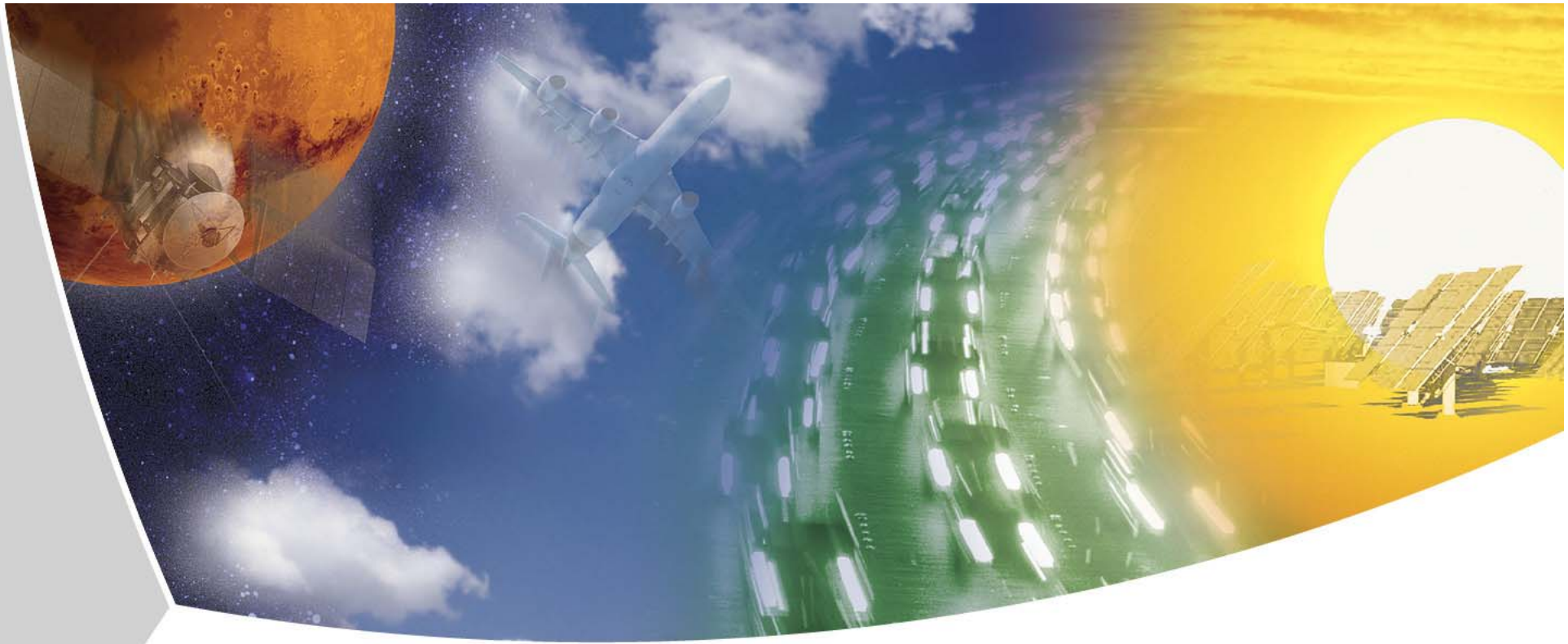




DSM generation and object extraction from satellite stereo data

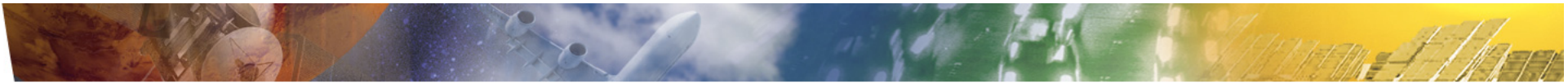
Peter Reinartz, Thomas Krauß, Pablo d'Angelo

Institut für Methodik der Fernerkundung (IMF)

Abteilung Photogrammetrie und Bildanalyse

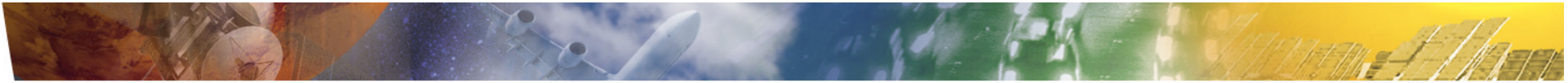


**Deutsches Zentrum
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in der Helmholtz-Gemeinschaft



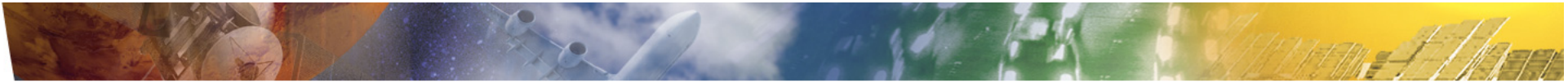
Stereo Images from Space, Worldview-2





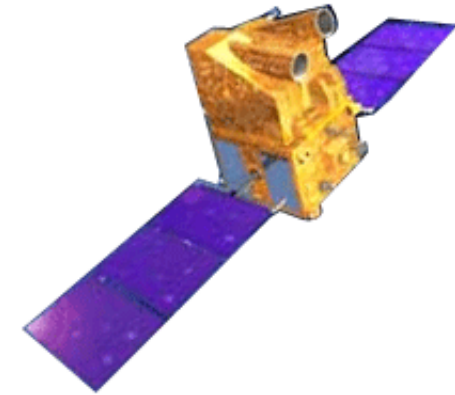
High resolution space borne stereo sensors

- Cartosat: 2.5 m x 2.5 m pixel
- Ikonos: 1 m x 1m pixel
- Worldview-2, GeoEye-1: 0.5 m x 0.5 m pixel

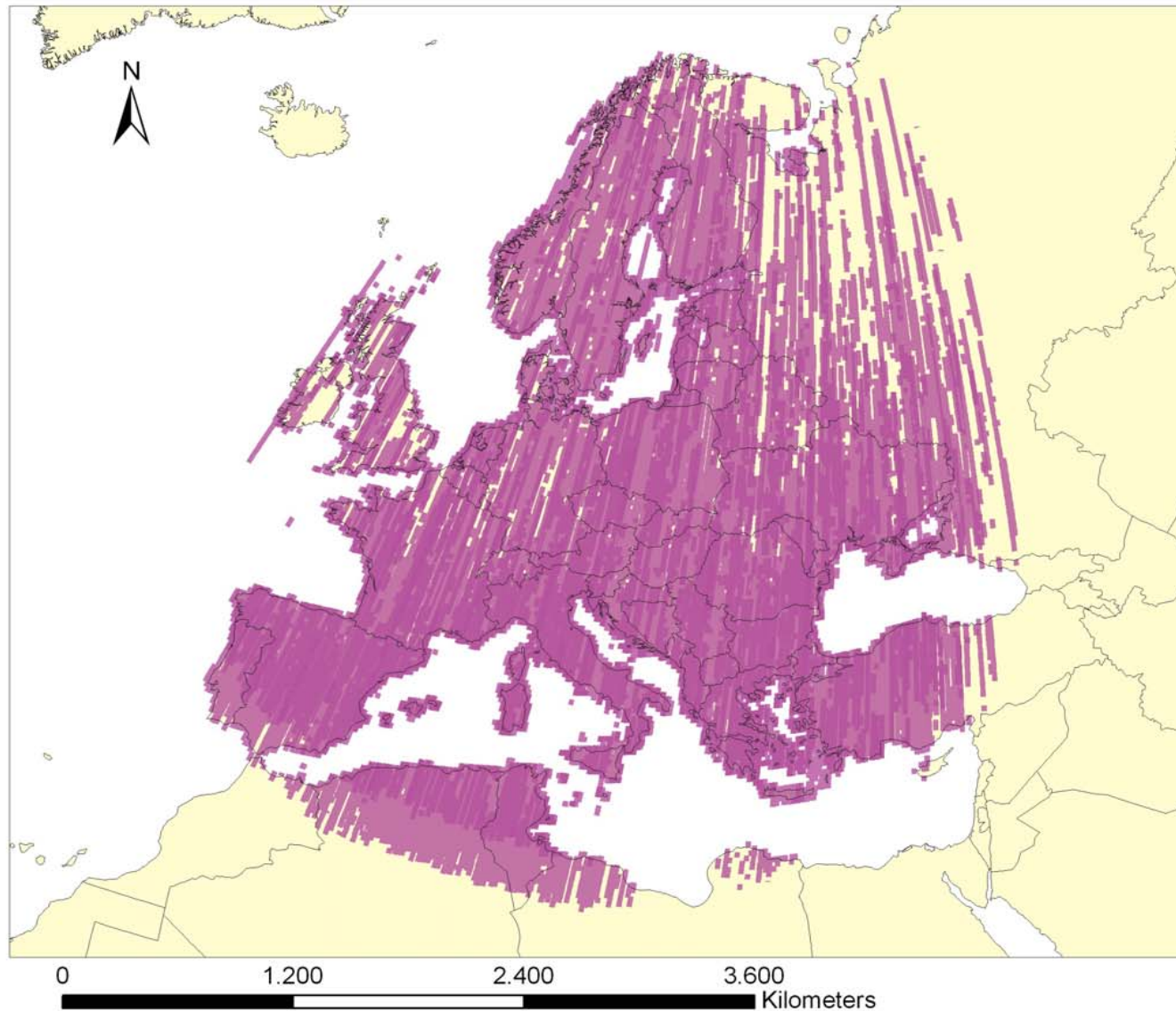


Cartosat-1 DEM Processor @ euromap

- Large scale DSM generation (Europe) using Cartosat-1 (IRS-P5) stereo images
 - Along track CCD scanner, 2 lines, 12000 pixel.
 - Ground resolution 2.5 m, stereo angle 31°.
 - 30 km x 30 km scene size
- Desired output
 - Application: large scale mapping.
 - DSM with 5 m grid spacing.
 - 2-3 m height error (1σ).
- Highly automated DSM generation process
 - Automatic georeferencing.
 - Image matching with consistency checks.
 - Limited manual editing.



IRS-P5 2.5m Stereo Data Coverage over Euromap Reception Cone (data usable for Euro-Maps 3D)



IRS-P5 Scene

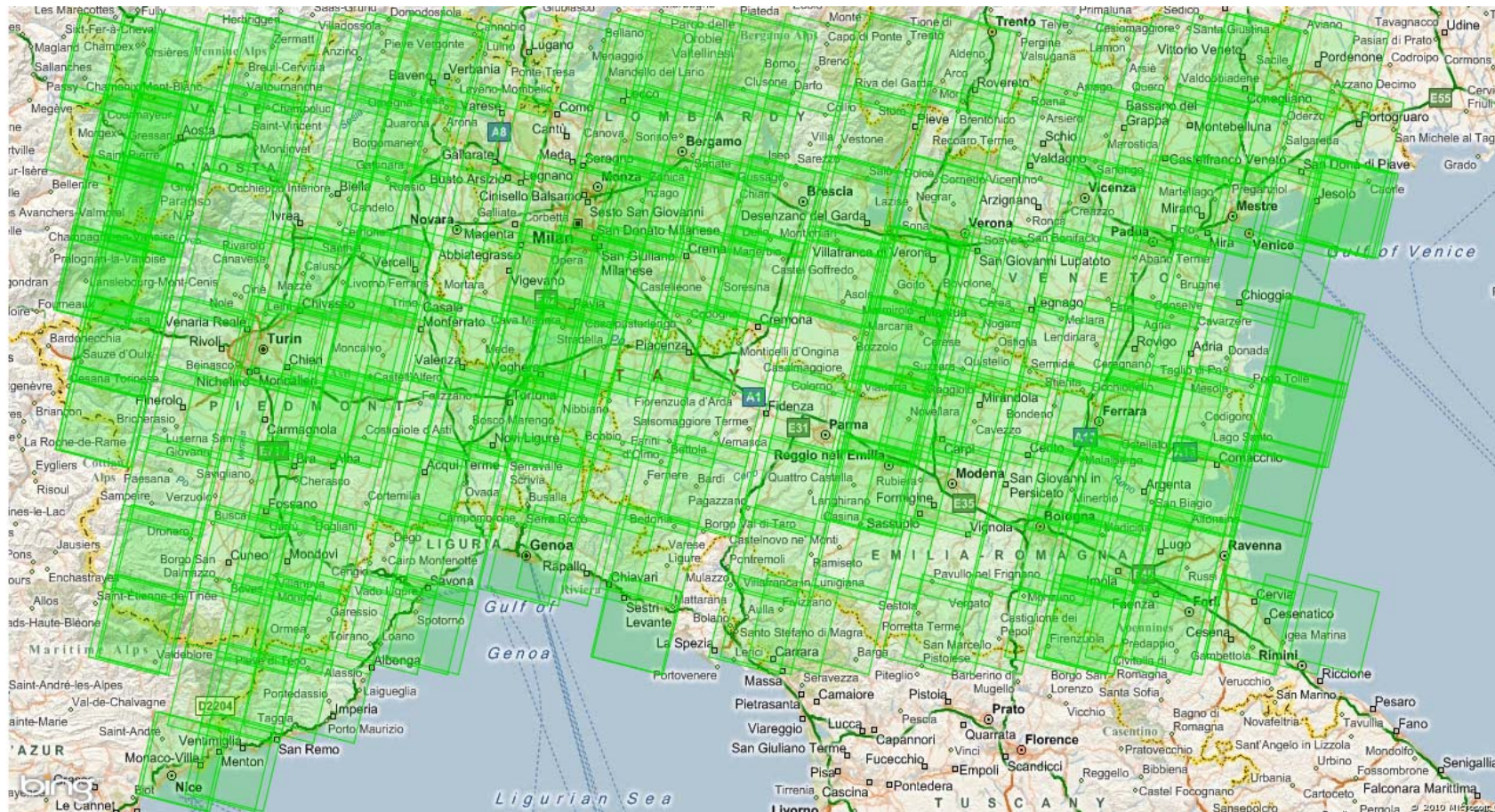
Data considered:
07-Nov-2007 to 08-Feb-2012

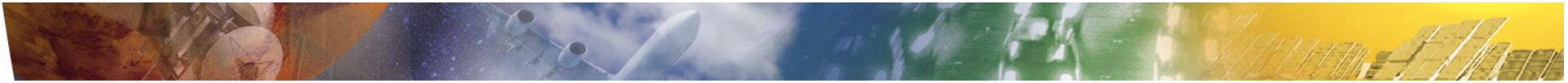
© 2012 Euromap GmbH



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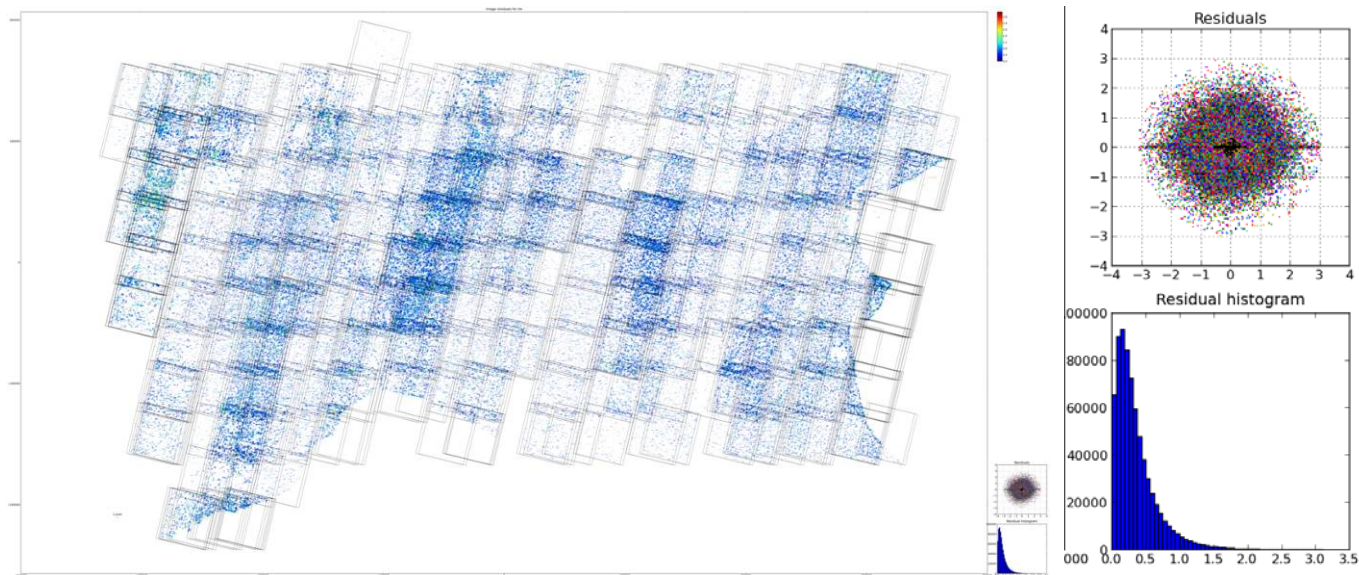
Northern Italy approximately 1000 Scenes

