdot X + a_6 \cdot Y \cdot Z + a_7 \cdot X \cdot Z + a_8 \cdot Y^2 + a_9 \cdot X^2 + a_{10} \cdot Z^2 + a_{11} X \cdot Y \cdot Z + a_{12} \cdot Y^3 + a_{13} \cdot Y \cdot X^2 + a_{14} \cdot Y \cdot Z^2 + a_{15} \cdot Y^2 \cdot X + a_{16} \cdot X^3 + a_{17} \cdot X \cdot Z^2 + a_{18} \cdot Y^2 \cdot Z + a_{19} \cdot X^2 \cdot Z + a_{20} \cdot Z^3$$

$$P_{i2}(X,Y,Z)_j = b_1 + b_2 \cdot Y + b_3 \cdot X + b_4 \cdot Z + \ldots + b_{19} \cdot X^2 \cdot Z + b_{20} \cdot Z^3$$

$$P_{i3}(X,Y,Z)_j = c_1 + c_2 \cdot Y + c_3 \cdot X + c_4 \cdot Z + \ldots + c_{19} \cdot X^2 \cdot Z + c_{20} \cdot Z^3$$

$$P_{i4}(X,Y,Z)_j = d_1 + d_2 \cdot Y + d_3 \cdot X + d_4 \cdot Z + \ldots + d_{19} \cdot X^2 \cdot Z + d_{20} \cdot Z^3$$

x_{ij}, y_{ij} - normalised (offset and scaled) image coordinates

X,Y,Z - object point cords. (normalised latitude, longitude and height)

Bias-Corrected RPCs

RPCs
(provided)
RMS ~ 5-30 (m)

→

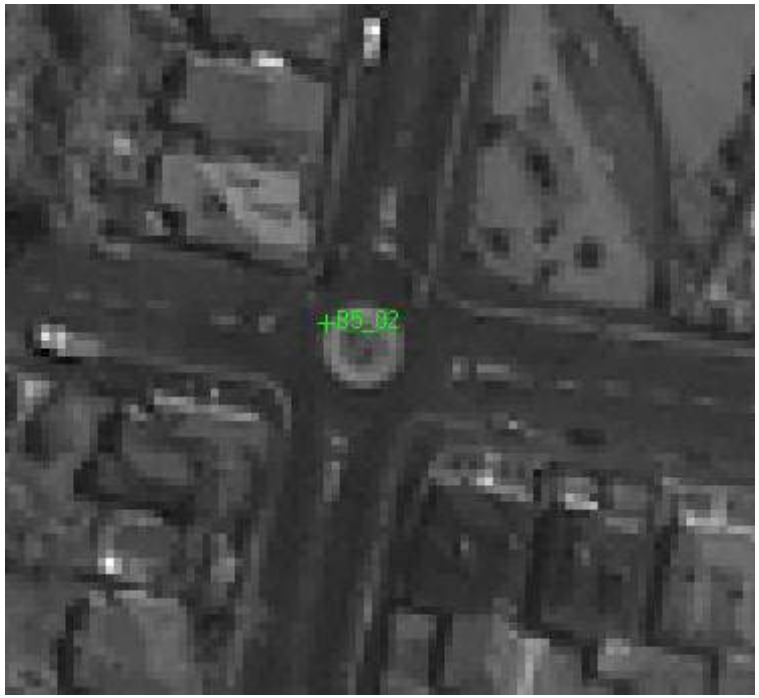
RPCs
(corrected)
RMS ~ 1 (m)

→

Bias-corrected RPCs were used as the sensor orientation model, with 3D positioning accuracy of better than 1 pixel

Bias-Corrected RPCs

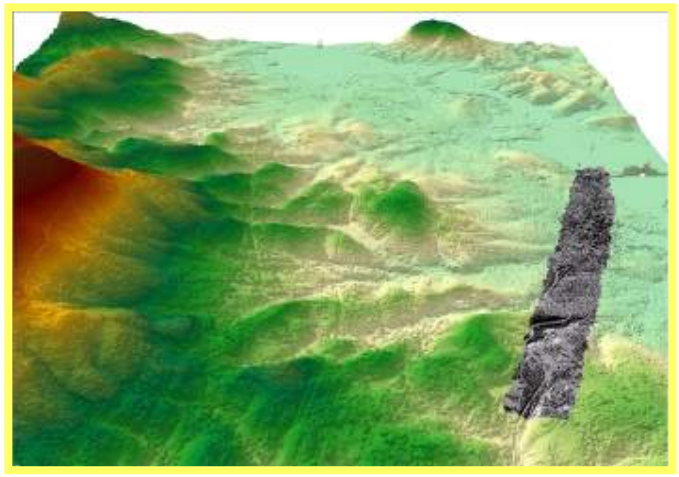
Projection of the center of a roundabout with GPS-surveyed ground coordinates in image space



