Generation of a digital elevation model of the Wadi Lebda basin, Leptis Magna - Lybia

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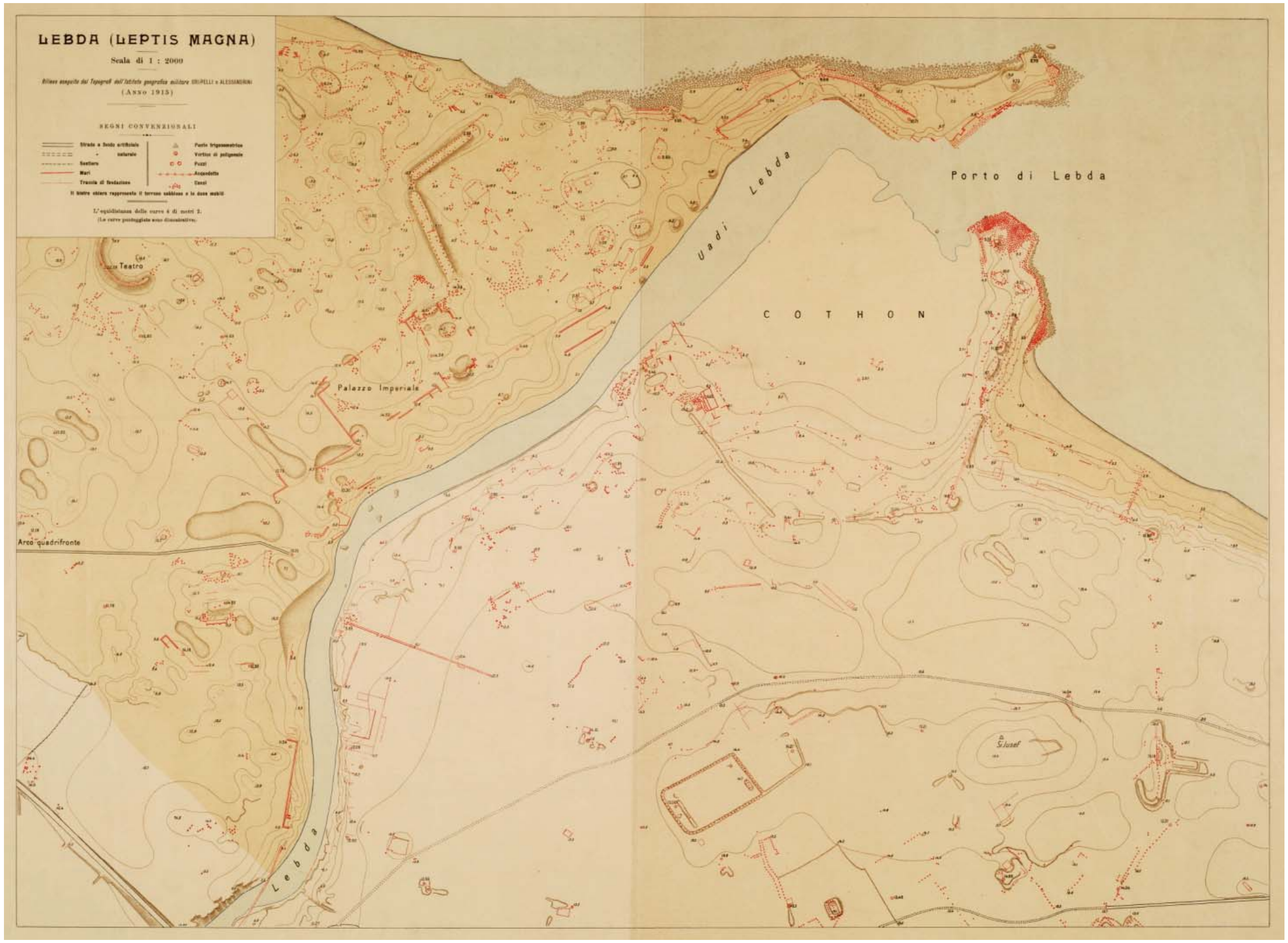
Summary

1. Archeological site
2. Project description
3. Choice about satellite technology
4. Digital Elevation Model: generation steps
5. Conclusion
6. Project Team

1. Archeological site Leptis Magna – Lybia (1/2)

1. Archeological site Leptis Magna – LybiaMap (1/2)

from Istituto Geografico Militare (1915) Leptis Magna - Lybia



2. Project description (1/4)

Project title: Safeguarding the Sabratha and Leptis Magna archaeological sites; preventing flooding of Leptis Magna from the Wadi Lebda

Project duration: 2009

Main contractor: Marco Polo Storica Ltd.