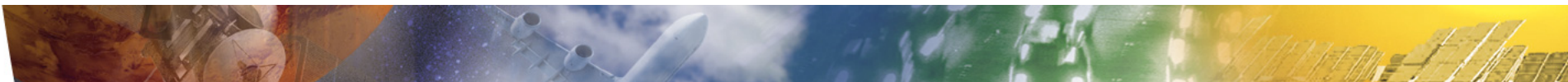




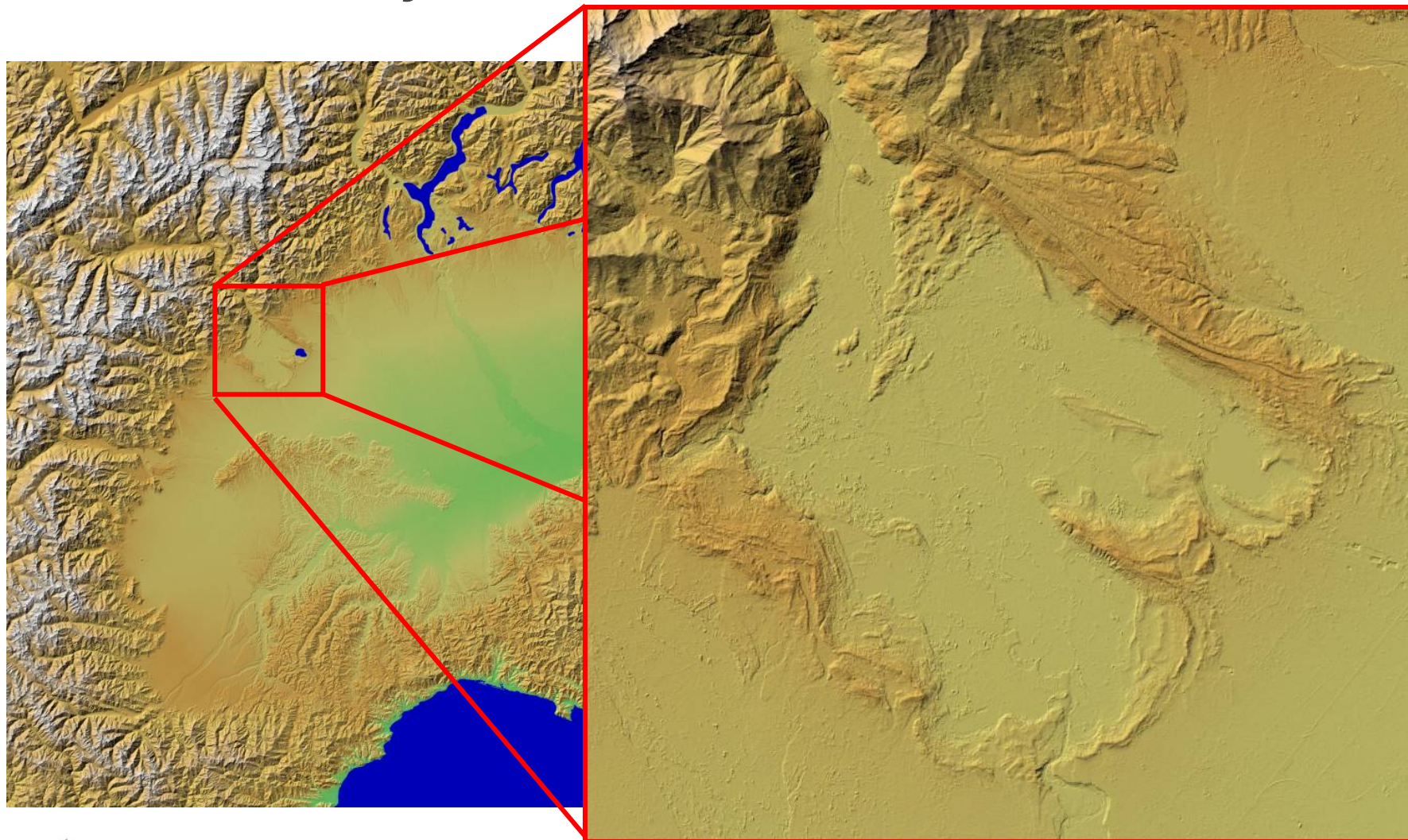
Large scale bundle block adjustment

- Motivation: Orientation of large Cartosat-1 blocks (> 1000 Scenes) with SRTM DSM as major ground control.
- Efficient, flexible adjustment package
 - New observations can be added easily
 - Supports millions of unknowns and observations.



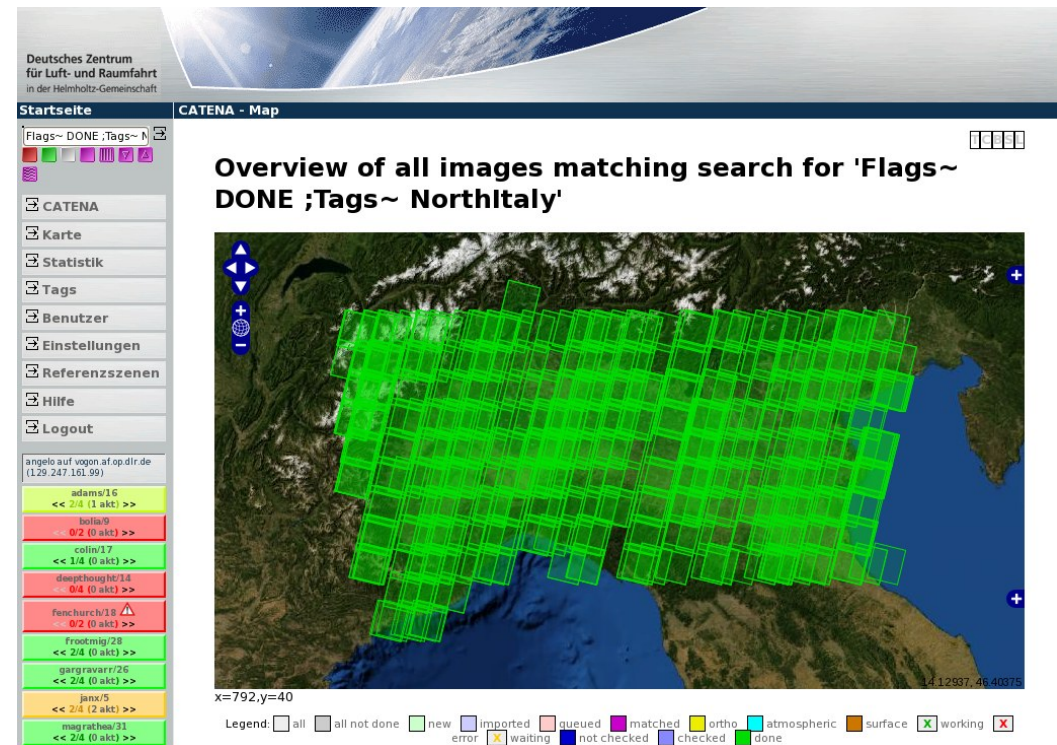


Northern Italy DSM, ~410 Cartosat-1 stereo scenes

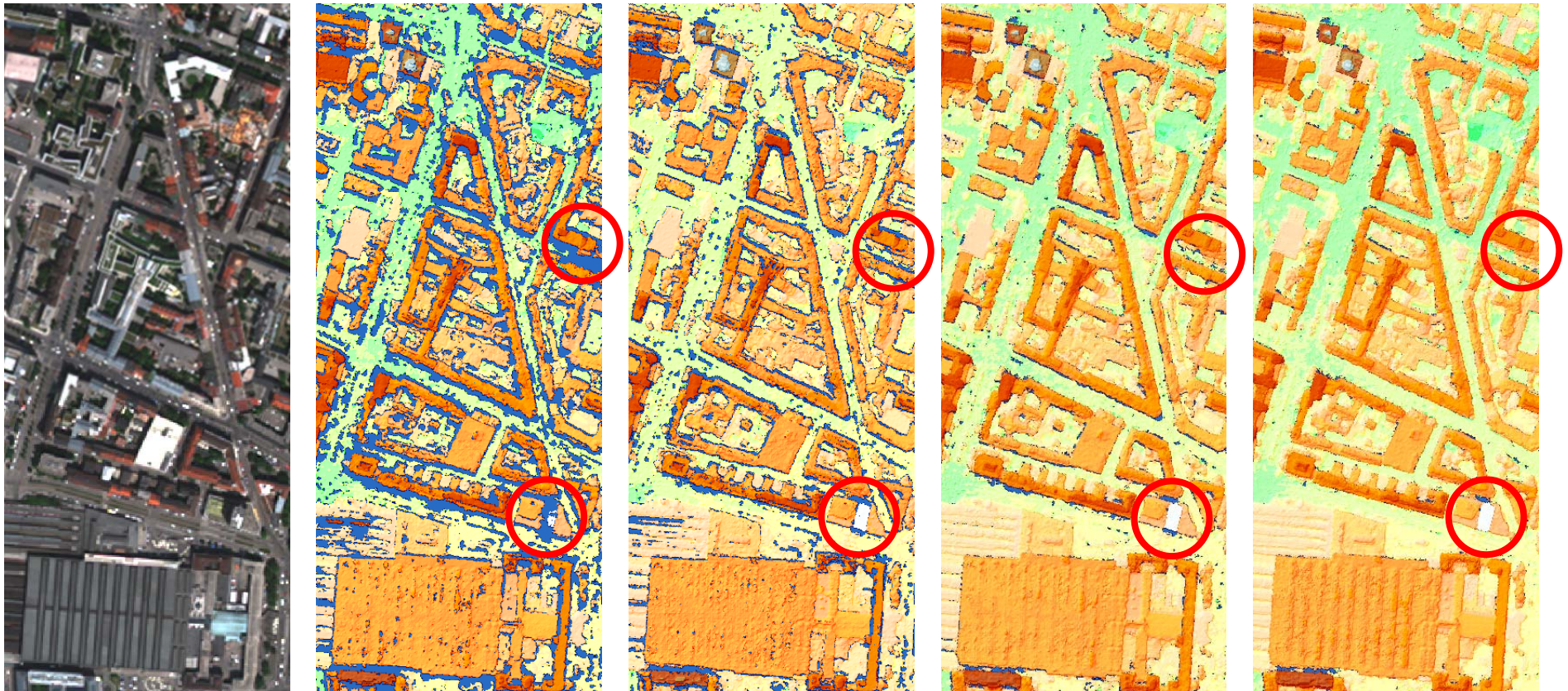


Operational DSM Generation CATENA System

- Fully operational for Cartosat-1 (most of Europe already processed)
- And now also for:
 - Worldview-1 & -2
 - IKONOS
 - GeoEye-1
 - Aerial images
- In house development
- Grid computing



Convergence angle and number of looks 2 overlapping stereo pairs, Worldview-2 data



Image

24° Stereo

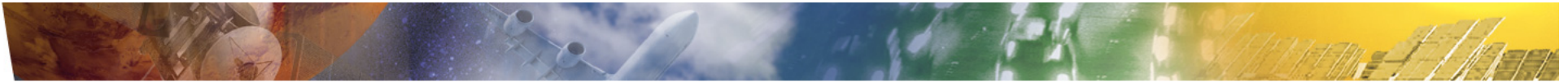
12° Stereo

Triple

Quadruple

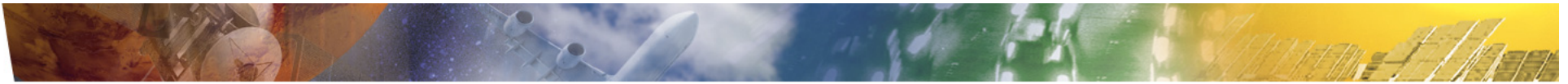
Blue color indicates unmatched or occluded areas.



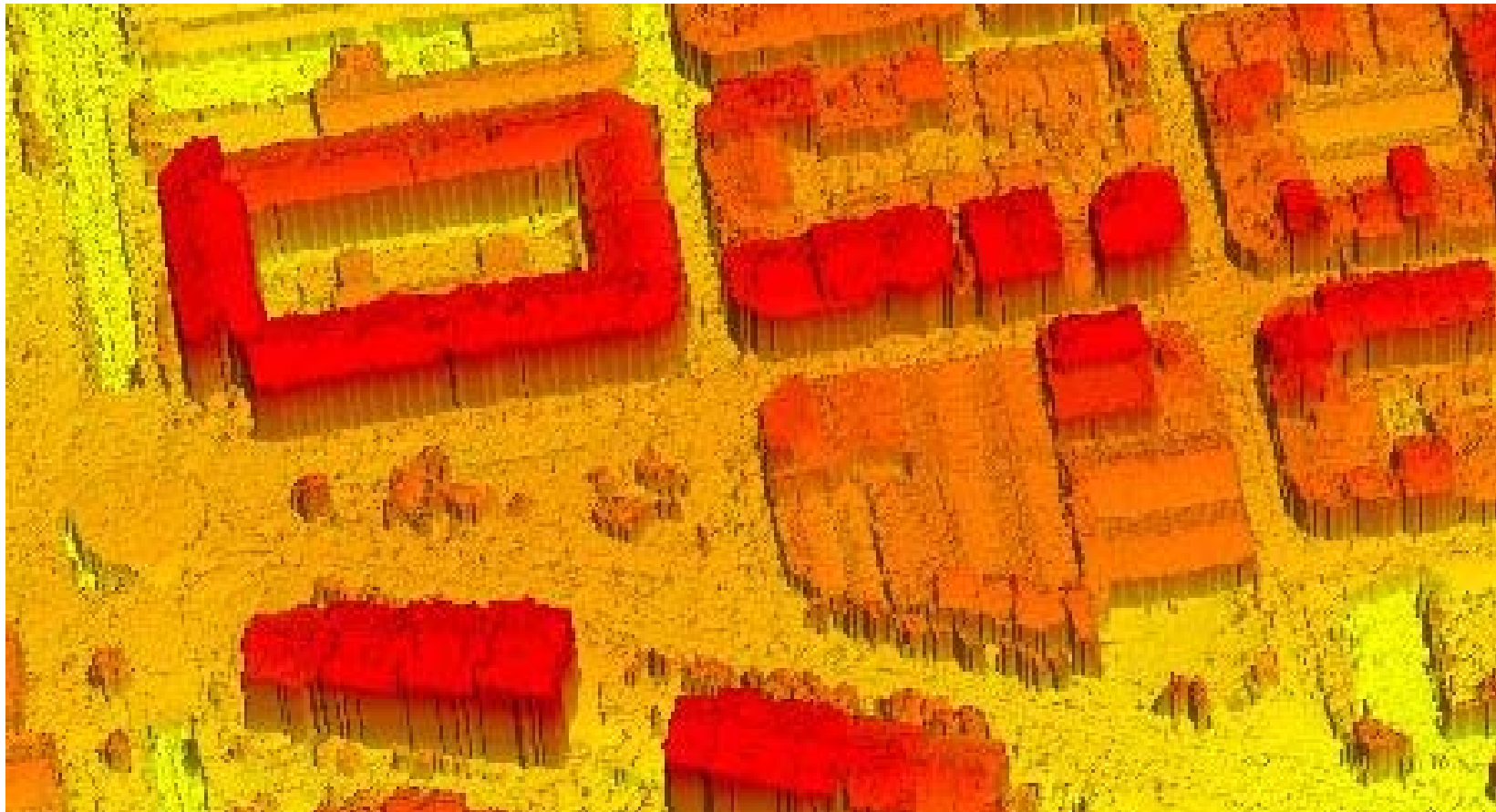


Worldview-2 DOM, Munich, 4 viewing directions





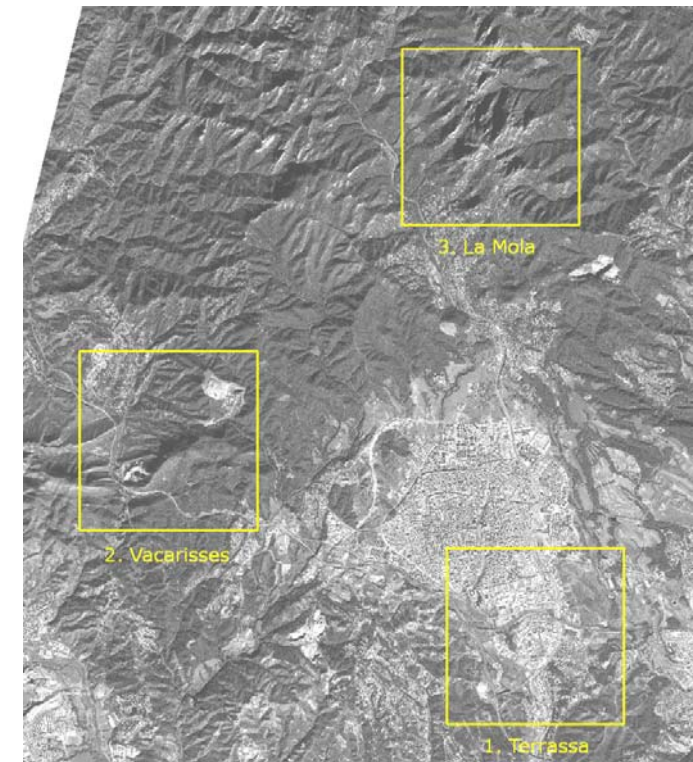
Quality of DSM



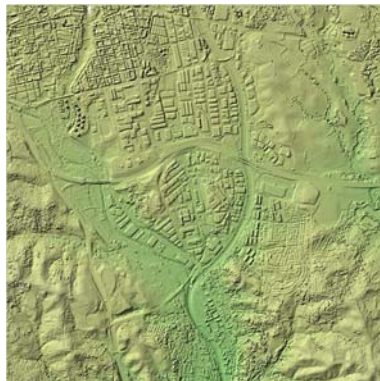
ISPRS Benchmarking WG I/4

Catalonia Test areas

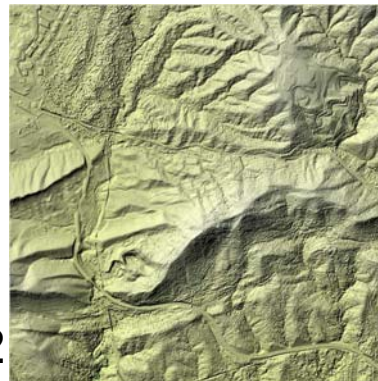
- Evaluation of different matching algorithms
- WV-1 pair, 34° stereo angle, Cartosat-1, ALOS PRISM
- Data available at <http://www.commission1.isprs.org/wg4/>
- Your participation is welcome