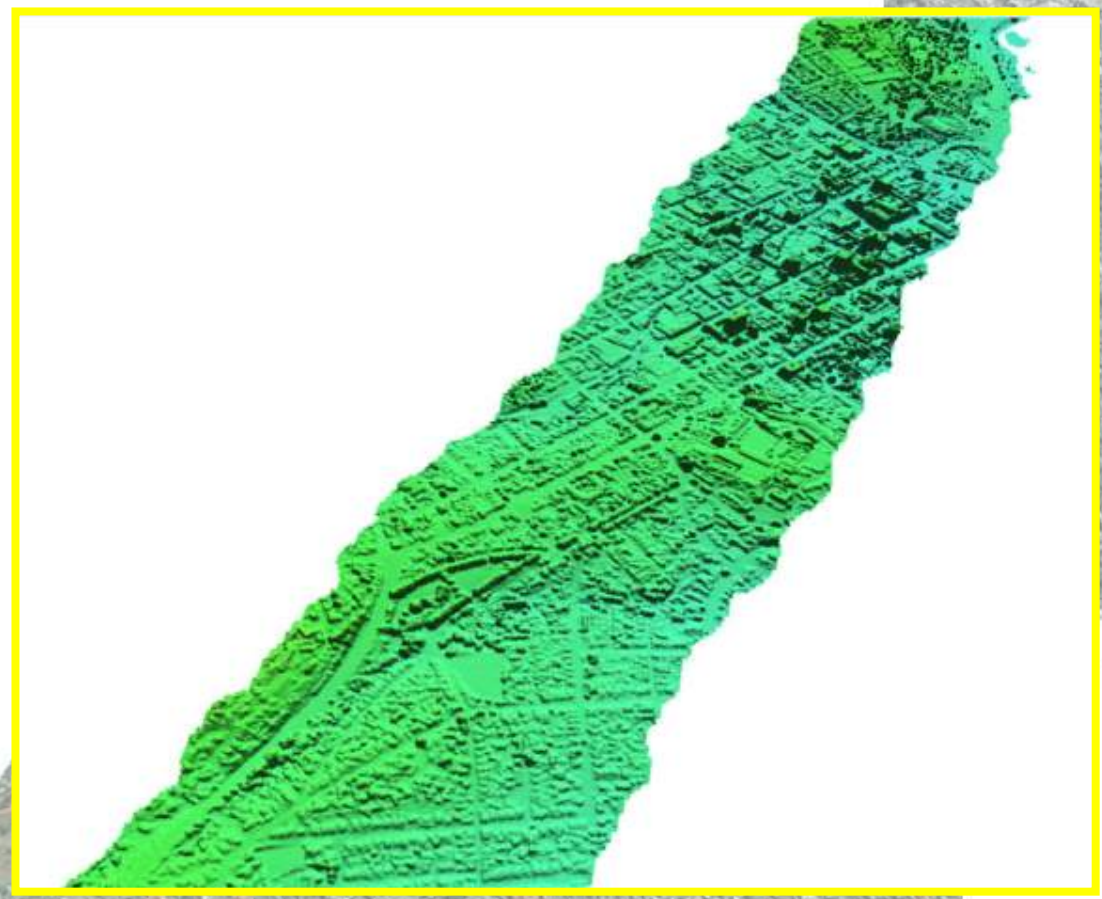
with vendor-supplied RPCs

with bias-corrected RPCs

Accuracy Evaluation

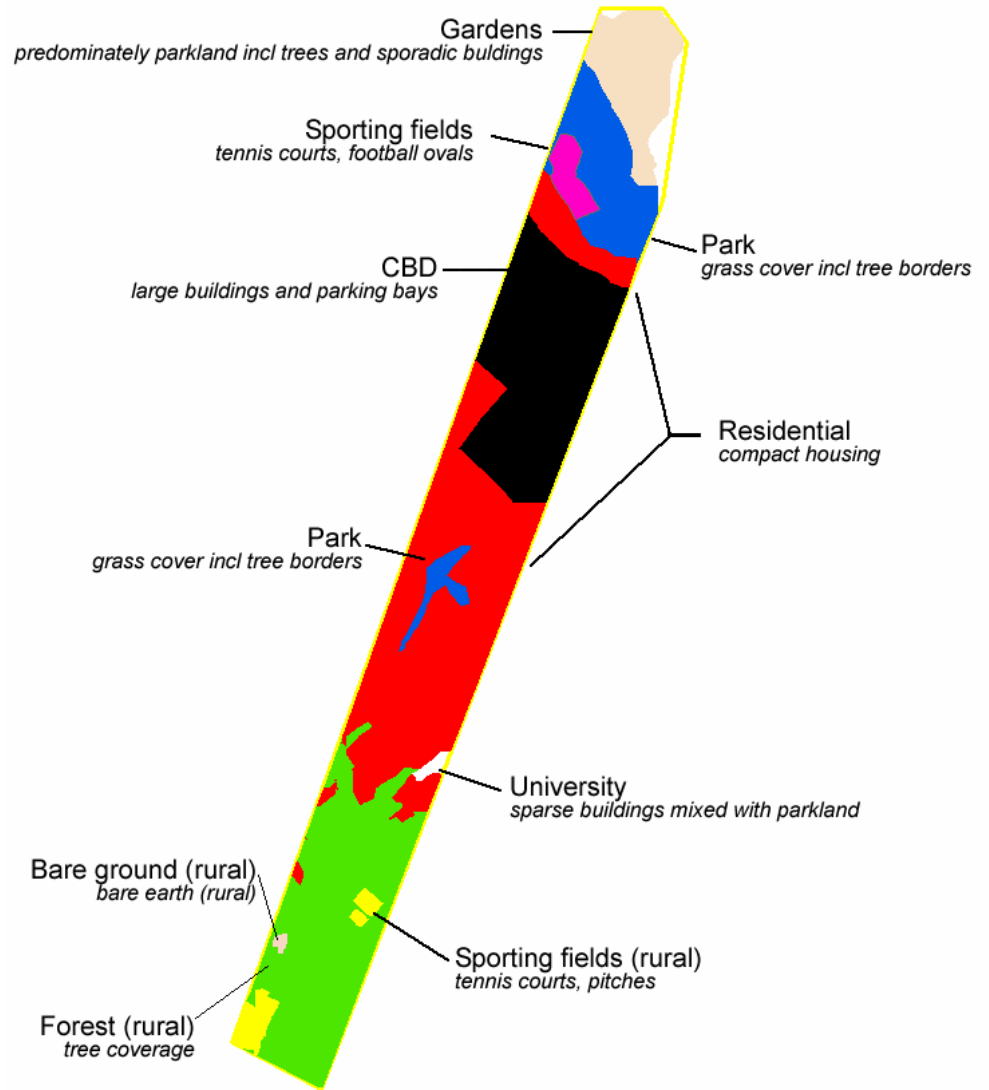