Thetis role: design the hydraulic re-arrangement of the final stretch of the Wadi Lebda which runs across the archaeological area of Leptis Magna

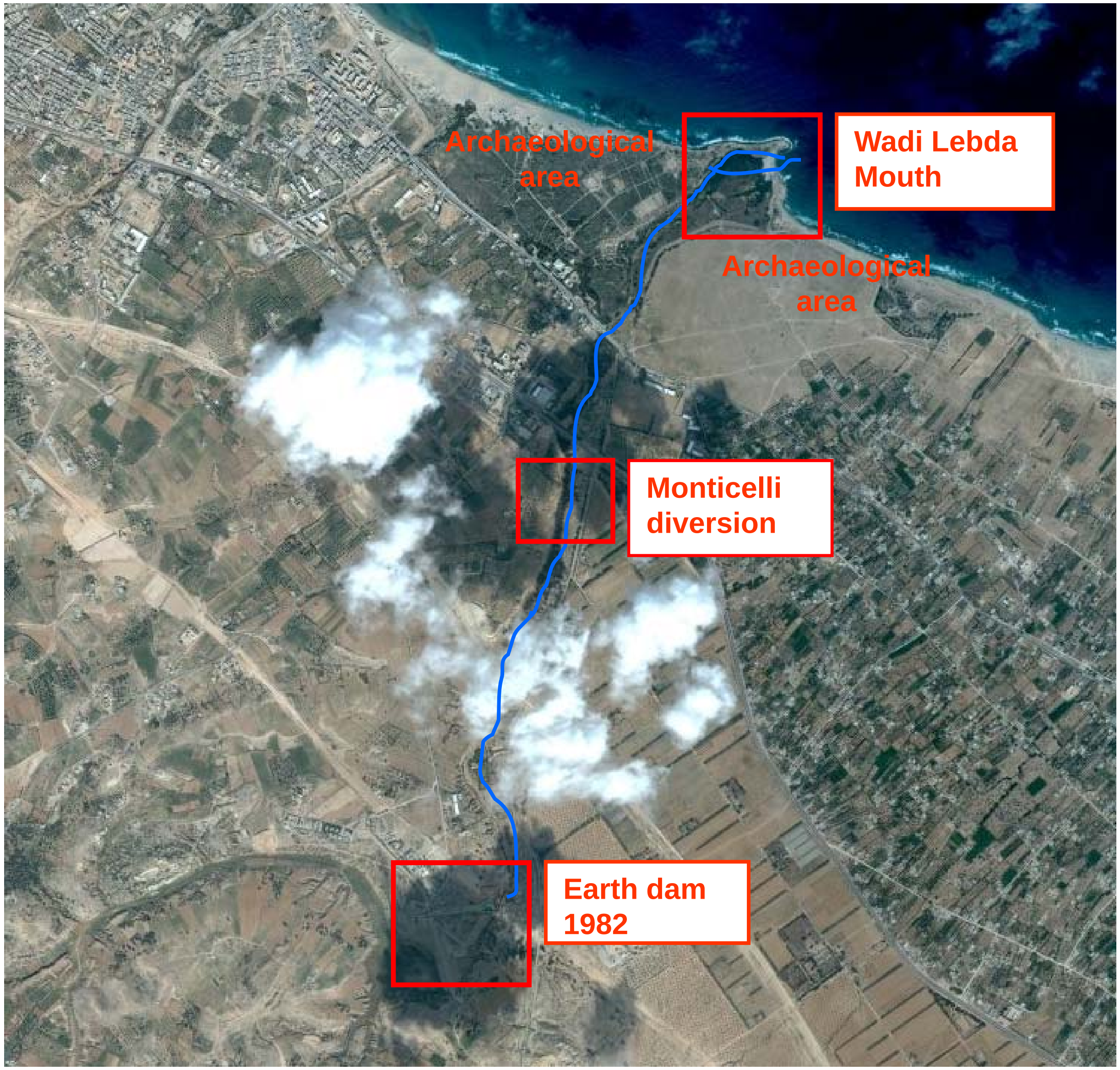
2. Project description (2/4)

Thetis main activities:

- Data collection both geographical and meteorological.
- On site survey of Wadi Lebda river.
- Generation of a three dimensional Digital Elevation Model (DEM) over a over an area of 100 km^2 with an error of +/- 5 metres in height.
- Design of the hydraulic re-arrangement of the final stretch of the Wadi Lebda.