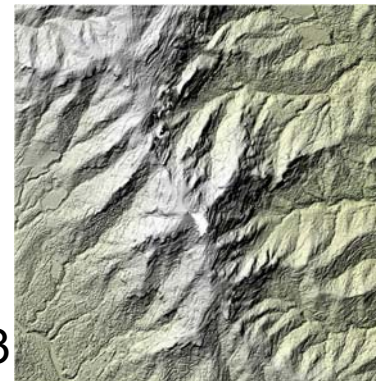
Terrassa



Vacarisse

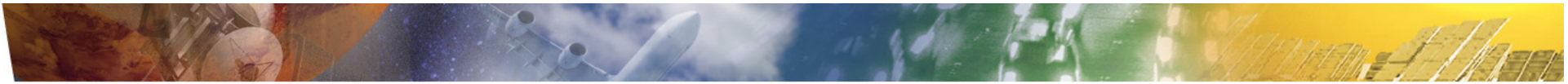


La Mola

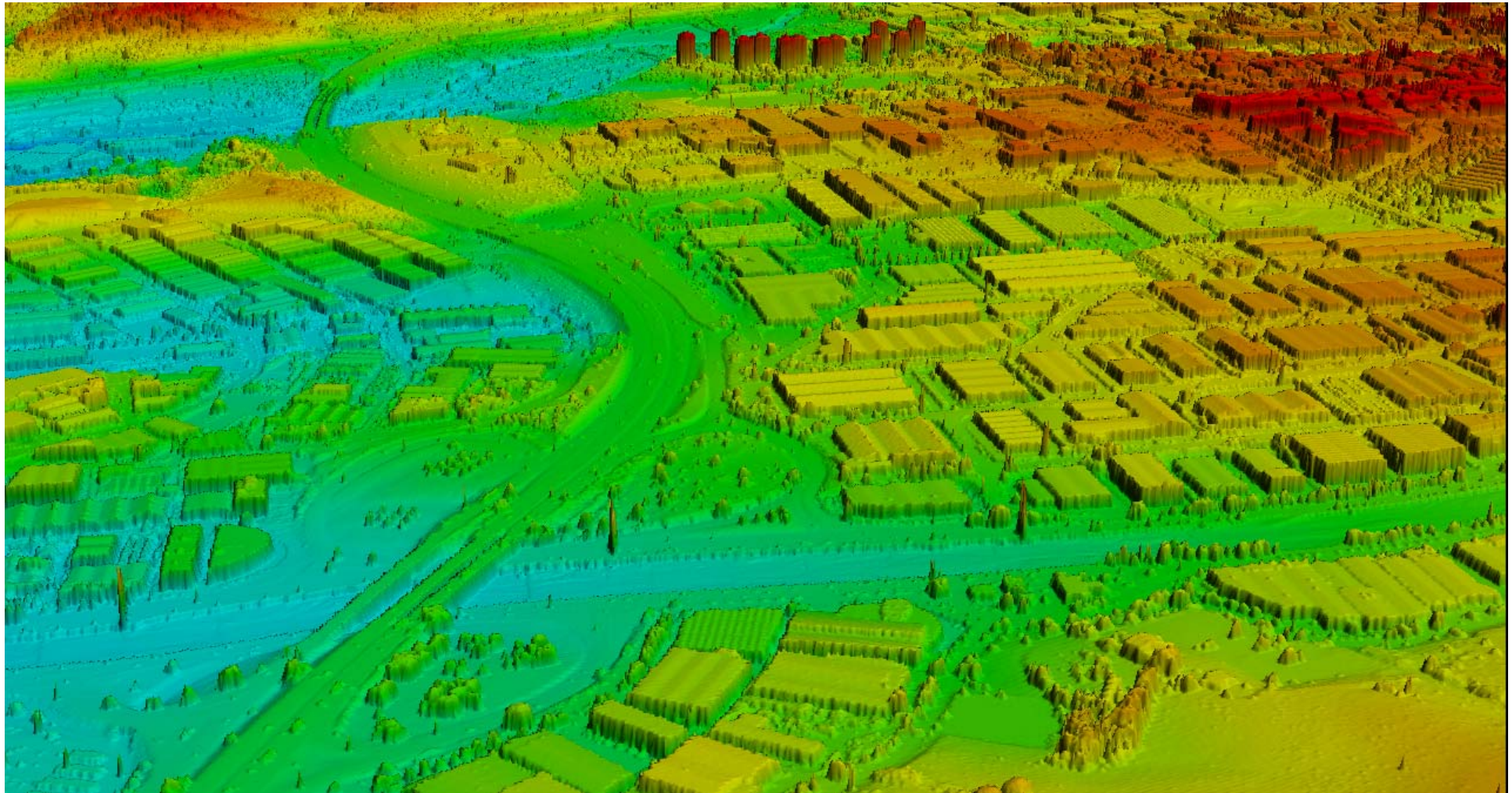


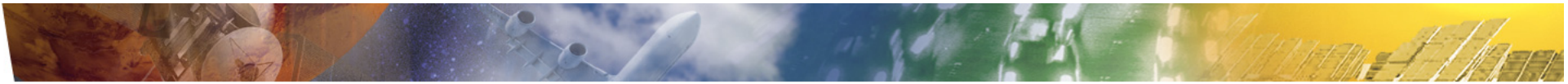
Test areas



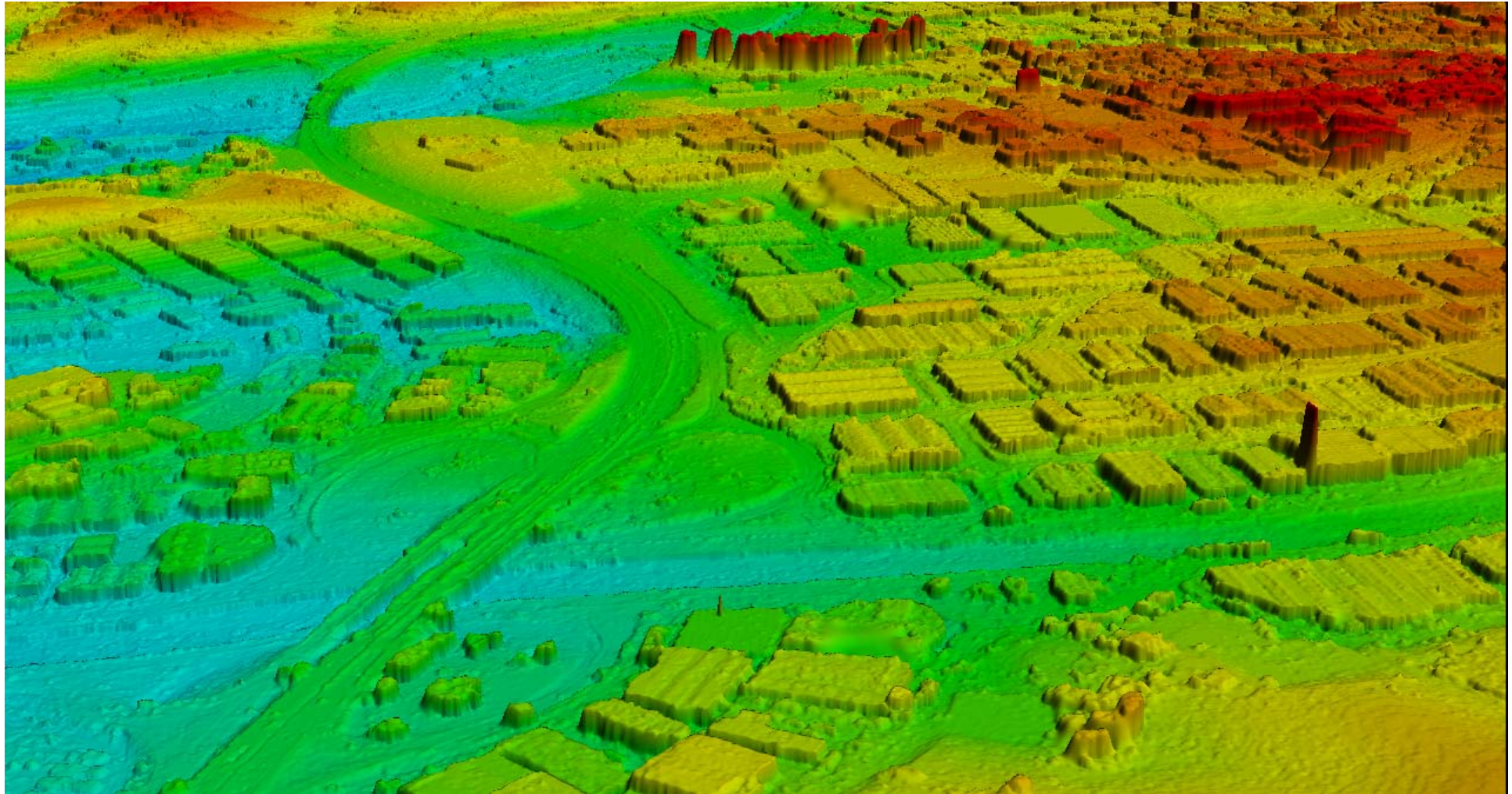


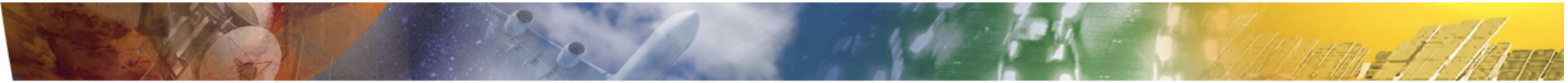
Terrassa LIDAR Reference



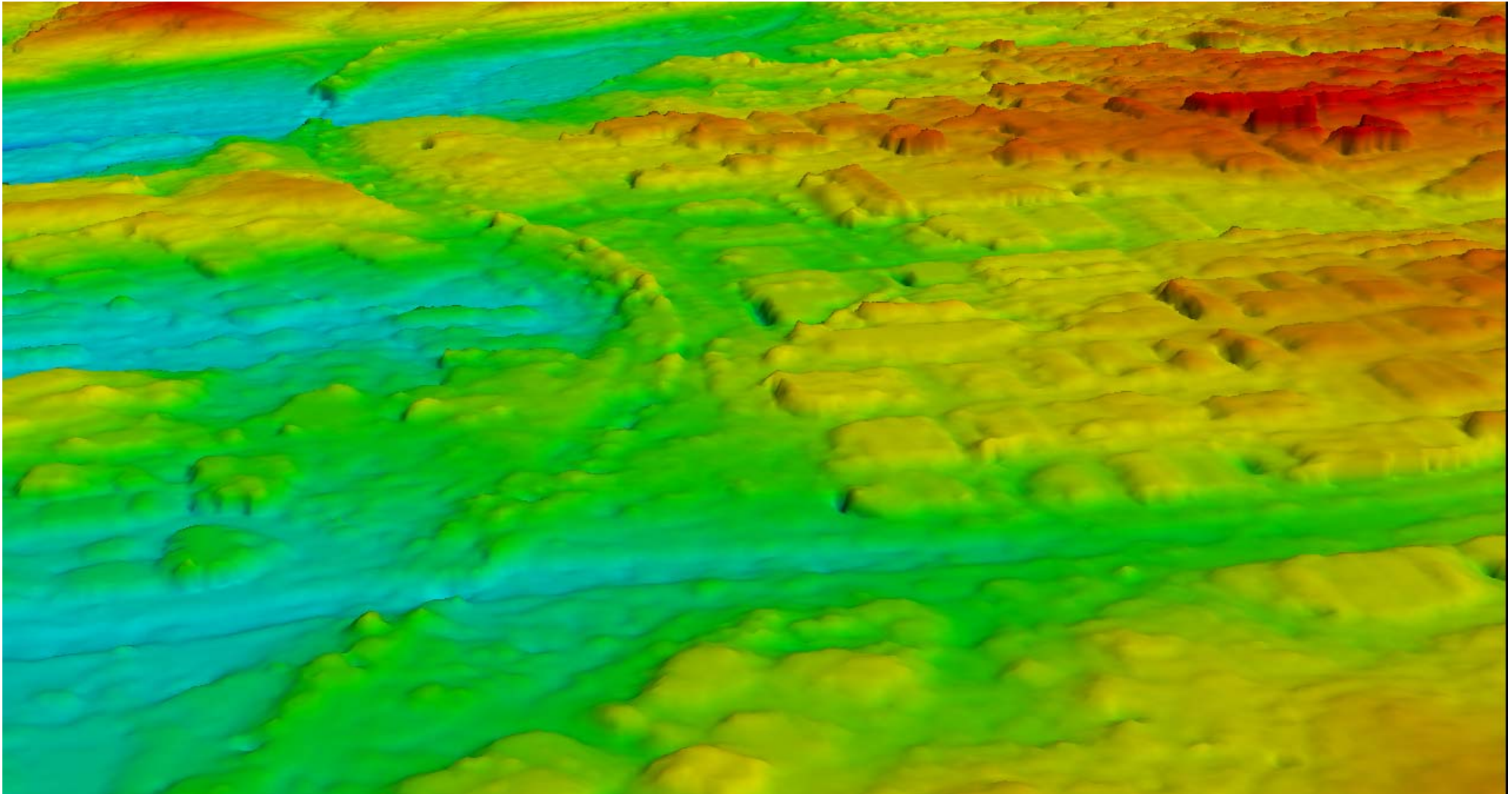


Terrassa - WV-1 34° convergence angle





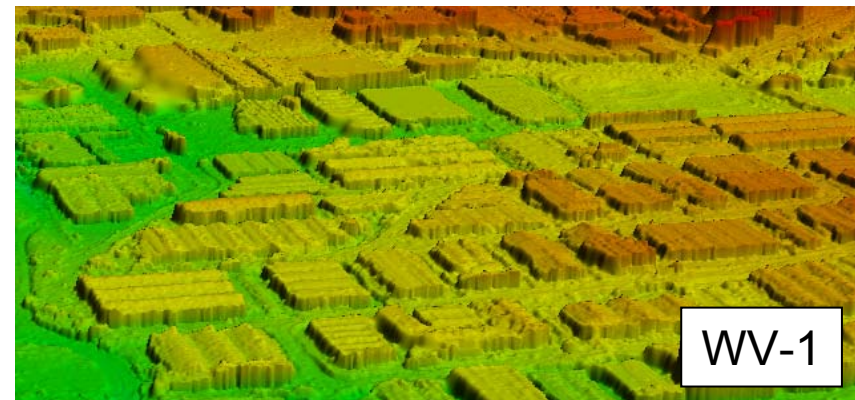
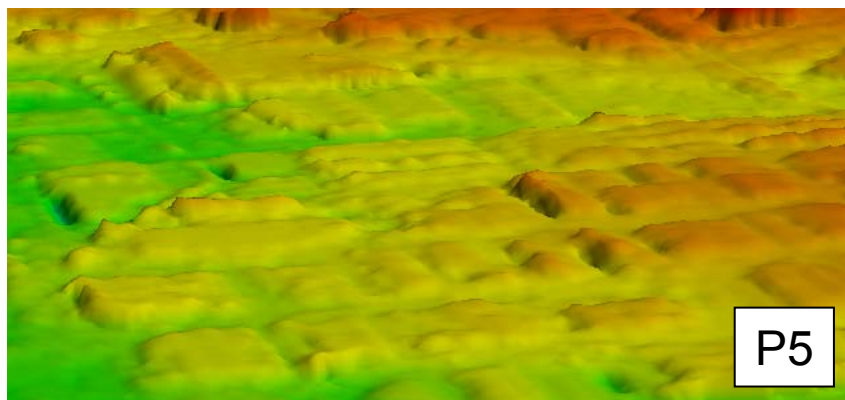
Terrassa – Cartosat-1 31° convergence angle