LIDAR Reference 2 m grid
First pulse returns



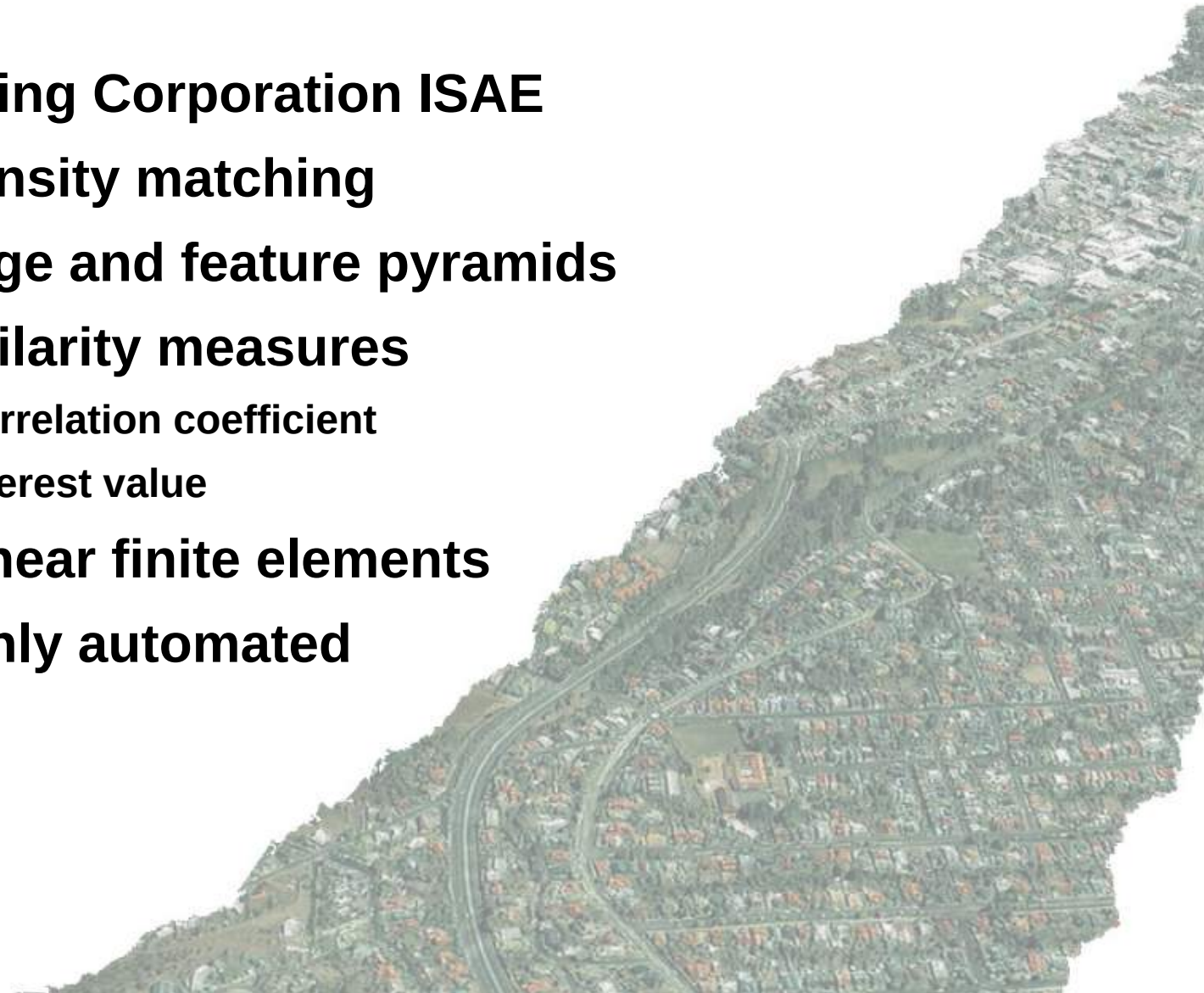
- **16 km² strip**
- **Representative of Testfield**
- **Representative season**