2. Project description (3/4)

DEM: Area of interest (AOI)



2. Project description (4/4)

DEM: Area of interest (AOI) with planned Ground Control Points (GCPs)

3. DEM: choice about satellite technology (1/2)

Satellite technology was selected because:

- Vastness of the investigation area
- Lack of cartography over the area of interest
- Too tight timeframe to perform a full land survey
- Aerial survey very difficult due to logistics and government authorizations
- Hard environmental conditions such as daily air temperature

3. DEM: choice about satellite technology (2/2)

Available satellites with stereo pair enabled:

- Quickbird – Ikonos - GeoEye-1

Given the main requirement (< 5 metres as vertical error) the choice was focused satellite sensors' technical characteristics.

GeoEye-1 satellite was selected for its better spatial, spectral and stereo capabilities (11- bit satellite images, 0,5 mt in GeoStereo panchromatic mode, 2 mt in multispectral mode)

GeoEye-1 also provides a rational polynomial coefficient (RPC) camera model file compatible with PHOTOMOD software package for block adjustment, photogrammetric extraction of three-dimensional coordinates and DEM creation

4. DEM: generation steps

- Selection and acquisition of the satellite data GeoEye-1
- Processing of satellite images
- TIN generation
- Optimization and validation of the TIN
- DEM Generation

4. DEM: generation steps

Selection and acquisition (4th July 2009) of satellite images (1/2)

Fig.1
Image: GeoEye 350565_rgb_0010000
Nominal Collection Azimuth: 230.4173 degrees
Nominal Collection Elevation: 72.78615 degrees
Sun Angle Azimuth: 118.4432 degrees
Sun Angle Elevation: 71.97118 degrees
Acquisition Date/Time: 2009-07-04 09:58 GMT
Percent Cloud Cover: 0

Fig.2
Image: GeoEye 350565_rgb_0000000
Nominal Collection Azimuth: 352.6983 degrees
Nominal Collection Elevation: 62.06266 degrees
Sun Angle Azimuth: 117.9573 degrees
Sun Angle Elevation: 71.76660 degrees
Acquisition Date/Time: 2009-07-04 09:57 GMT
Percent Cloud Cover: 0

4. DEM: generation steps

Selection and acquisition (4th July 2009) of satellite images (2/2)

- High-resolution stereo pairs in the panchromatic band are collected in the same orbital pass, minimizing changes in lighting or scene content.
- Stereo pairs comprise two images both above 60° elevation with 30°- 45° convergence.
- The map projection was the Universal Transverse Mercator (UTM) 33 N with a WGS84 Datum, radiometrically corrected and rectified.

4. DEM: generation steps

Processing of satellite images (1/5)

- The procedure described required the use of PHOTOMOD 4.4 software
- The first steps in the processing of the satellite data were focused on the stereo orientation; this was achieved creating a catalog of the Ground Control Points (GCP's)
- The 16 GCP's (out of 29 planned) where identified using photointerpretation over the image GeoEye 350565_rgb_0000000 and subsequently transferred over the image GeoEye 350565_rgb_0010000.