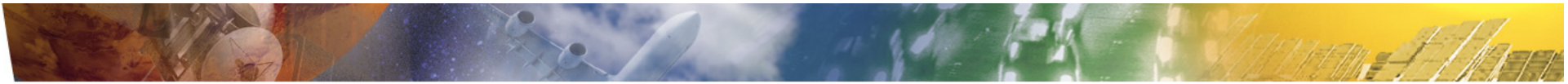


Quantitative Evaluation Difference Statistics

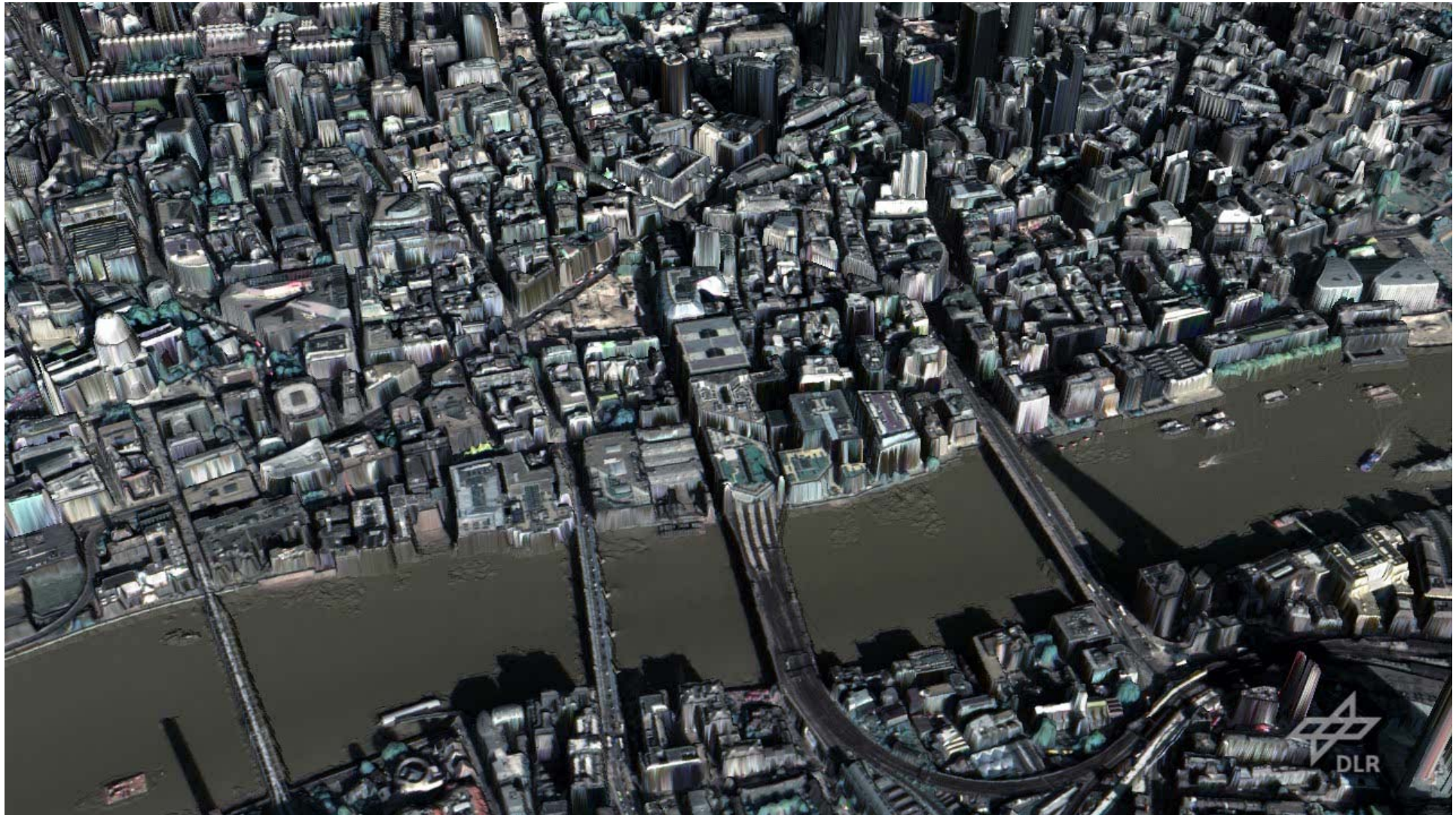
Test area	Sat	Mean	Median	Std	NMAD	AQ95
Terrassa	P5	0.0	0.0	3.4	2.1	6.8
	WV-1	-0.1	0.0	2.9	0.6	5.9
Vacarisses	P5	-0.2	0.1	4.1	2.8	7.5
	WV-1	0.2	0.0	3.7	1.1	7.8
La Mola	P5	-1.2	0.0	8.2	3.7	12.6
	WV-1	-0.1	0.0	4.7	1.3	9.3

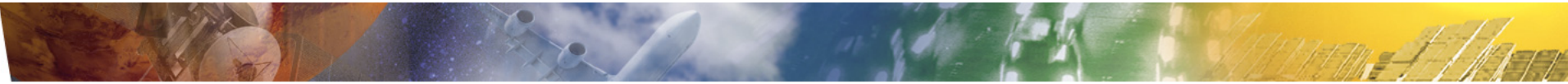
Unit: m





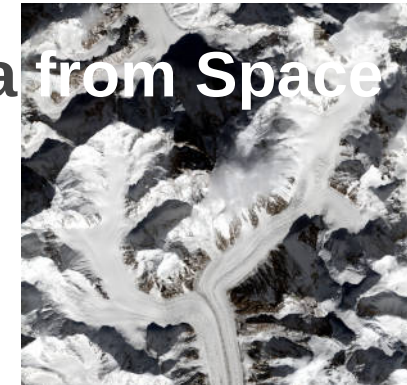
London Animation





K2 Simulation using 0.5 m Image Data from Space WorldView-2 Triple Stereo

- DSM generated by automatic image matching
- First very detailed view of K2
- Film: http://www.dlr.de/dlr/desktopdefault.aspx/tabid-10212/332_read-921/



15°



0°

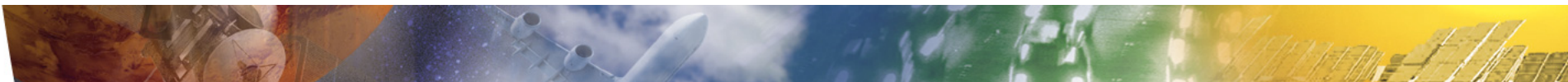


-15°







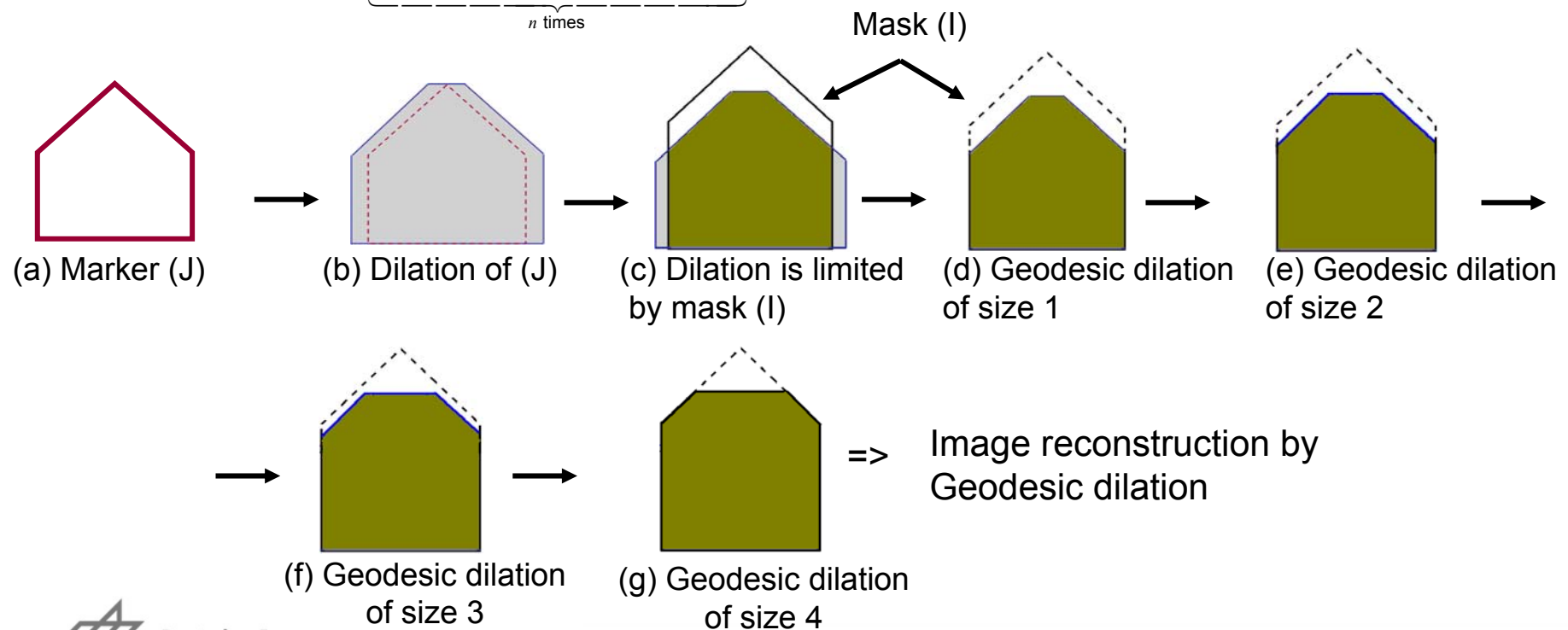


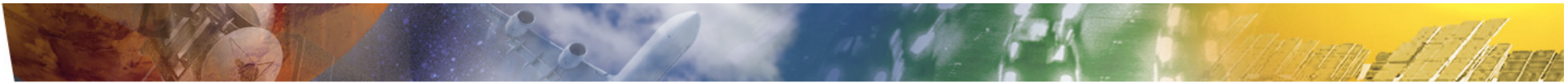
Geodesic Dilation for Generation: DTM from DSM

- Basic concept for local maxima extraction
- In geodesic dilation the result after dilating is limited by a mask:
- Image reconstruction: Geodesic transformation repeated until stability

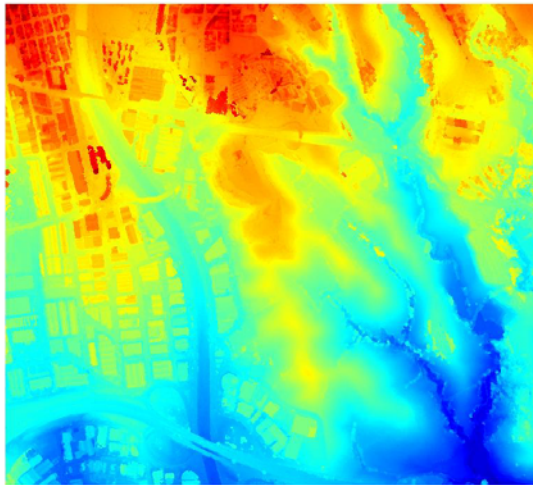
$$\delta_I(J) = \delta(J) \wedge I$$

$$\delta_I^{(n)}(J) = \underbrace{\delta_I^{(1)}(J) \circ \delta_I^{(1)}(J) \circ \dots \circ \delta_I^{(1)}(J)}_{n \text{ times}}$$

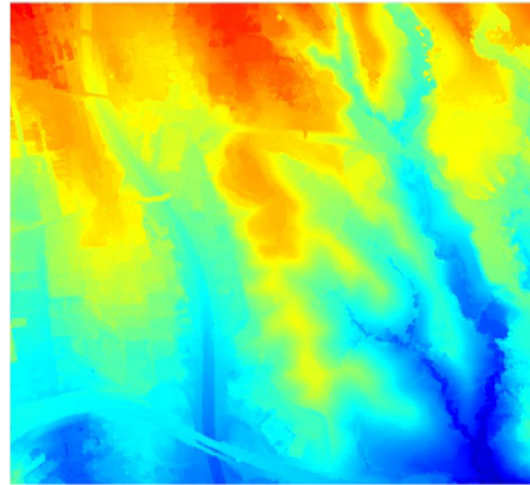




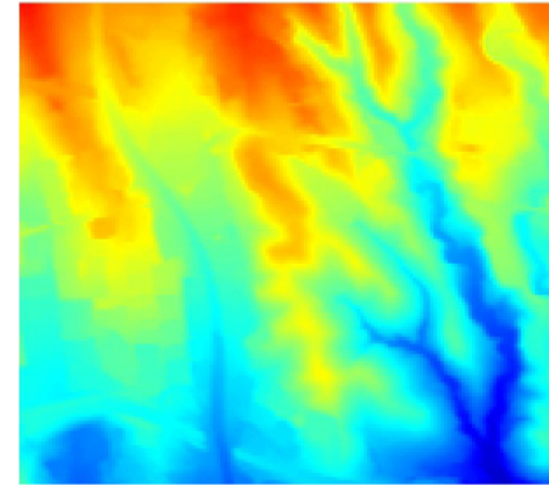
DTM from DSM - Worldview



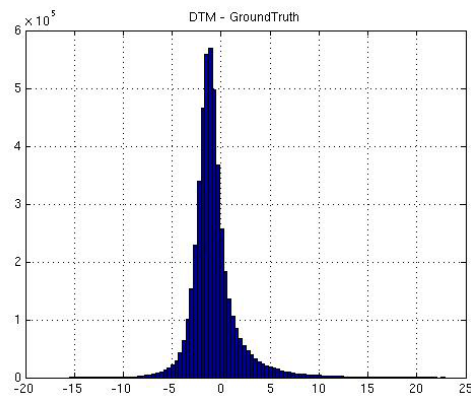
DSM; 1m



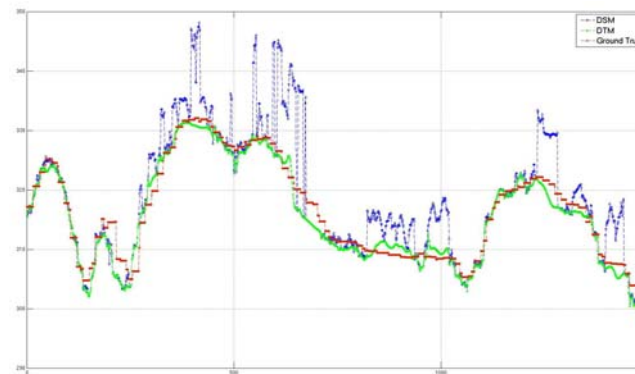
DTM; 1m



Reference DTM; 1m



Histogram: DTM - Reference



Profile: DSM (blue), DTM (green), Reference (red)

$$\text{Diff} = \text{DTM} - \text{Reference}$$

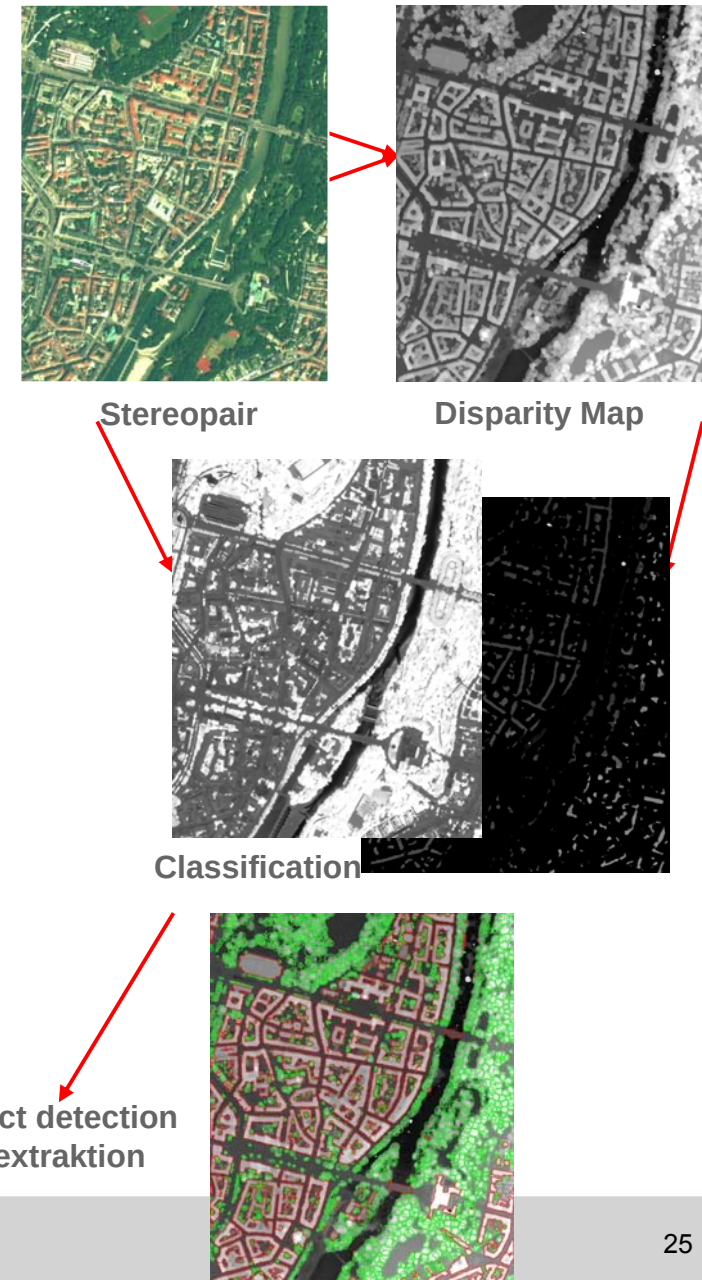
$$\text{Mean}(\text{Diff}) = -0.76\text{m}$$

$$\text{StandardDev.}(\text{Diff}) = 2.34\text{m}$$



3D Object extraction from one Stereo-Pair

- DSM generation
- Mark occlusions
- Disparity map should fit to one multispectral image
- Classification through combined evaluation of spectral and height information in 4 classes, + DTM, nDSM
 - Veg. + high = trees
 - Veg. + low = low veg.
 - Non-veg. + high = building
 - Non-veg. + low = street, parking, water
- Water and vegetation masks
- Detection, Extraction and modeling of single objects