Landcover


Gardens
predominately parkland incl trees and sporadic buldings
Sporting fields
tennis courts, football ovals
Park
grass cover incl tree borders
CBD
large buildings and parking bays
Residential
compact housing
Park
grass cover incl tree borders
University
sparse buildings mixed with parkland
Bare ground (rural)
bare earth (rural)
Sporting fields (rural)
tennis courts, pitches
Forest (rural)
tree coverage

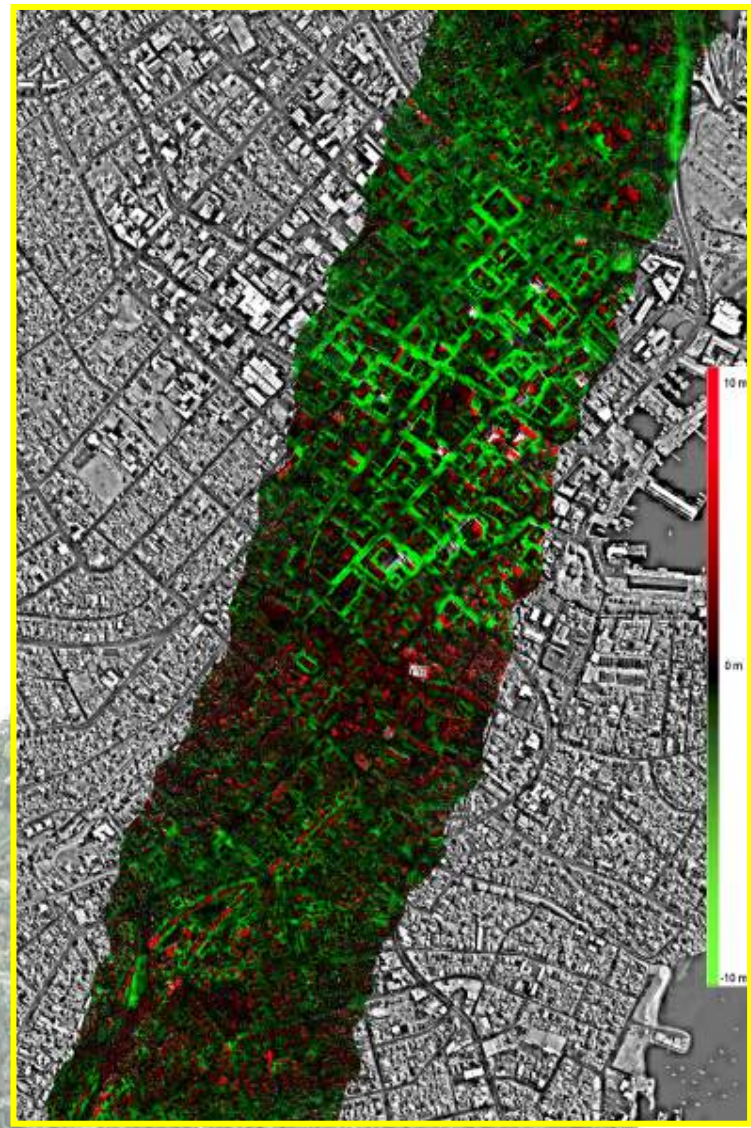
Matching Algorithms

- **Z/I Imaging Corporation ISAE**
  - **Intensity matching**
  - **Image and feature pyramids**
  - **Similarity measures**
    - **Correlation coefficient**
    - **Interest value**
  - **Bilinear finite elements**
  - **Highly automated**