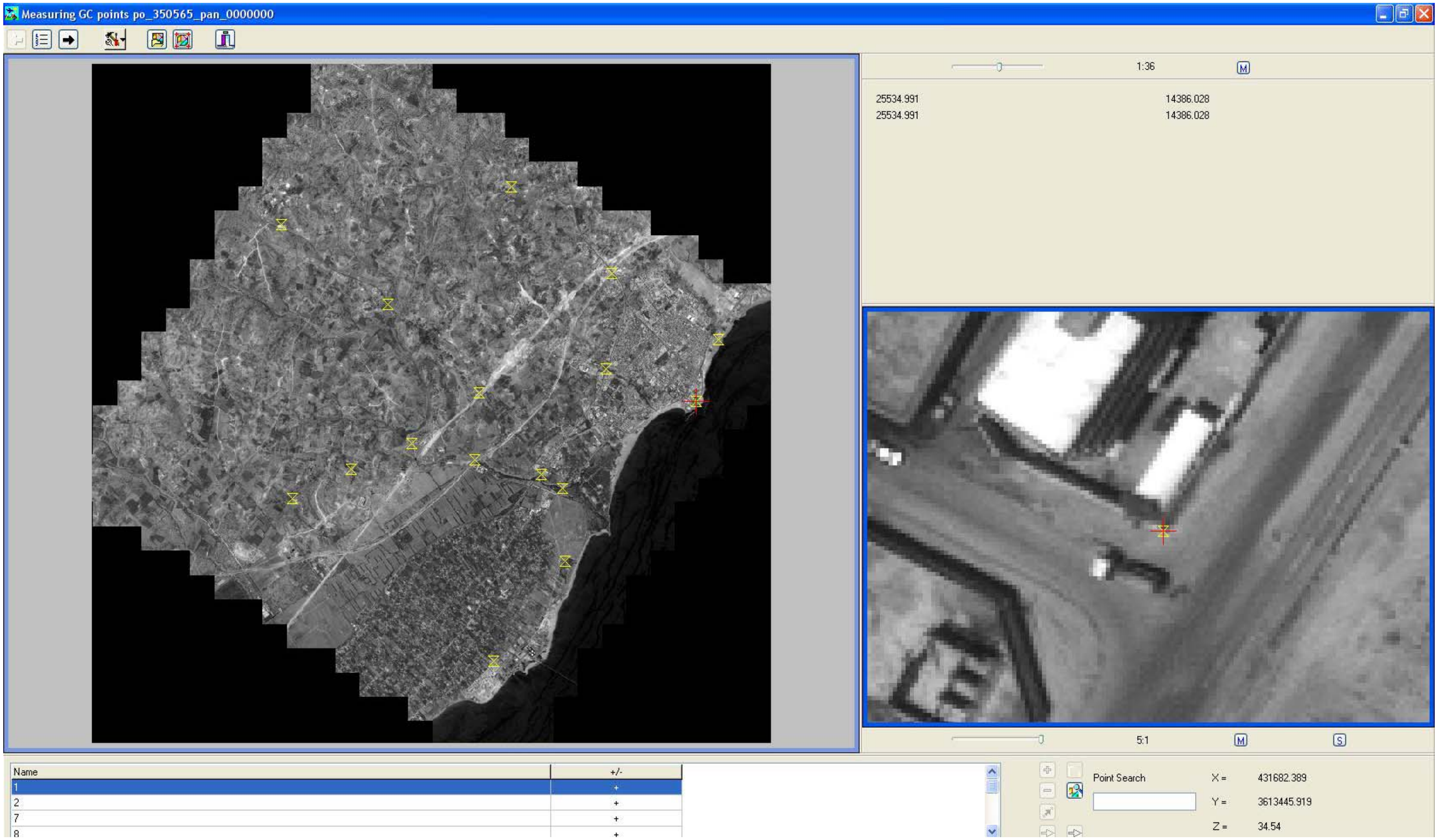
4. DEM: generation steps

Processing of satellite images (2/5)

- In order to improve positioning, correct deformations and reduce the shift between the images, 43 TIE points were added on both images to perform a “Block adjustment”.
- Once measured and verified the 59 points (43 TIE + 16 GCP), the “block adjustment” procedure was implemented.
- The methods used for the “block adjustment” was a polynomial model using the geometry of the sensor (RPC).
- The result was a precise positioning of the stereopair with regards to the GCP’s.

4. DEM: generation steps

Processing of satellite images (3/5)