Vegetation- and Water-Masks

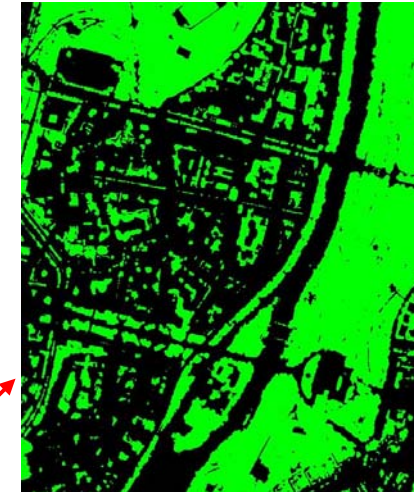
Pan
sharpened
image



$$\text{NDVI} = \frac{(\text{red} - \text{NIR})}{(\text{red} + \text{NIR})}$$

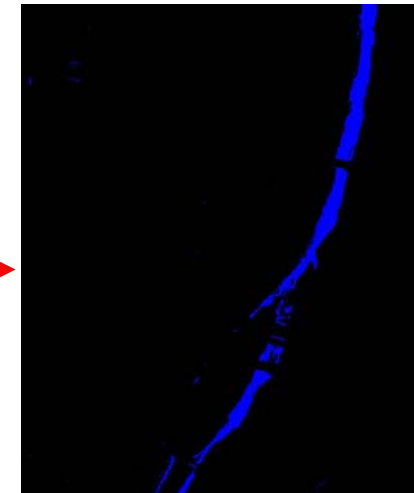


$\text{NDVI} > +t_v$



Vegetation Mask

$\text{NDVI} < -t_w$

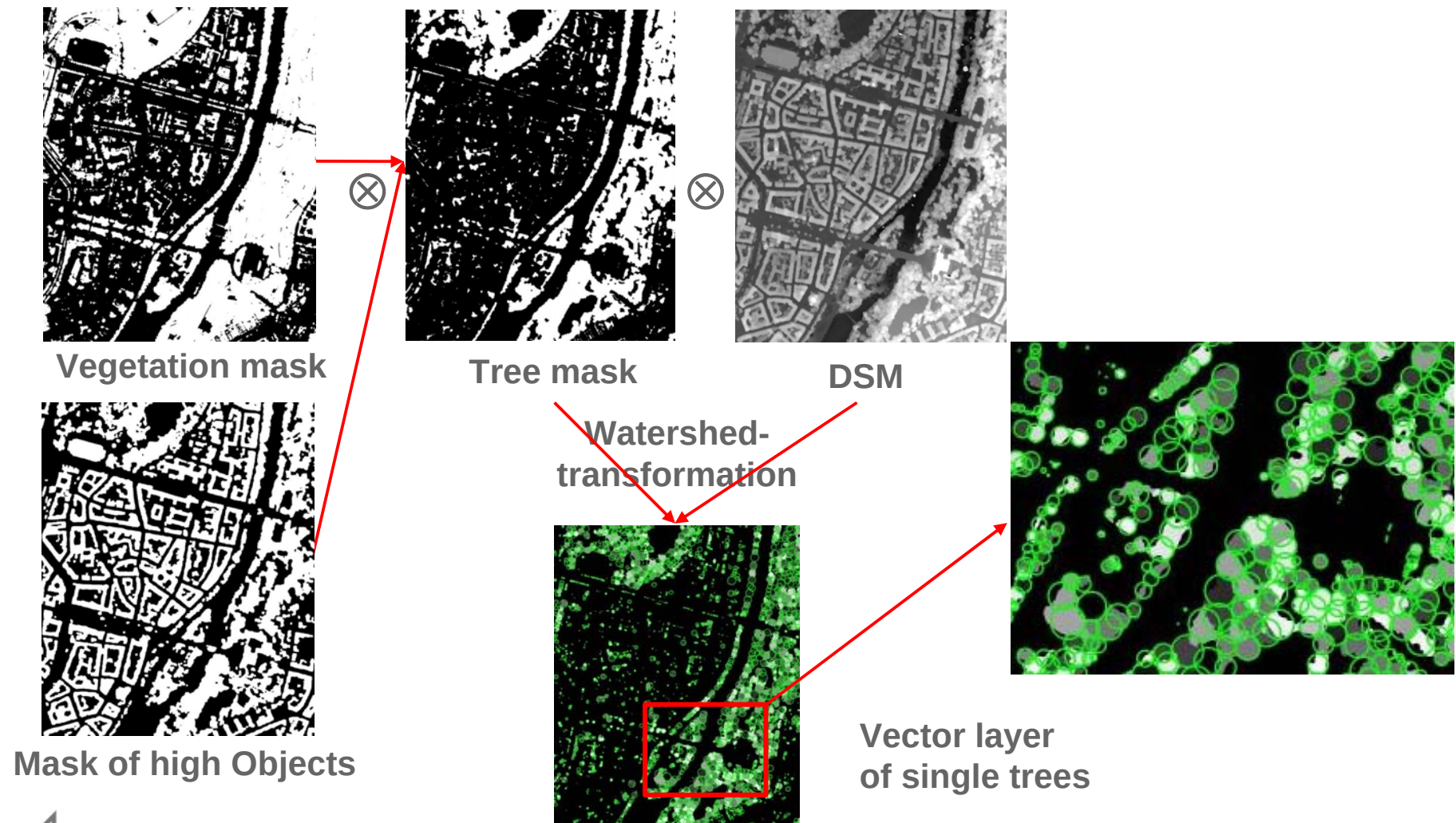


Water Mask



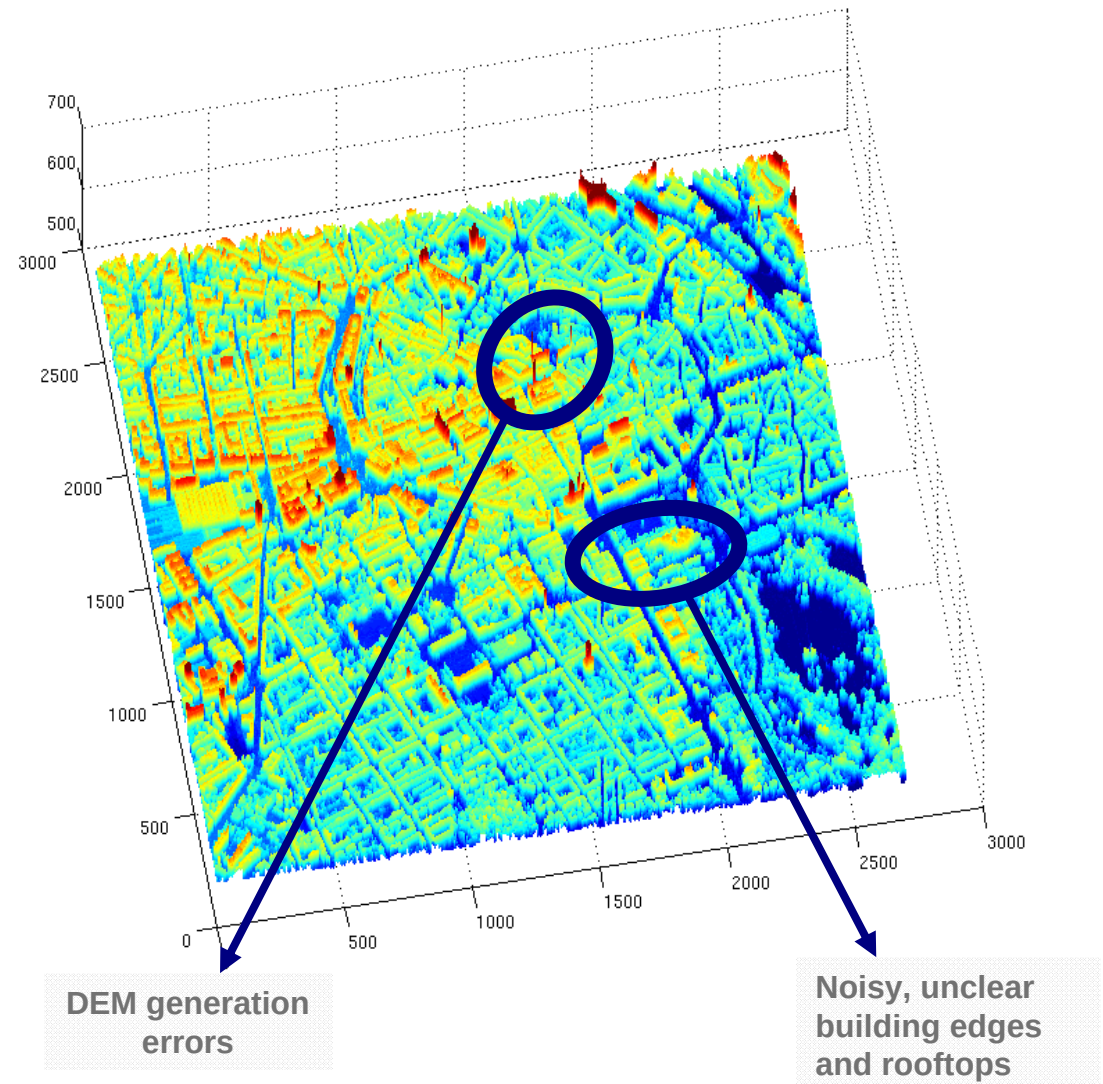
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Object Detection and Modelling – Trees



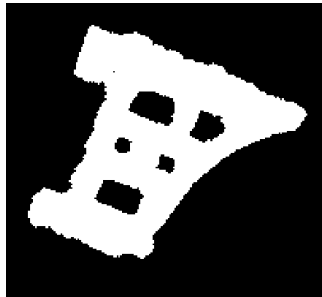
Building Extraction from WV-2, IKONOS and Cartosat

- Digital Surface Model (DSM) is automatically obtained from one stereo pair
- Occluded areas have no value in DSM
- Fully automatic approach based on automatic building shape detection

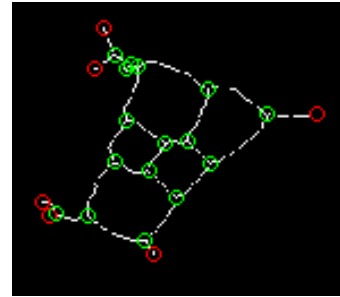
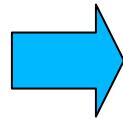


Building Extraction: Complex Shapes

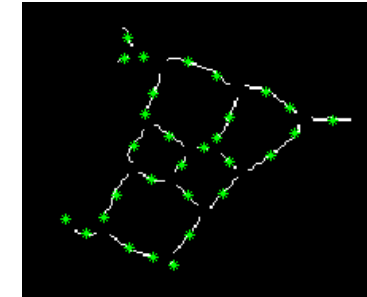
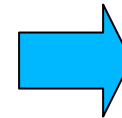
Detecting Complex Building Shapes:



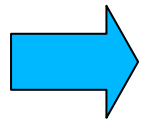
Building segments
by local
thresholding



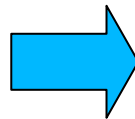
Skeleton of building segment



Elongated pieces divided
sub-pieces again. Centers of
sub-pieces as seed-points.

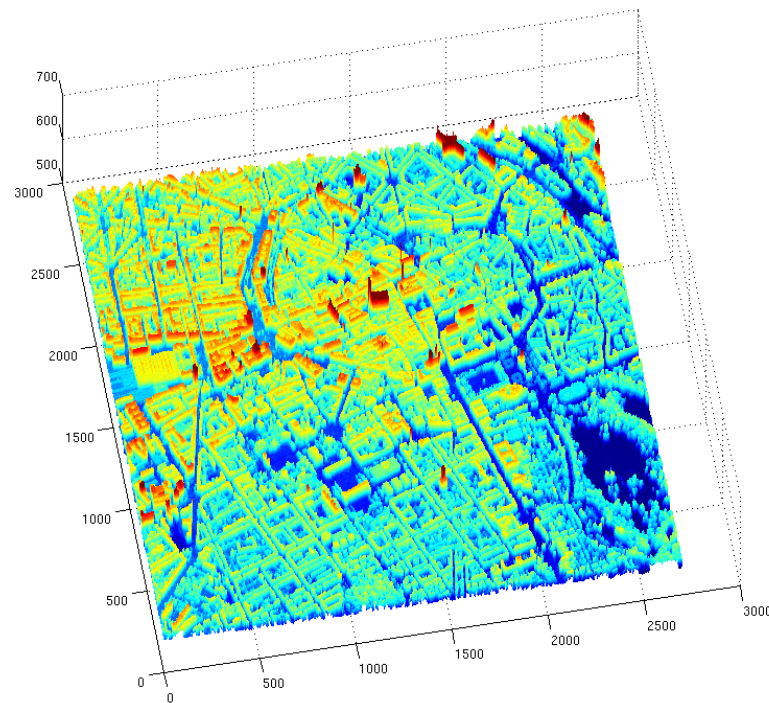


Box-Fitting algorithm for
each seed-point.

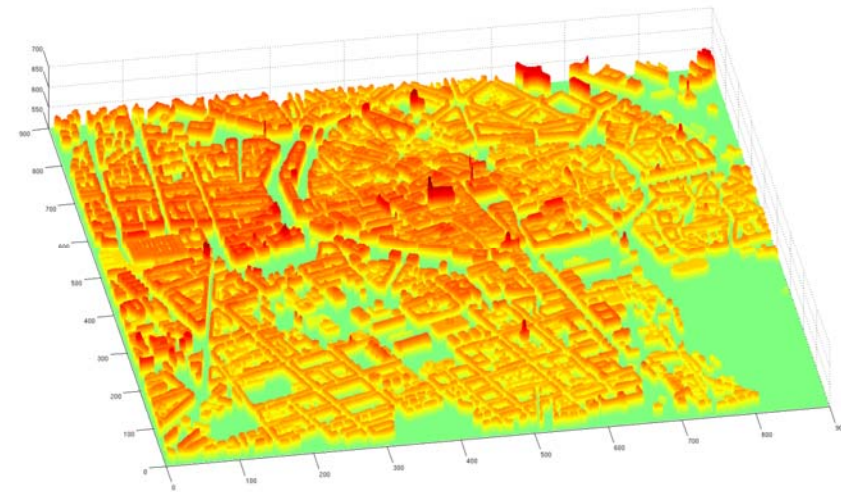
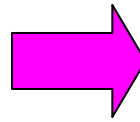


Boxes merged with
morphological operations

Building Extraction: Quantitative Results, WV-2



Original DEM



Automatically enhanced DEM

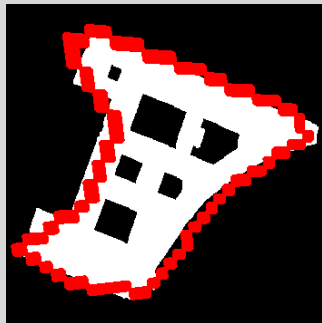
Reconstruction Performance of Enhanced DEM:

429 of **459** buildings are detected and their footprint and height are extracted (LOD1).