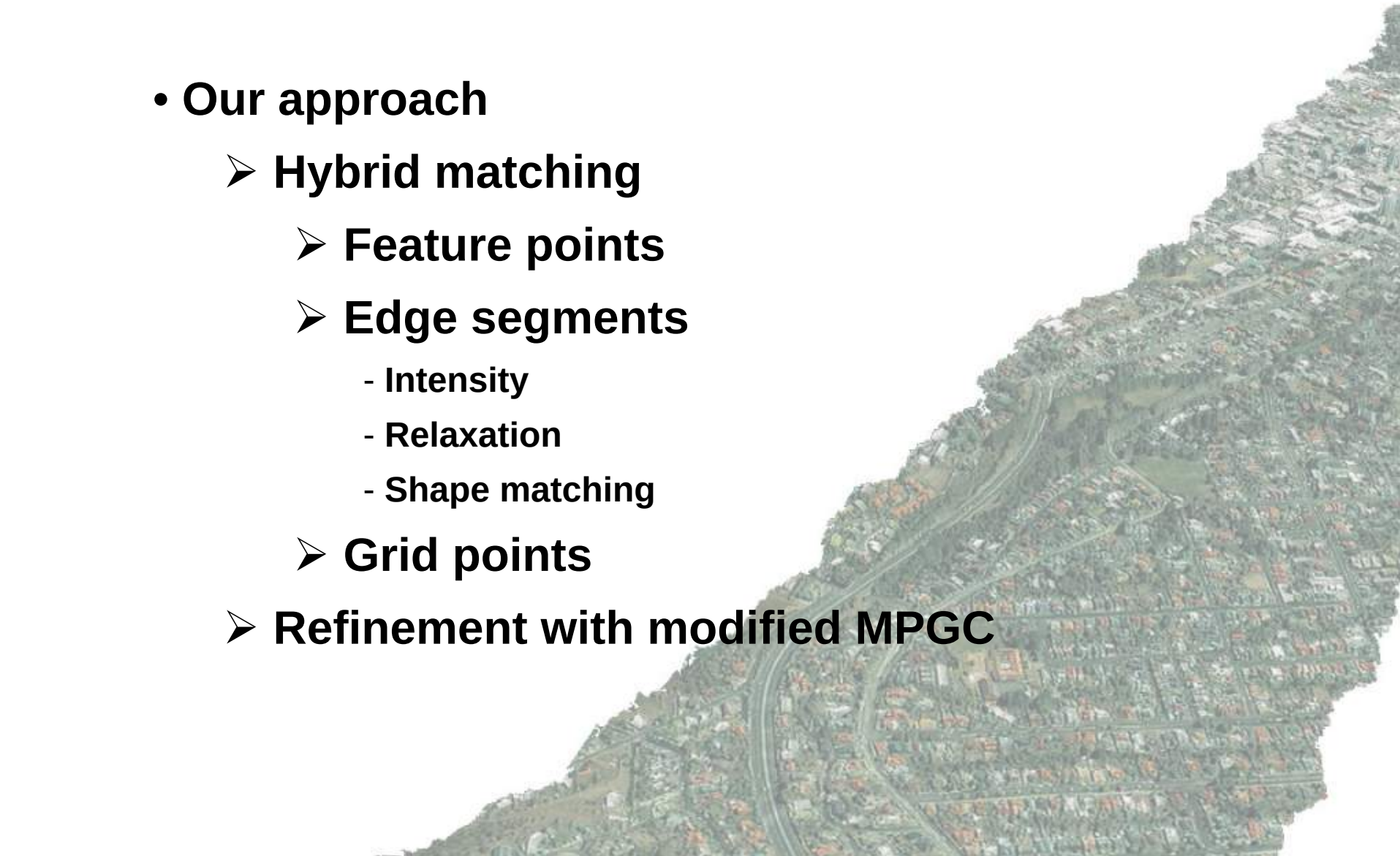
ISAE-generated DSM

Class	*No. of points*	*Height Discrepancy at CKPs (m)*		
		RMSE	*Mean*	*Abs Max*
Overall	**580 965**	**4.0**	**0.3**	**49**
URBAN				
CBD	**124 157**	**4.5**	**1.0**	**49**
Residential	**230 149**	**3.1**	**0.6**	**23.0**
University	**499**	**3.3**	**-0.3**	**15.1**
Building	**626**	**4.0**	**2.7**	**15.3**
Sporting fields	**12 105**	**3.6**	**0.3**	**24.0**
Park	**54 545**	**3.8**	**-0.7**	**36.8**
Gardens	**59 905**	**3.7**	**-0.6**	**36.8**
RURAL				
Bare ground	**271**	**2.8**	**-0.5**	**16.9**
Sporting fields	**19 732**	**3.8**	**0.1**	**31.2**
Forest	**78 976**	**4.3**	**-0.6**	**34.8**