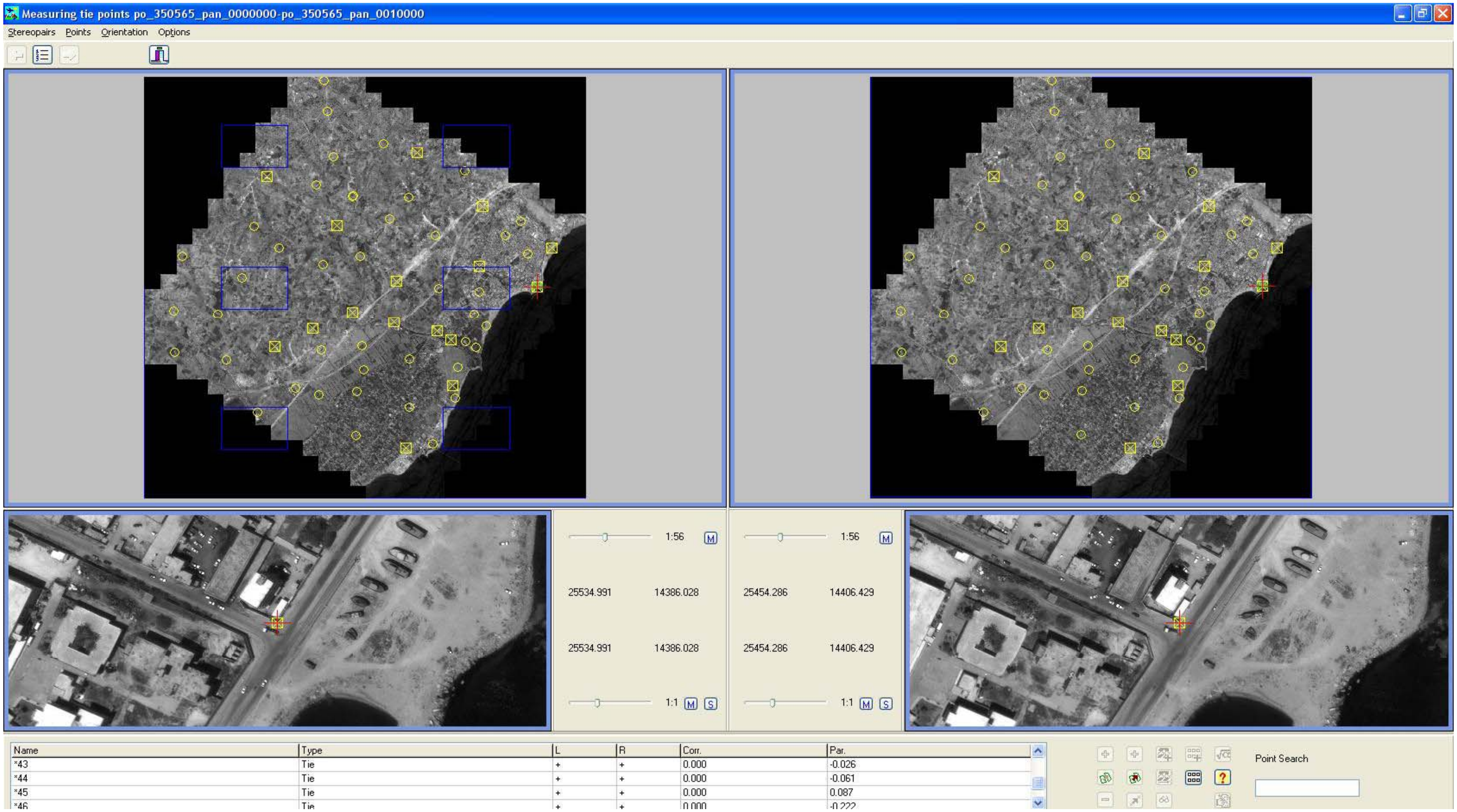


Ground Control Points Individuation (16 out of 29)

Criteria of selection were ‘best viewed’, ‘along river’, ‘most representative’

4. DEM: generation steps

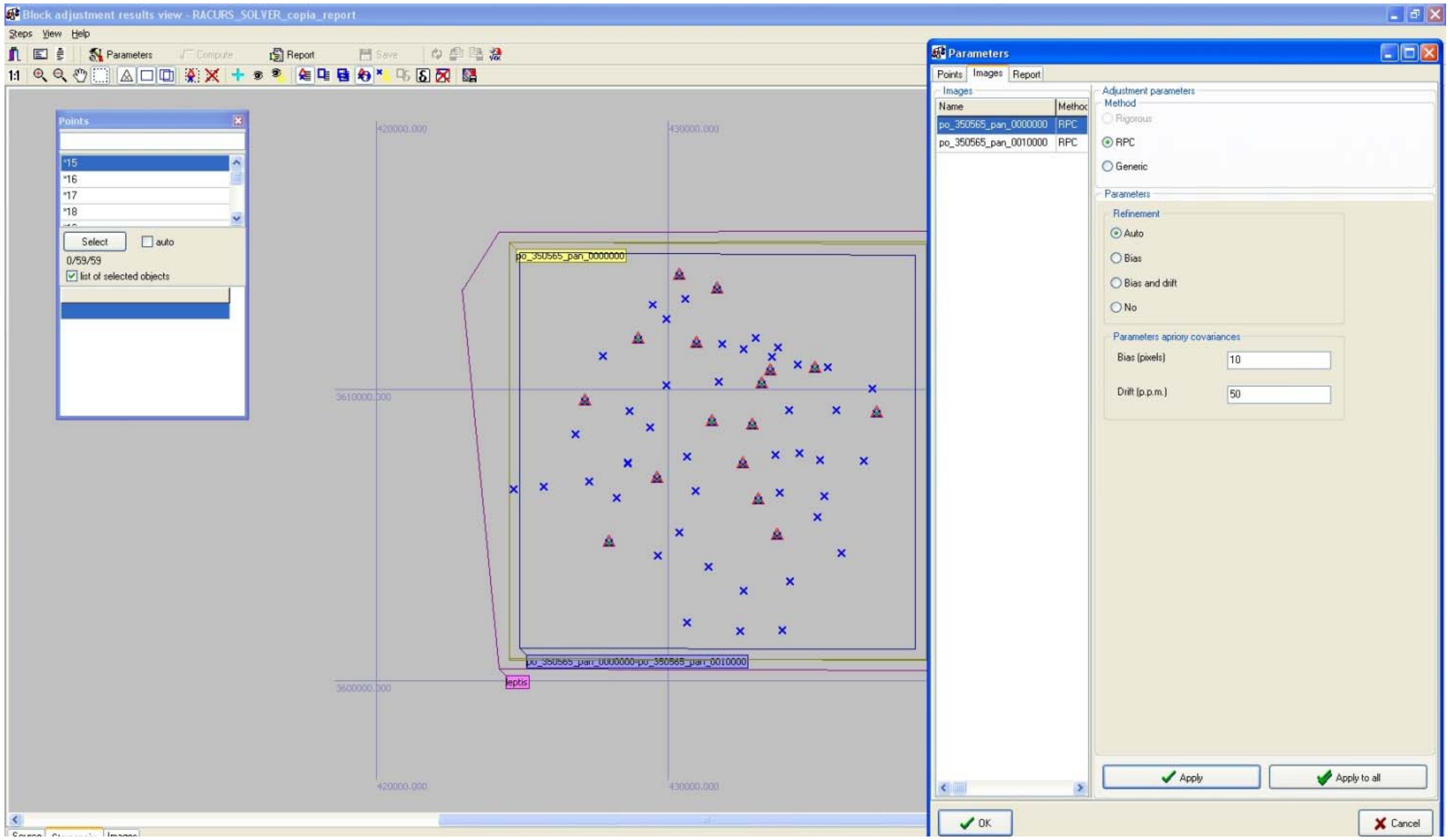
Processing of satellite images (4/5)