Detection performance is calculated as: **93.5%**

Building Extraction: Results for different Stereo Sensors

*Shape Detection
Cartosat-1 Data*

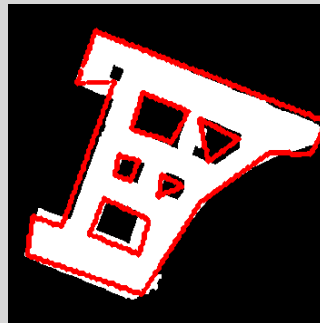


*True Detection = 93,2 %
False Detection = 37,3 %*



*True Detection = 94,7 %
False Detection = 40,5 %*

*Shape Detection
Ikonos data*

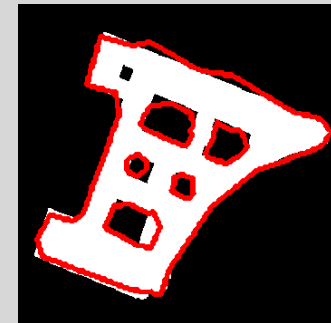


*True Detection = 90,3 %
False Detection = 12,3 %*

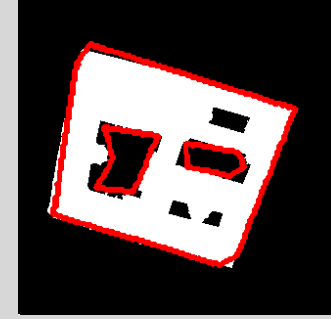


*True Detection = 93,4 %
False Detection = 14,8 %*

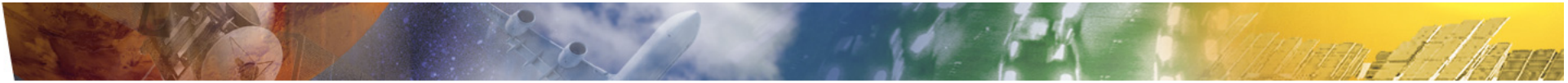
*Shape Detection
Worldview-2 data*



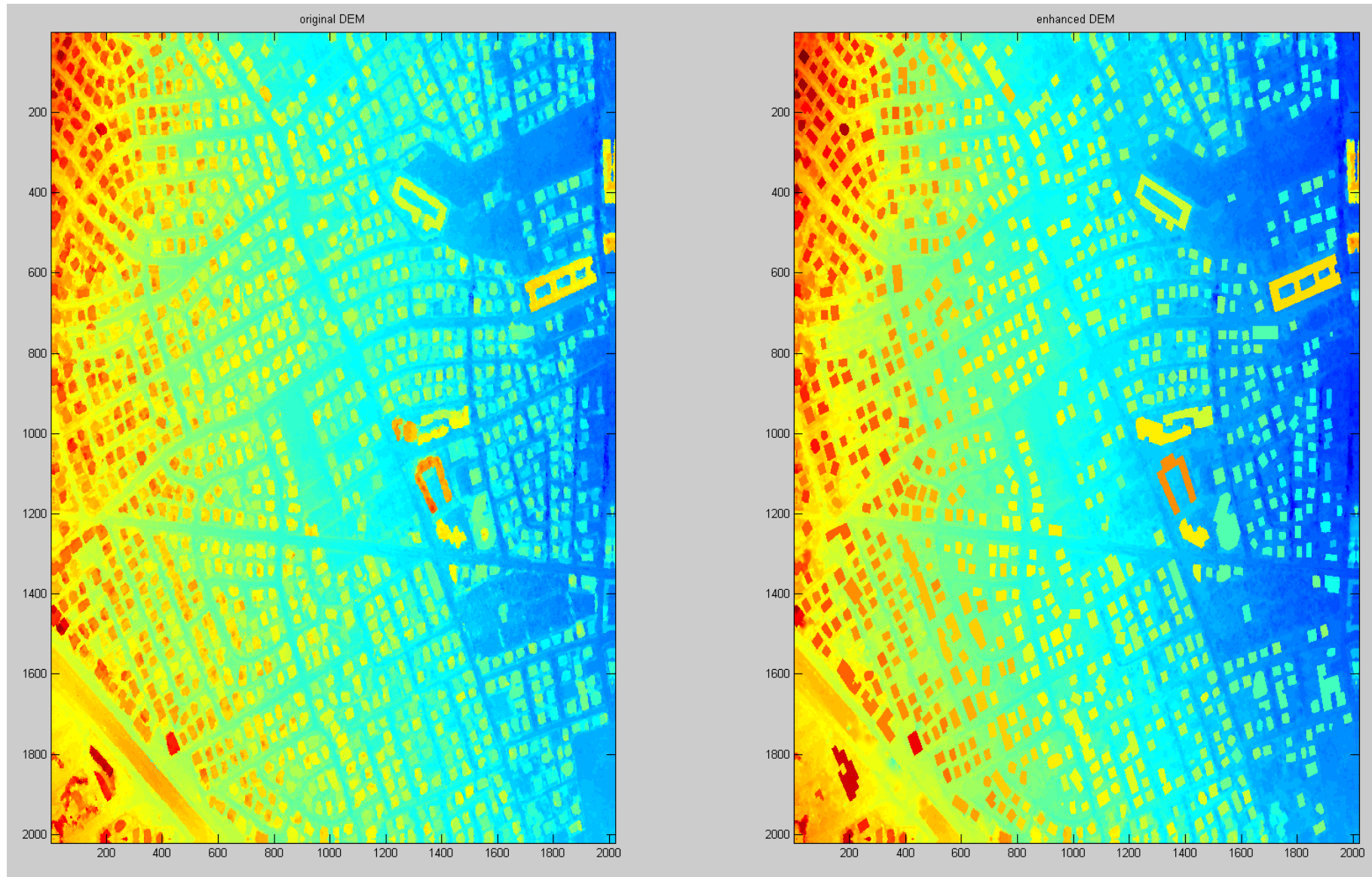
*True Detection = 92,3 %
False Detection = 9,58 %*



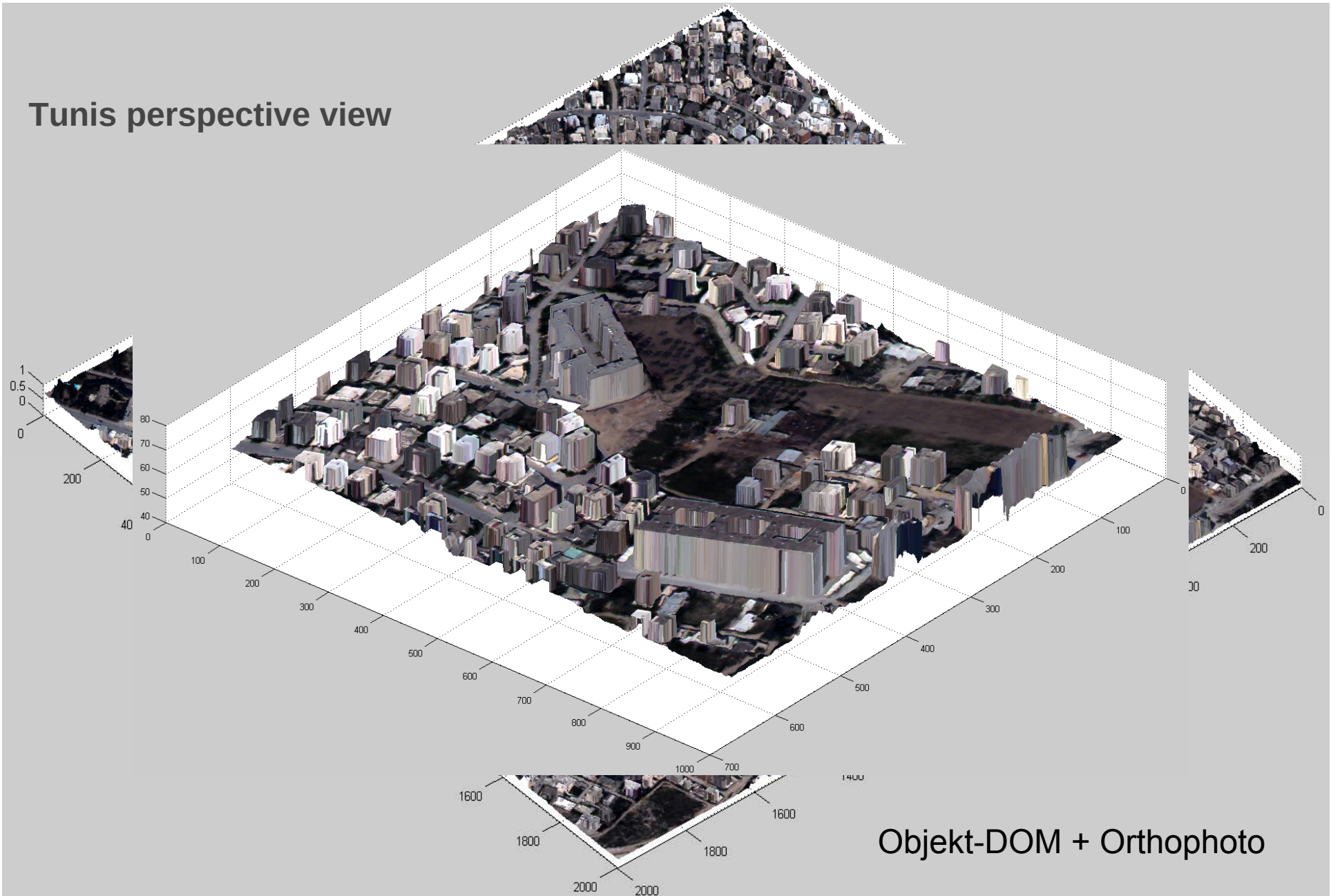
*True Detection = 98,0 %
False Detection = 8,92 %*