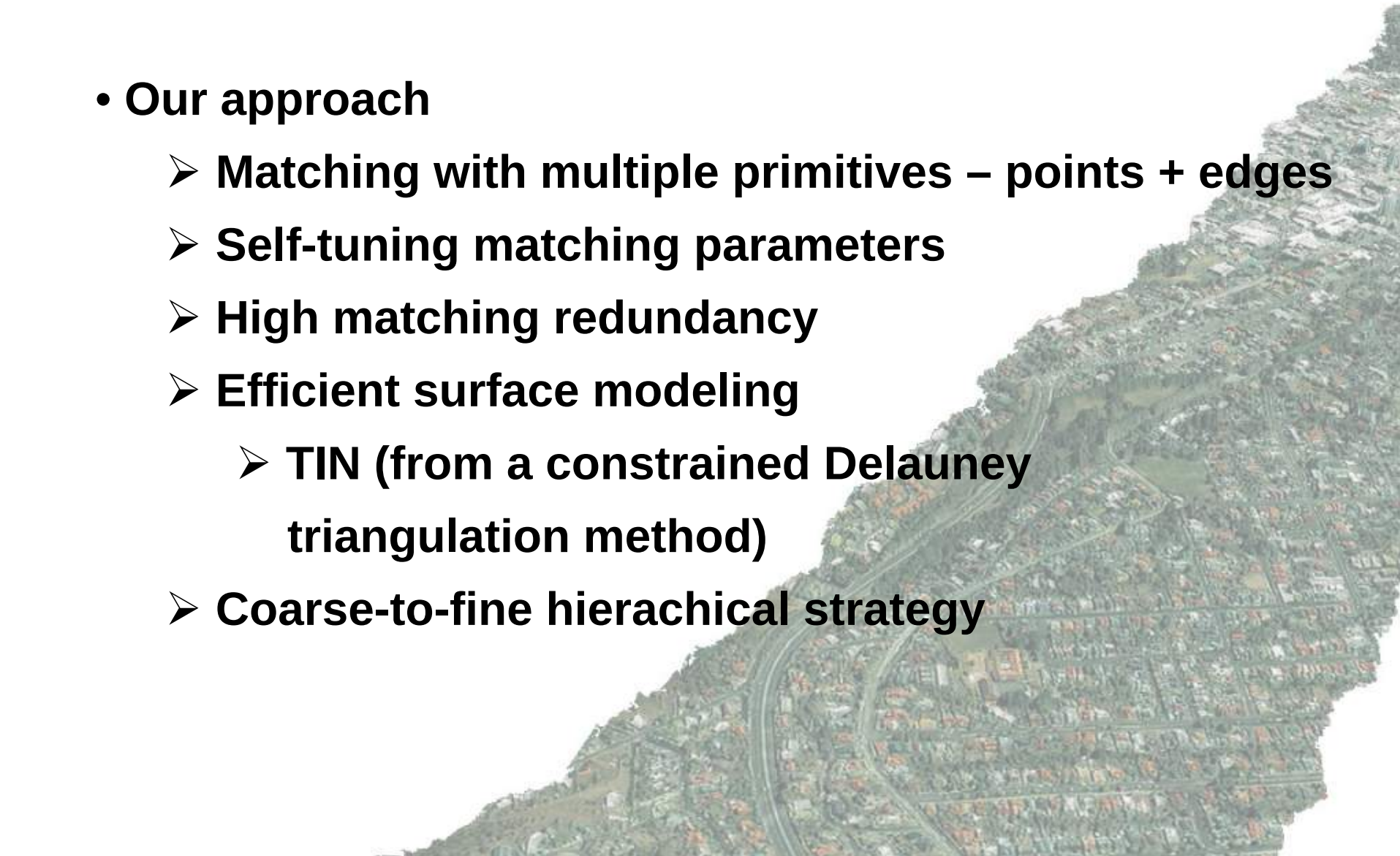
Matching Algorithms

- **Our approach**
  - ➢ **Hybrid matching**
    - ➢ **Feature points**
    - ➢ **Edge segments**
      - **Intensity**
      - **Relaxation**
      - **Shape matching**
    - ➢ **Grid points**
  - ➢ **Refinement with modified MPGC**



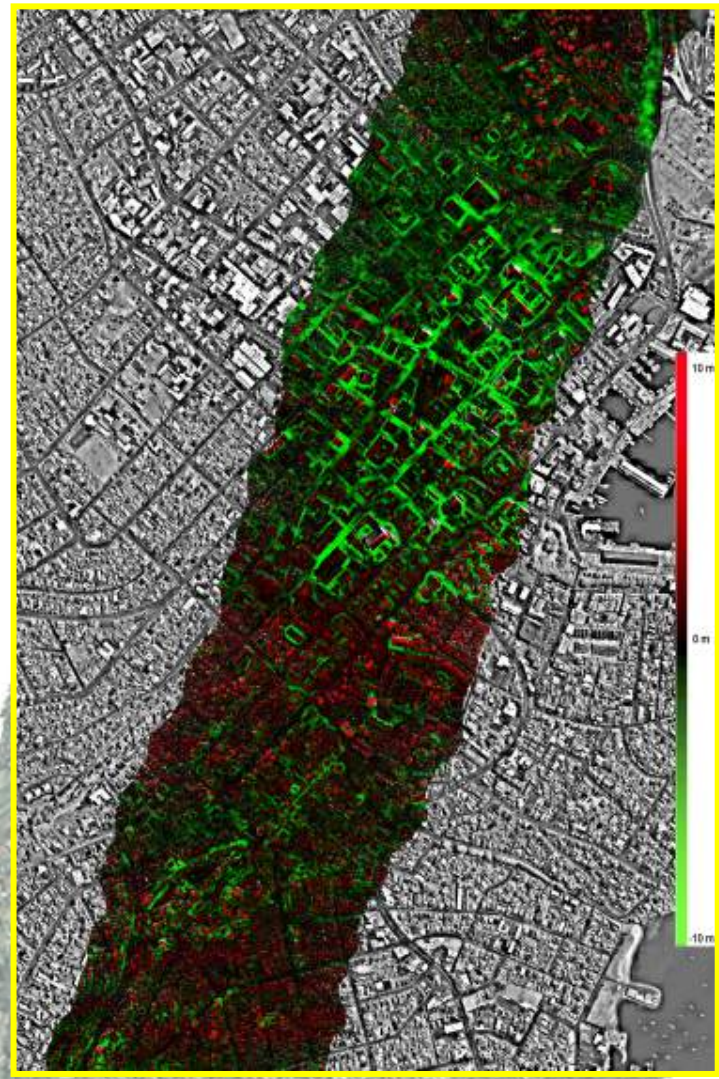
Matching Algorithms

- **Our approach**
  - **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 hierachical strategy**