TIE Points individuation (43)

4. DEM: generation steps

Processing of satellite images (5/5)



Block Adjustment window with GCP’s and TIE points

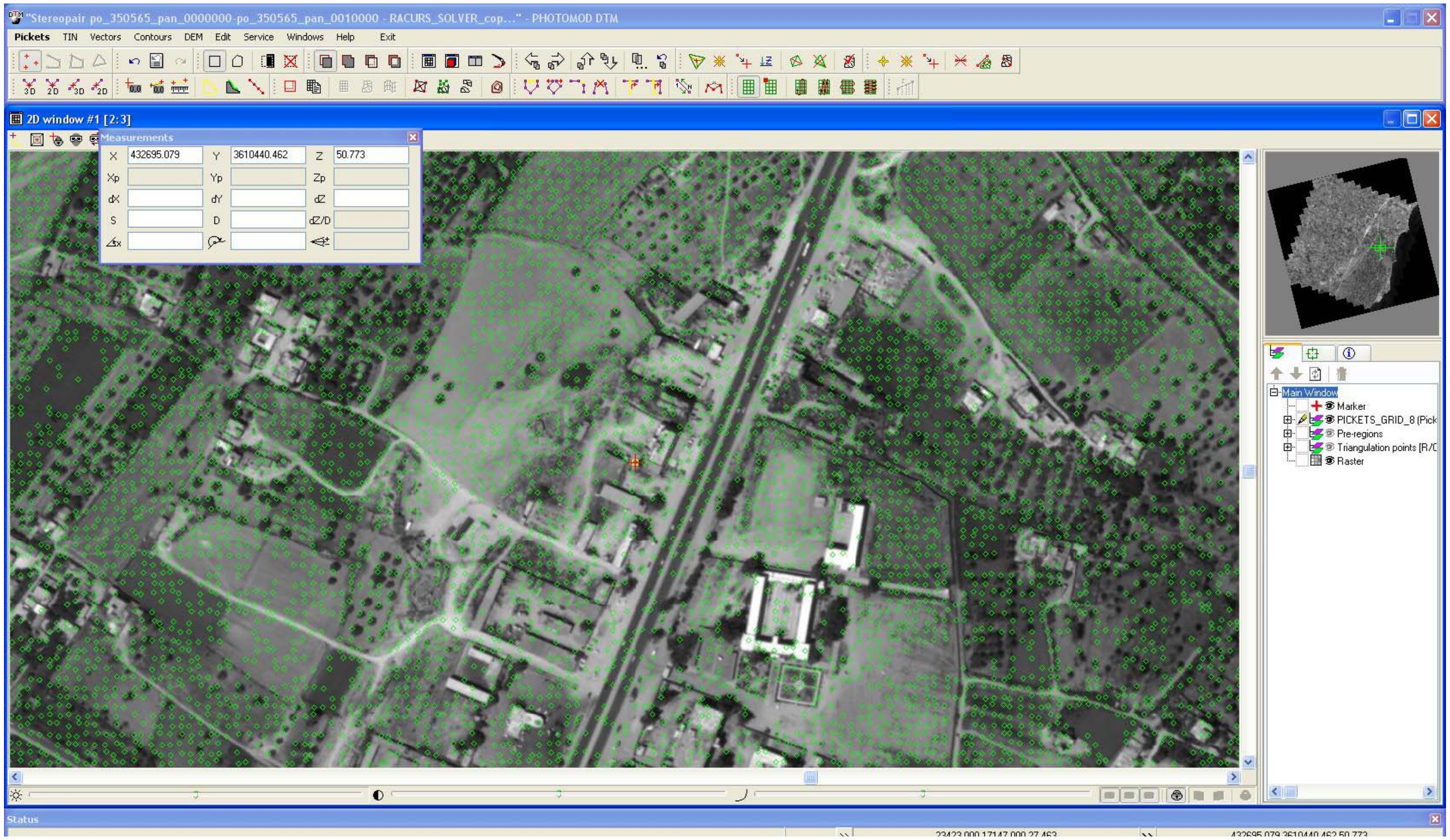
4. DEM: generation steps

TIN Generation (1/4)

- The digital elevation model (DEM) was generated using a Triangulated Irregular Network (TIN).