Original DSM vs. Enhanced: Tunis, Tunisia



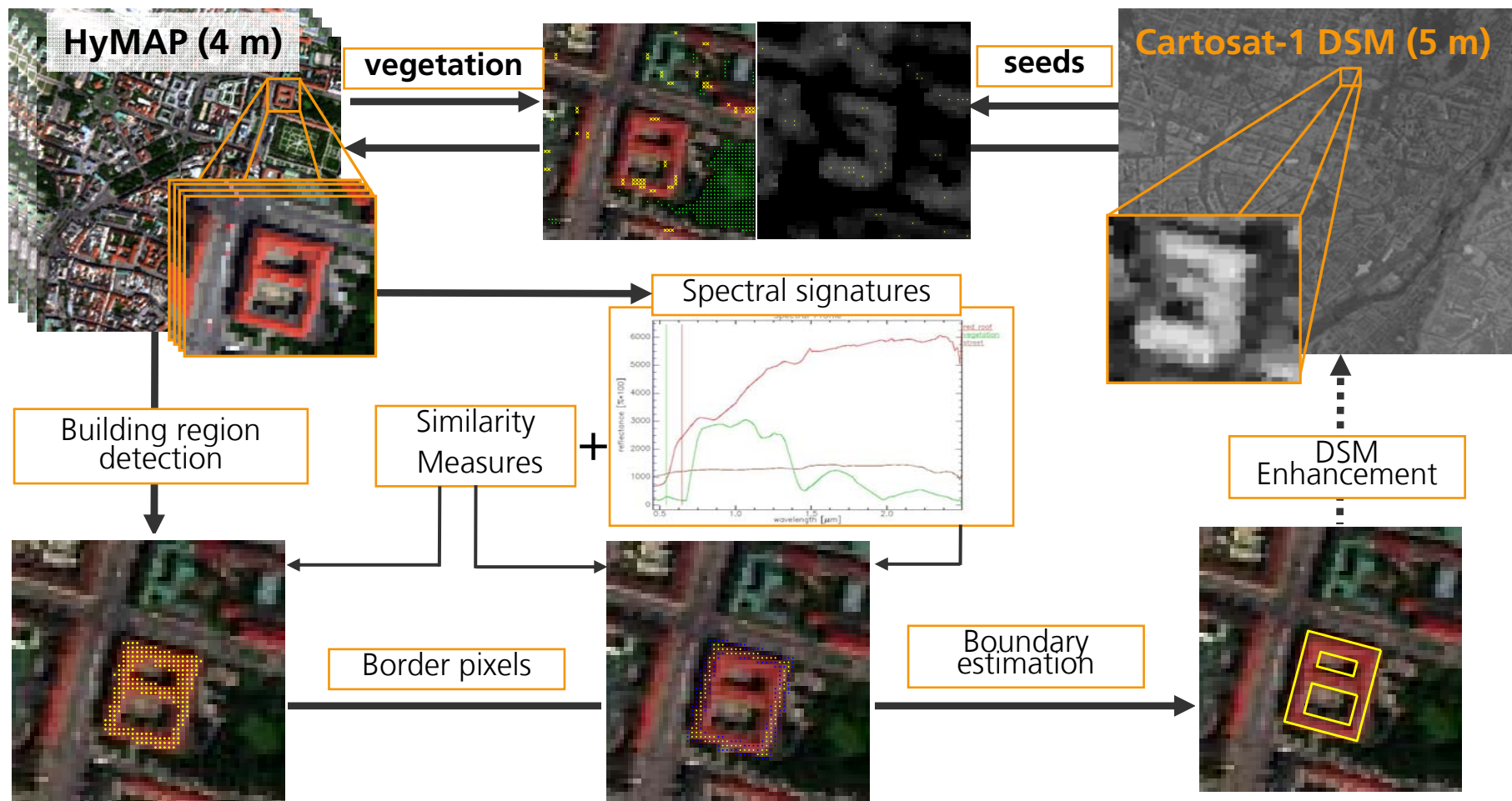
Tunis perspective view

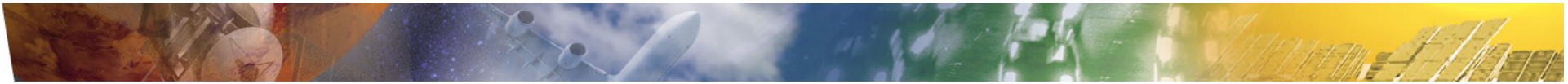


Objekt-DOM + Orthophoto

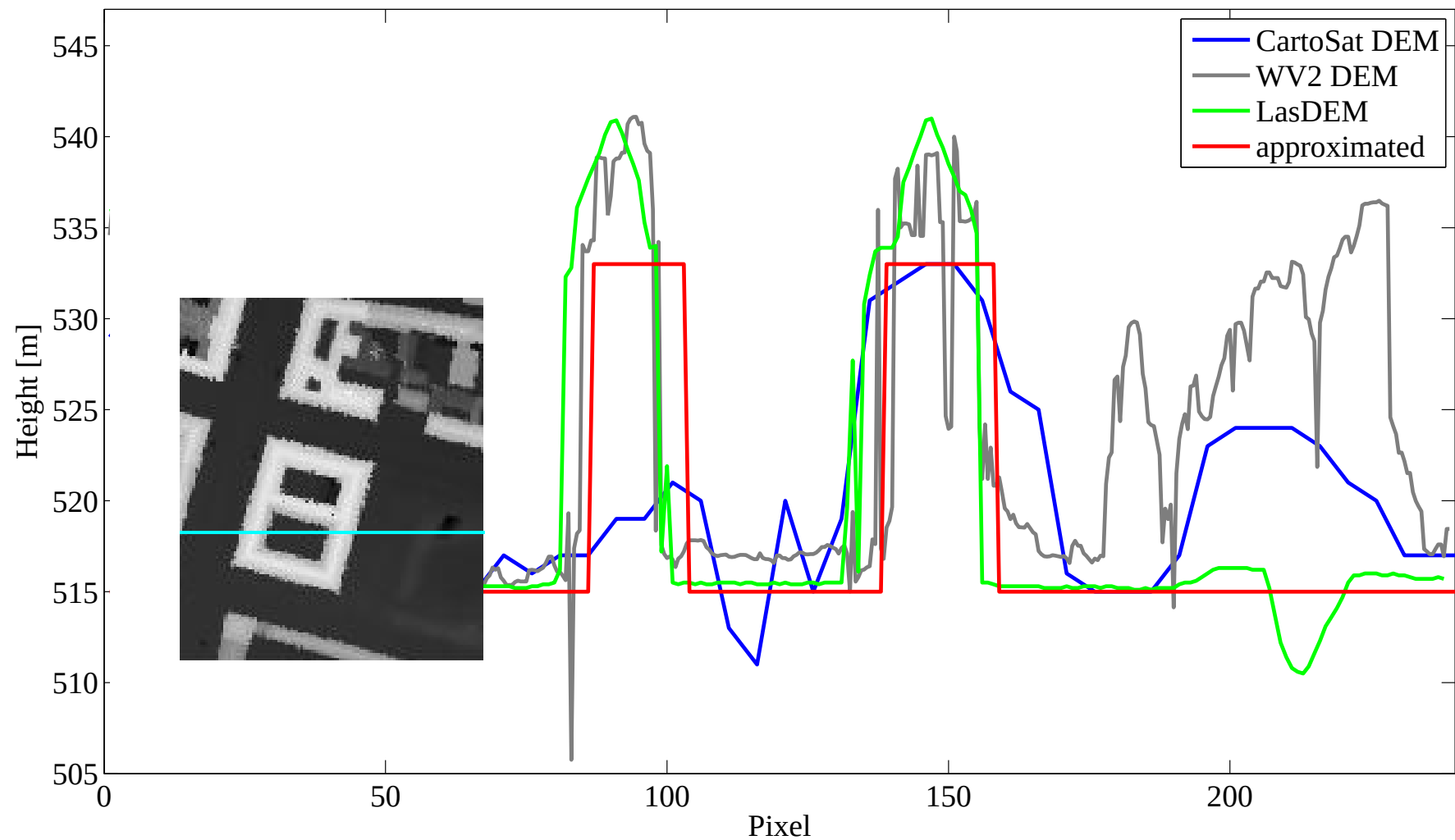


Fusion of Hyperspectral images and digital surface models in urban areas



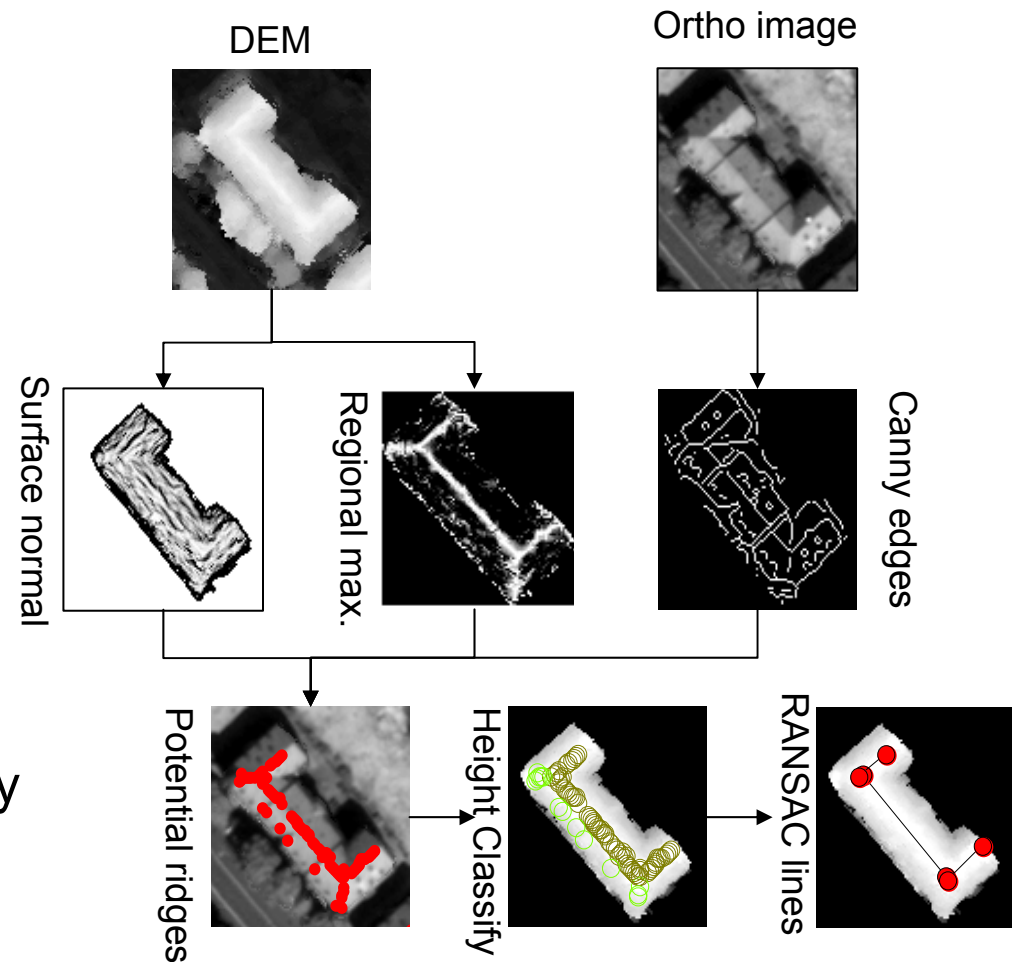


Hyperspectral image (4 m) + DSM (5 m)



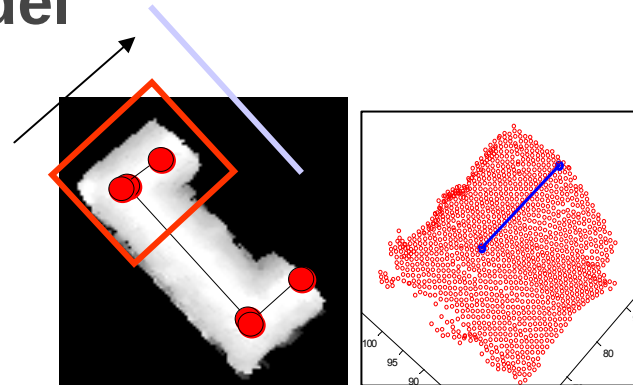
Roof Extraction: Ridge based decomposition

- Ridge extraction:
 - Local maxima extraction; Geodesic morphology based method
 - Edge extraction from ortho-rectified image
 - Surface normals
 - Height classification
- Ransac based line fitting
- Line refinement/extension by analysis of neighbouring pixels

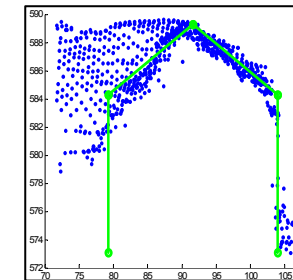


Projection based Model

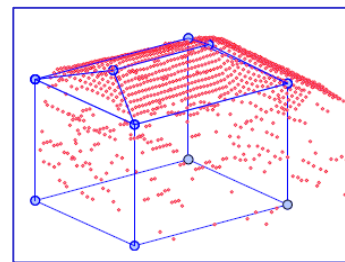
- Parametric roof modeling:
 - Localization
 - Projection into 2D plane
 - 2D model of maximum supported pixels
 - Extrusion into 3D space
 - 3D model of part
 - Merge 3D models and refine common nodes



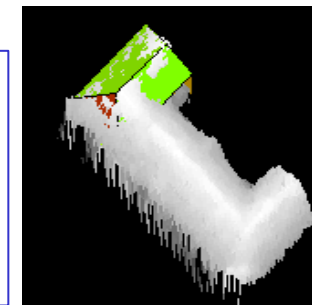
(a) Localized pixels



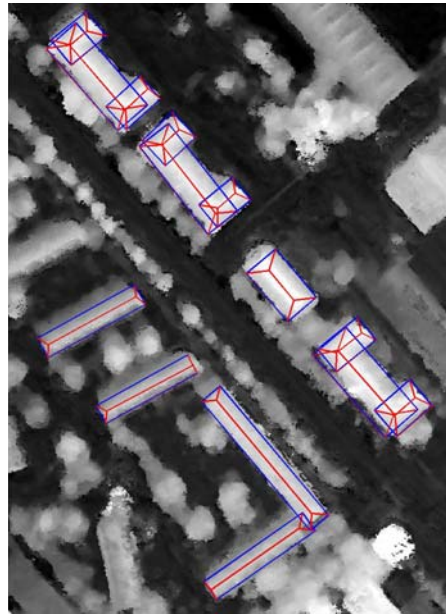
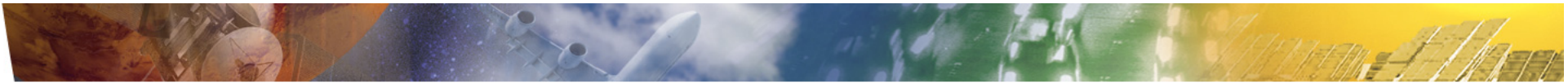
(b) Projection & Fitting 2D model



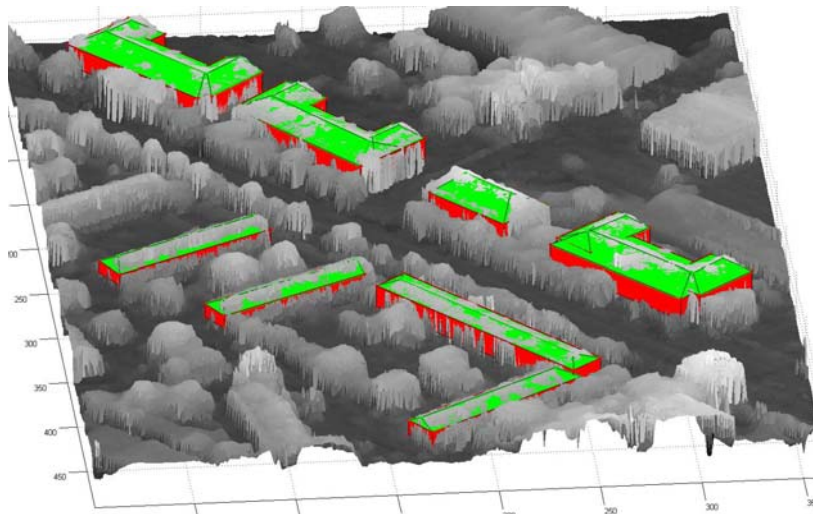
(c) 3D model of building part

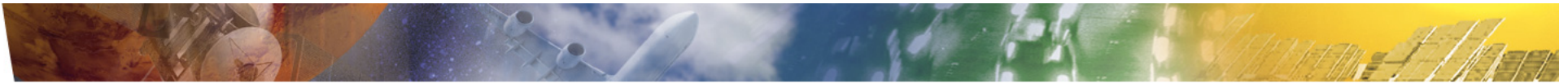


(d) Merge



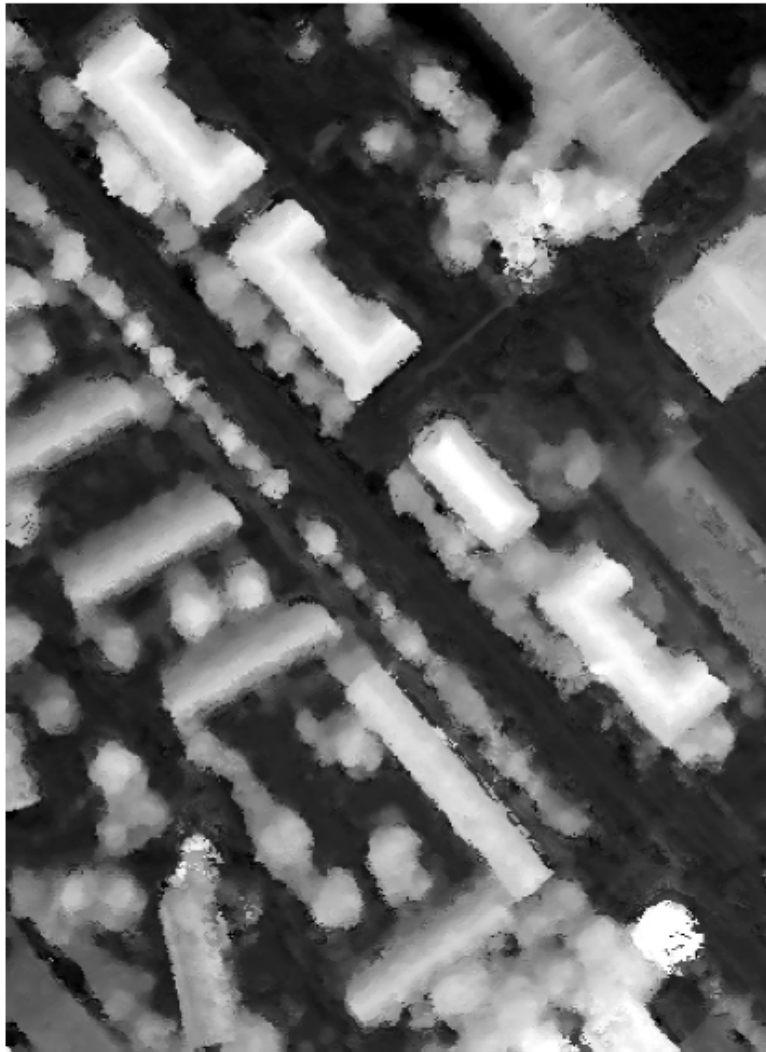
Roof reconstruction Munich



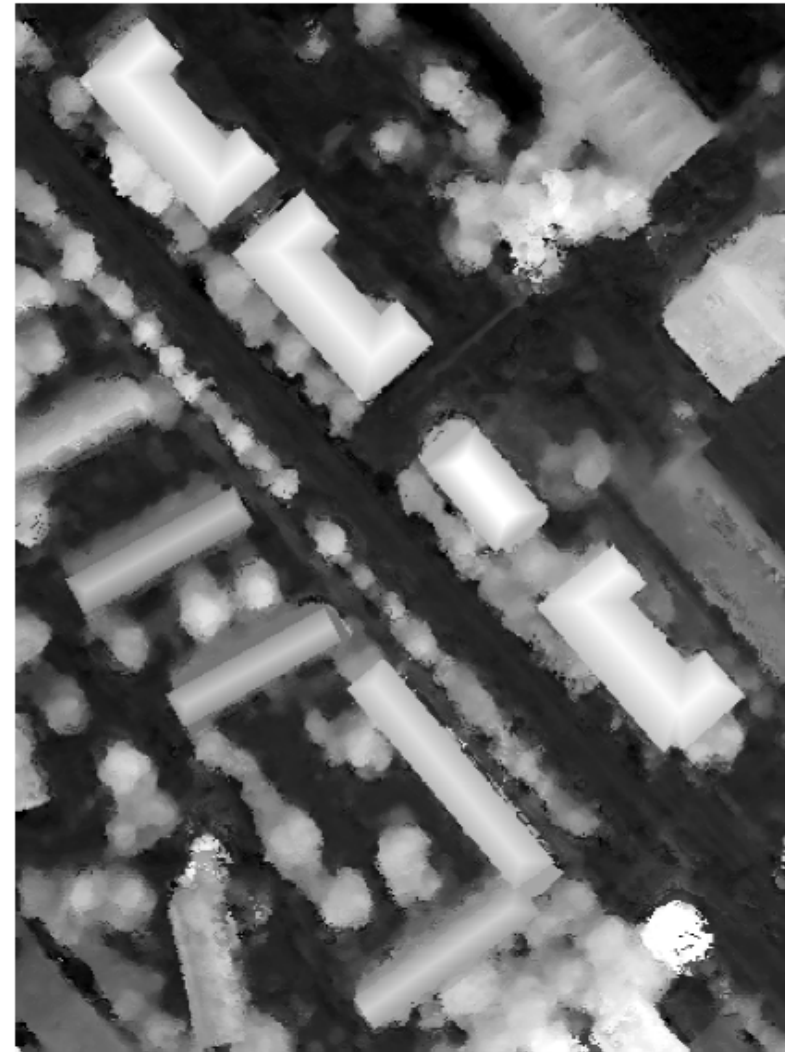


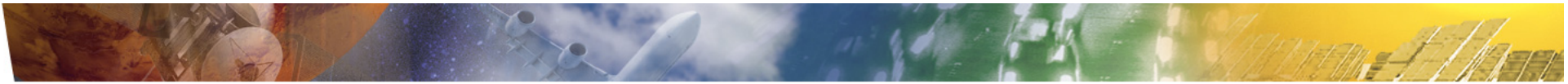
DSM Enhancement

original DSM

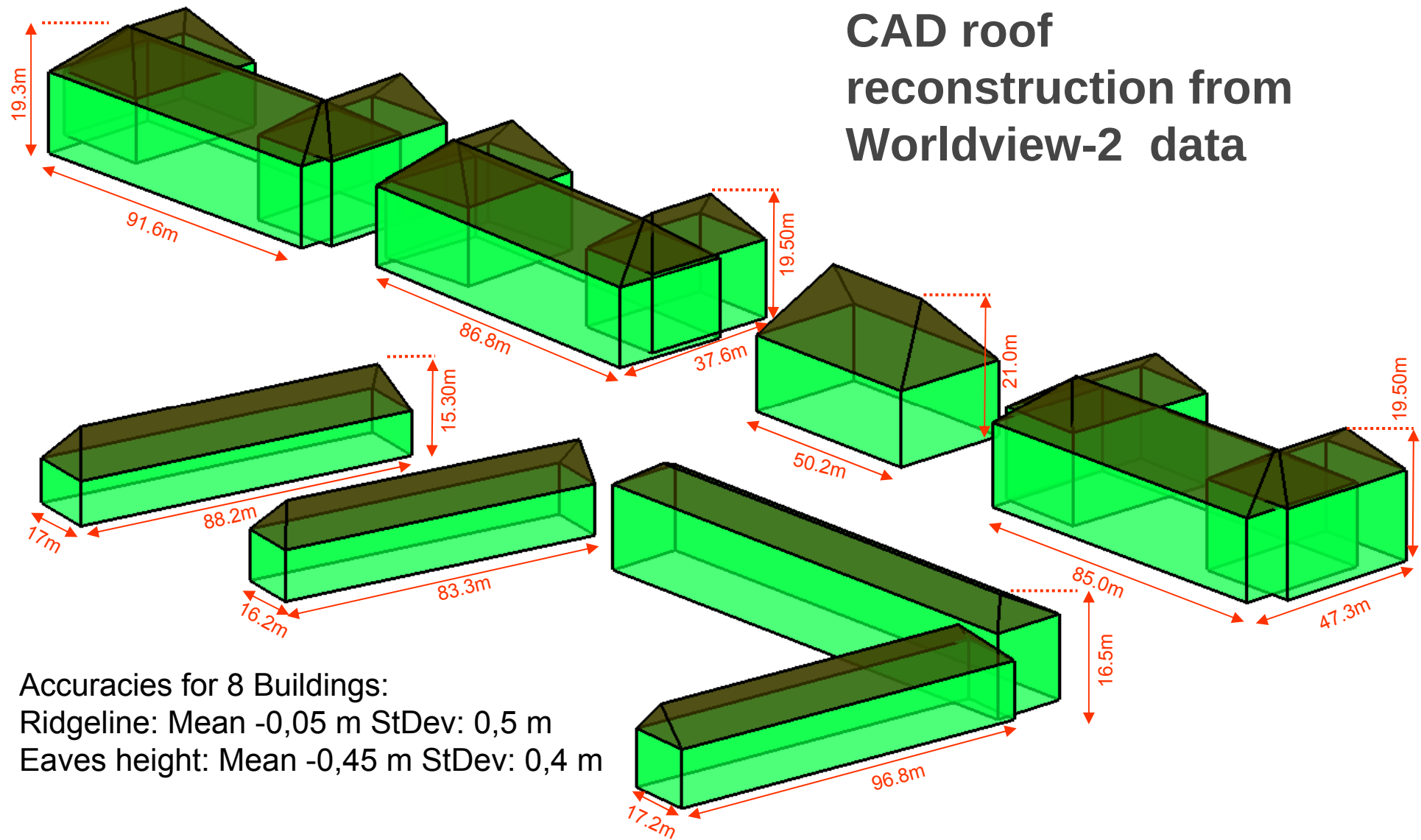


enhanced DSM



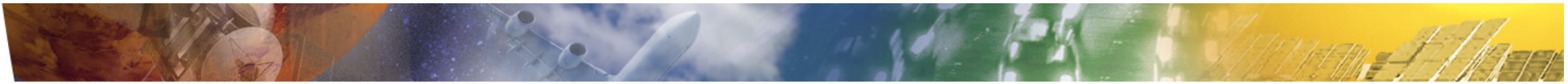


CAD roof reconstruction from Worldview-2 data



Accuracies for 8 Buildings:
 Ridgeline: Mean -0,05 m StDev: 0,5 m
 Eaves height: Mean -0,45 m StDev: 0,4 m