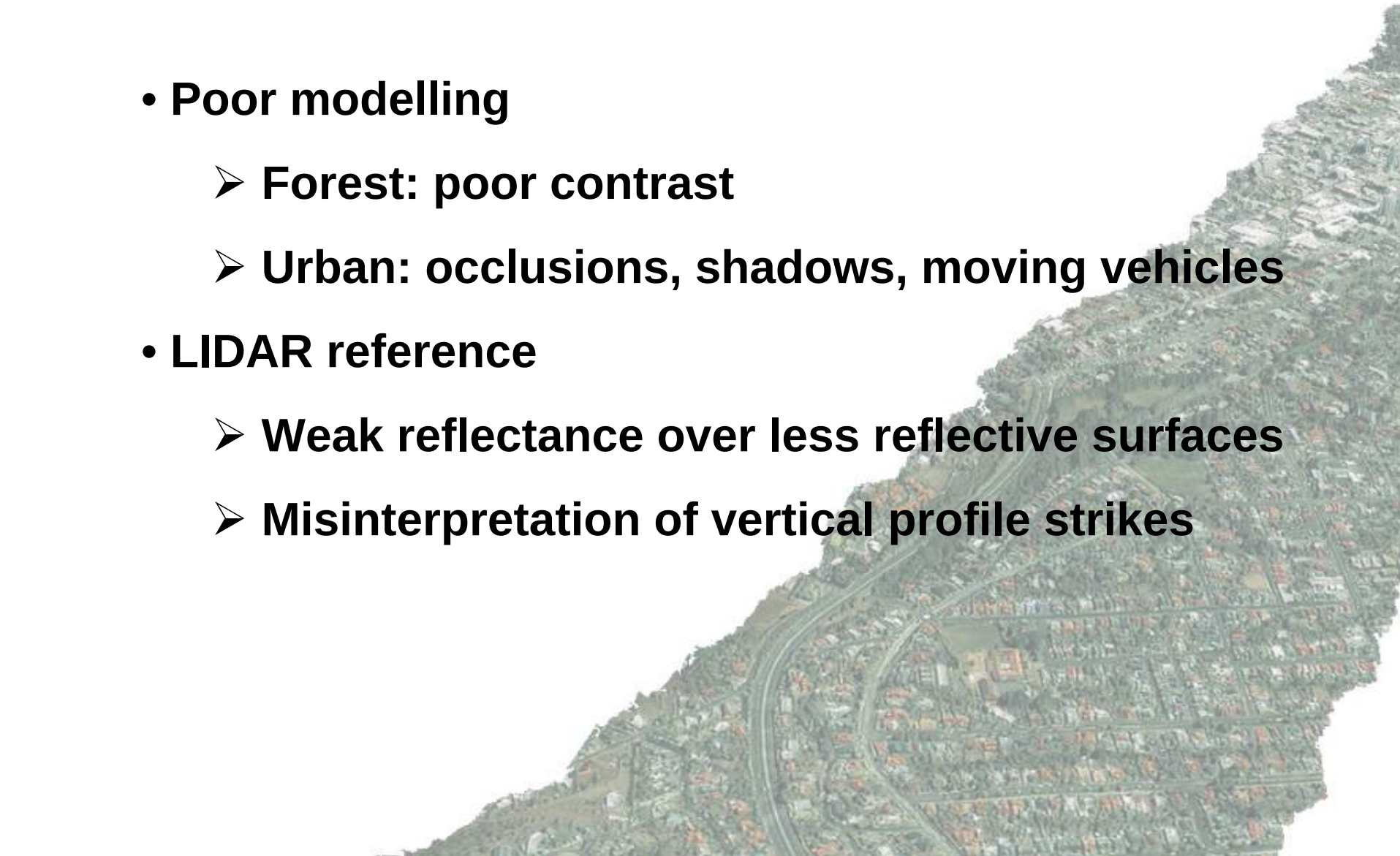
DSM by our approach

Class	*No. of points*	*Height Discrepancy at Checkpoints (m)*		
		RMSE	*Mean*	*Abs Max*
Overall	**756 073**	**2.7**	**0.2**	**32.7**
URBAN				
CBD	**147 908**	**3.4**	**1.1**	**27.2**
Residential	**291 923**	**2.0**	**0.4**	**25.0**
University	**736**	**2.2**	**0.04**	**10.1**
Building	**1 252**	**2.5**	**1.3**	**16.1**
Sporting fields	**14 156**	**2.2**	**0.1**	**19.0**
Park	**73 807**	**2.9**	**-0.6**	**30.4**
Gardens	**65 217**	**2.7**	**-0.5**	**31.7**
RURAL				
Bare ground	**763**	**1.7**	**0.4**	**9.8**
Sporting fields	**23 551**	**2.4**	**0.1**	**30.2**
Forest	**136 760**	**3.2**	**-0.5**	**32.7**