- For the creation of the TIN the “Pickets” were created over an 8 meter grid using the “adaptive method”.
- The adaptive method calculates 3D coordinates for points “most correlated” with each grid node the TIN nodes coordinates (in the grid nodes)
- The final TIN is triangulated from grid nodes by modified Delaunay algorithm.

4. DEM: generation steps

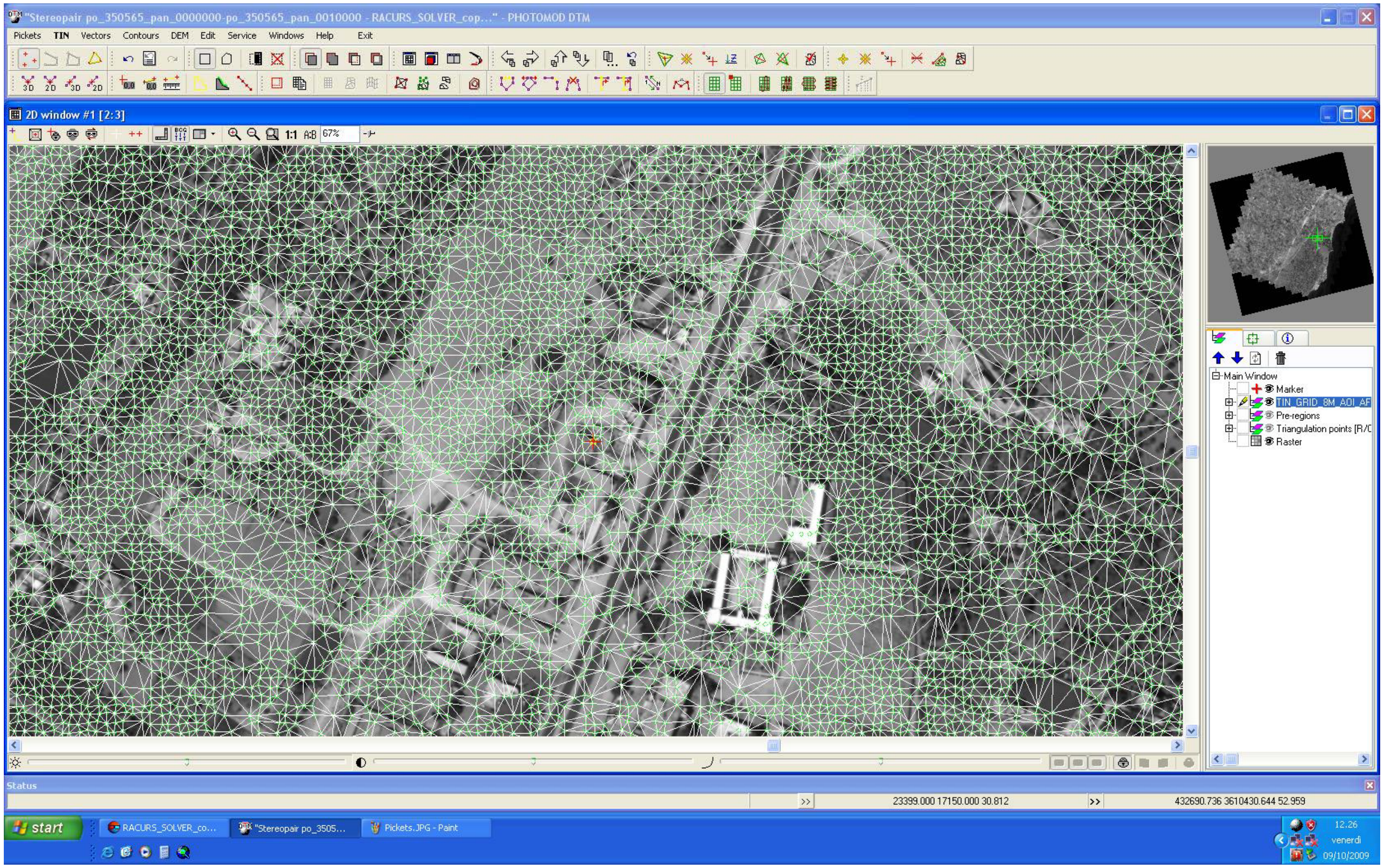
TIN Generation (2/4)