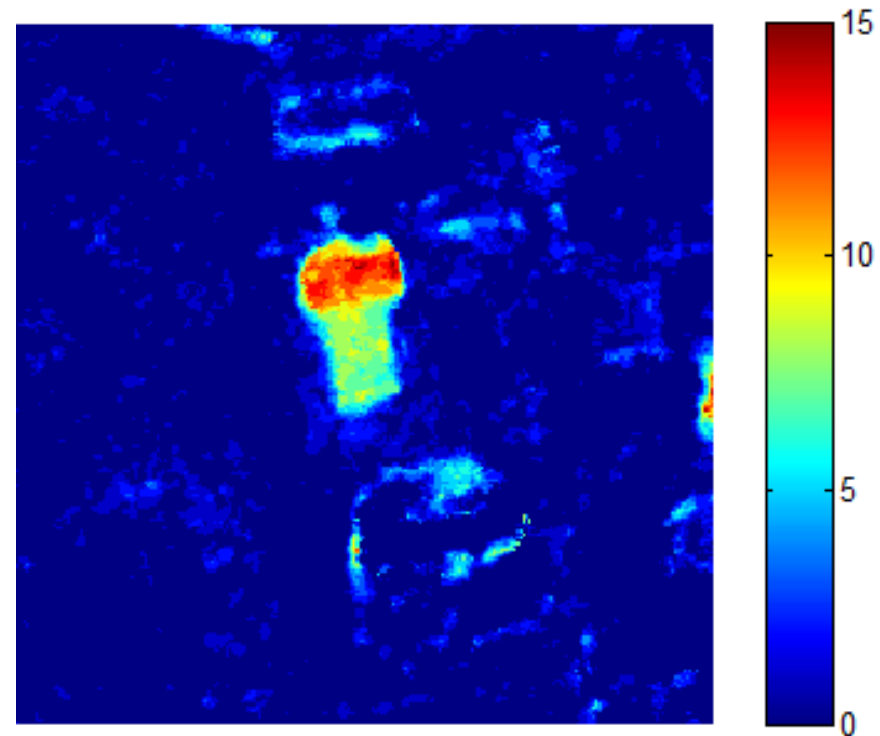




Change detection with DSMs



Ikonos data
2006 (summer),
2010 (winter)



Change map

Building Change Detection

Step1: Dempster-Shafer fusion

$$m(A) = \frac{\sum_{B_1 \cap \dots \cap B_p = A} \prod_{i=1}^p m_i(B_i)}{1 - K}$$

i : indicator, and $1 \leq i \leq p$,

m : probability mass

p : amount of indicators

$$K = \sum_{B_1 \cap \dots \cap B_p = \emptyset} \prod_{i=1}^p m_i(B_i)$$

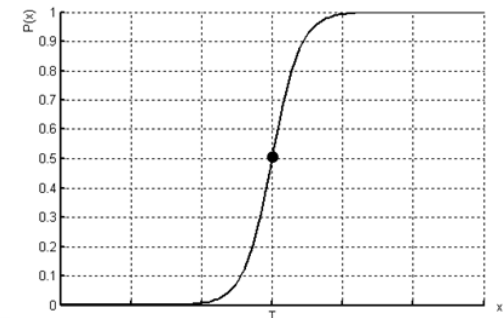
Building change indicators

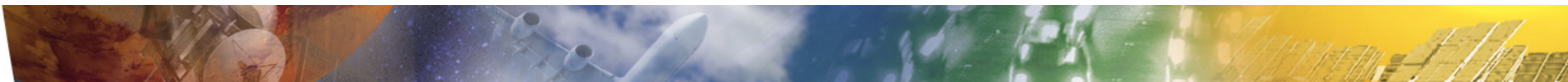
- Robust Height Change (DSM)
- Kullback-Leibler Divergence similarity measurement (Panchromatic images)

No-building change indicators

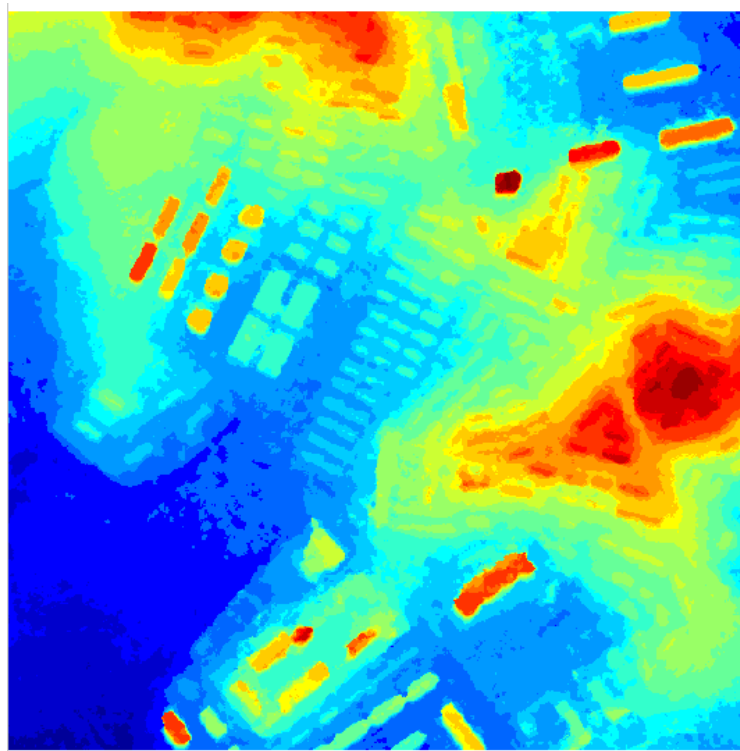
- Shadow (Multispectral images)
- Vegetation (Multispectral images)

Step2: Object based building extraction

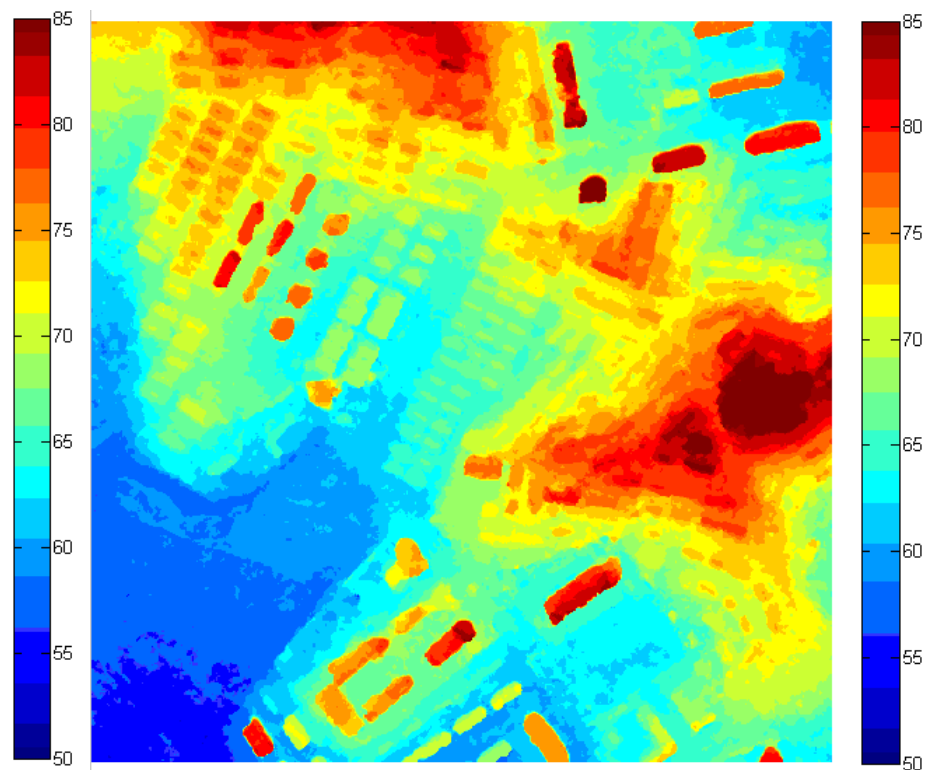




DSMs from Ikonos Stereo Data (32° an 36°)

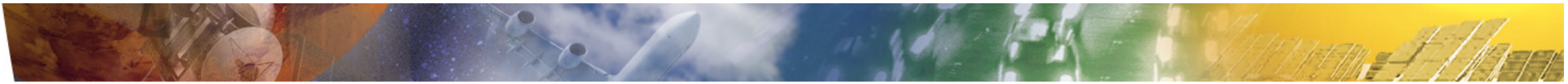


DSM_year 2006

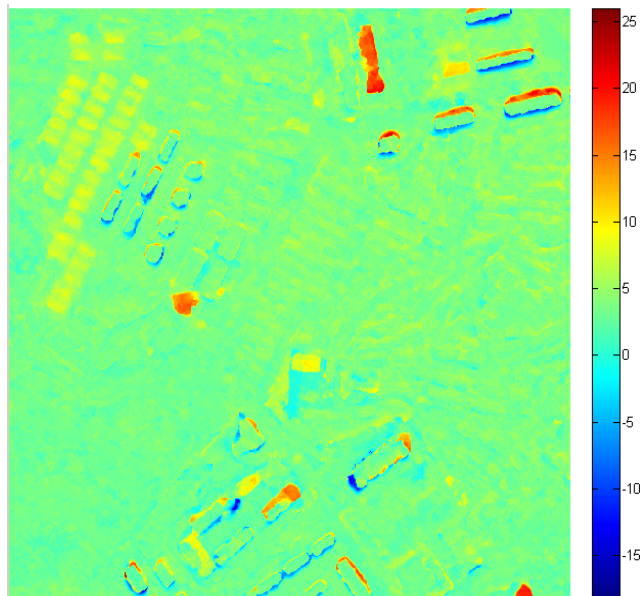


DSM_year 2011

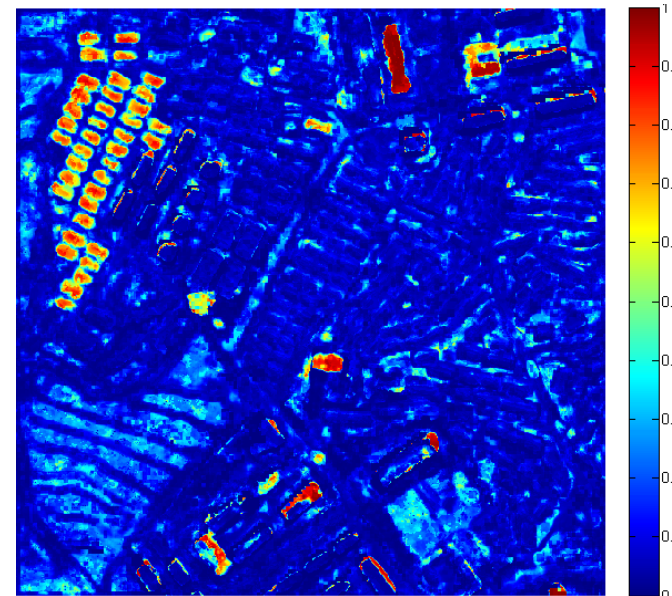




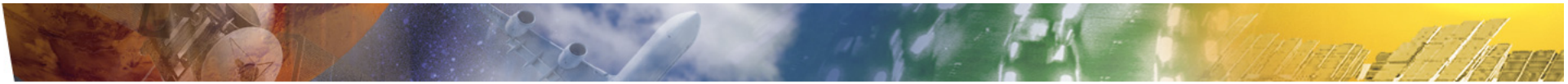
Results



Original Height Difference
(Area Under ROC=0.9299)

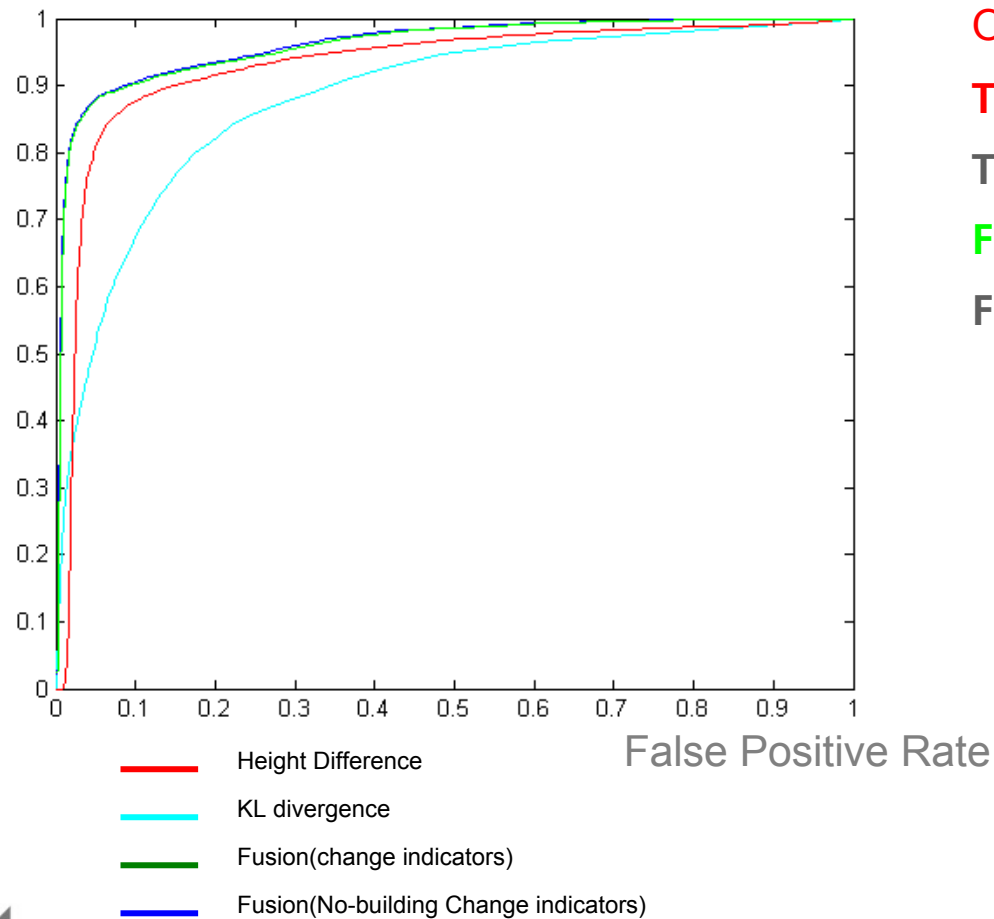


Fusion Result
(Area Under ROC=0.9621)



Result evaluation

True Positive Rate



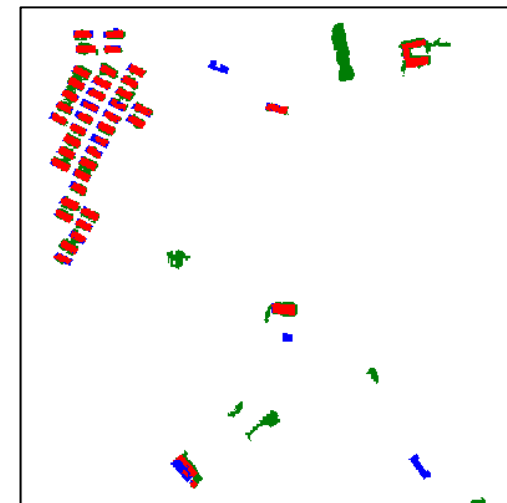
Object / pixel based evaluation

True detected :42

True detected rate (pixel): 93.33%

False detected:6

False detected rate (pixel): 15.49%





Thank you for your attention



Deutsches Zentrum
für Luft- und Raumfahrt e.V.
in der Helmholtz-Gemeinschaft