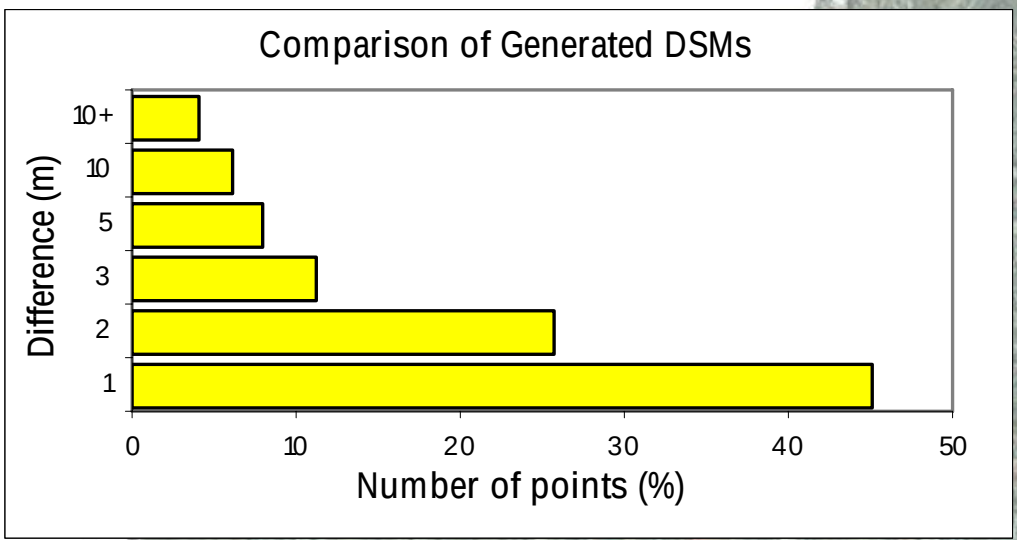
Comparison of DSM approaches

- **Poor modelling**
  - **Forest: poor contrast**
  - **Urban: occlusions, shadows, moving vehicles**
- **LIDAR reference**
  - **Weak reflectance over less reflective surfaces**
  - **Misinterpretation of vertical profile strikes**



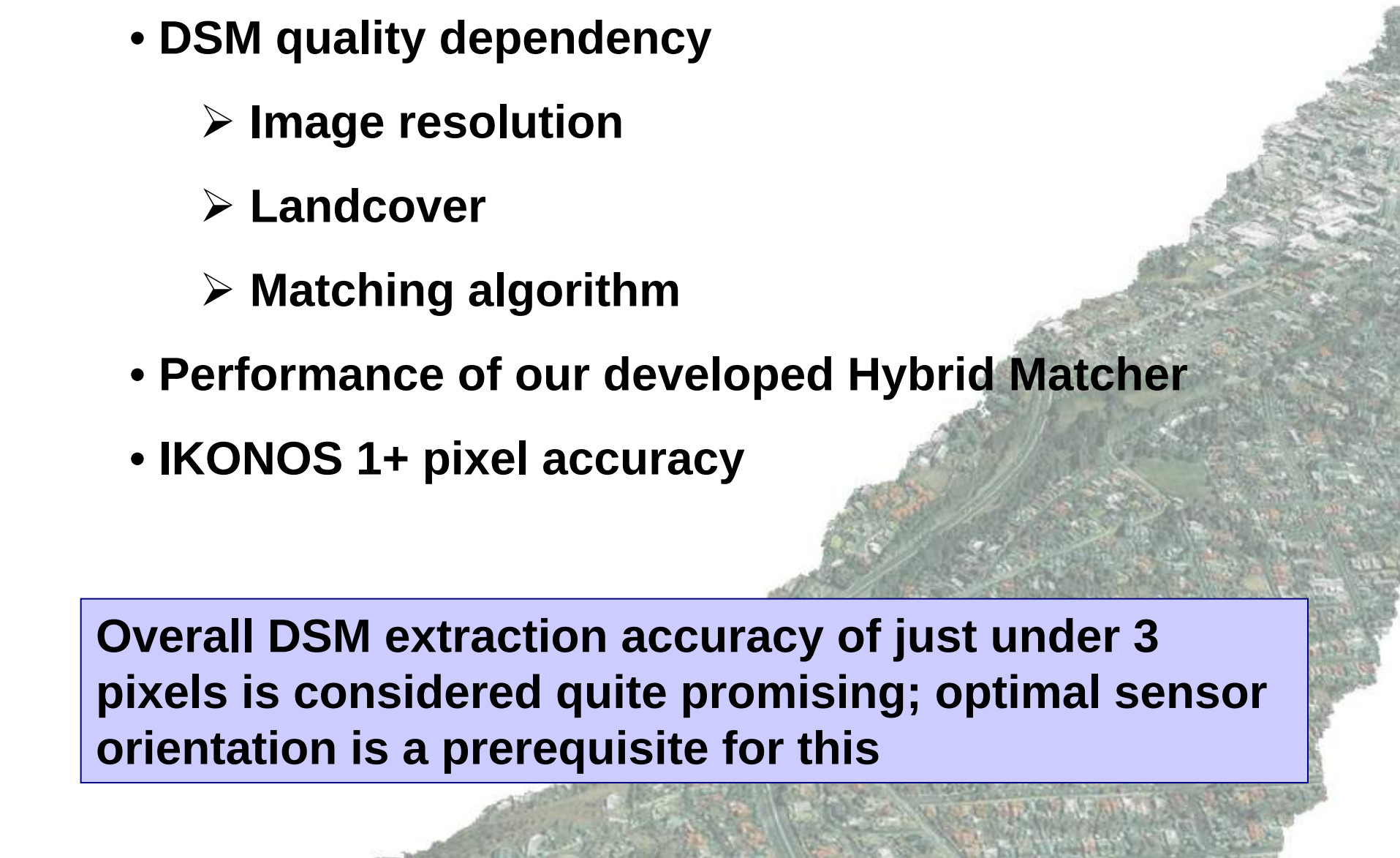
Comparison of DSM approaches

- **The developed matching approach significantly better than ISAE**
  - ➢ **All Landcover classes**
  - ➢ **Greater no. of matches**
- **Edge matching and detail insufficient in ISAE**
- **Incorrect modelling / Interpolation inadequacy**



Conclusion

- **DSM quality dependency**
  - **Image resolution**
  - **Landcover**
  - **Matching algorithm**
- **Performance of our developed Hybrid Matcher**
- **IKONOS 1+ pixel accuracy**



Overall DSM extraction accuracy of just under 3 pixels is considered quite promising; optimal sensor orientation is a prerequisite for this