Pickets creation using the Adaptive Method

4. DEM: generation steps

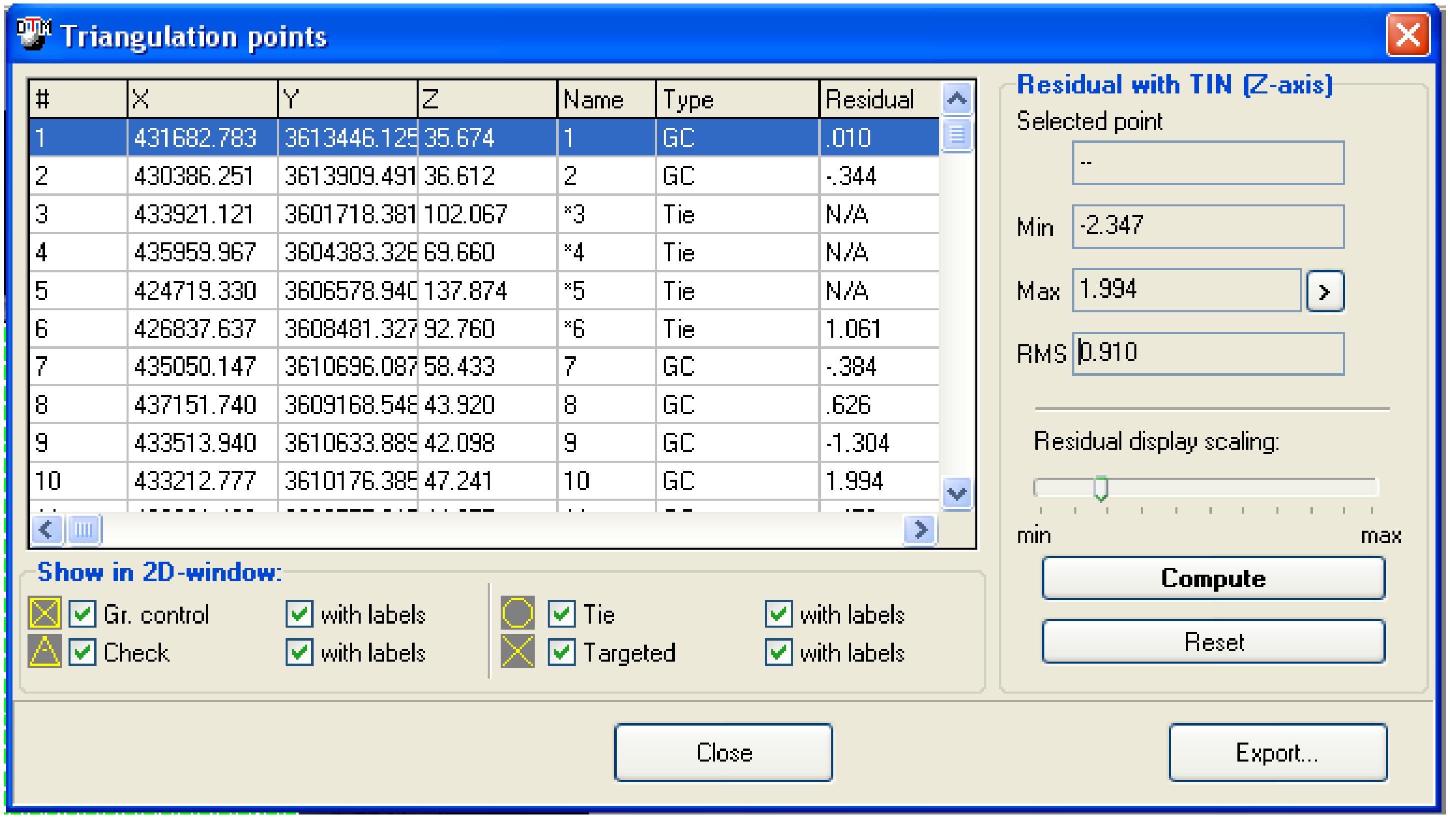
TIN Generation (3/4)



TIN generation from Pickets

4. DEM: generation steps

TIN Generation (4/4)



To verify the validity of the TIN generated using the procedure, an accuracy control was applied obtaining an very high accuracy (Root mean square RMS = 0.910) which validates the possibility to obtain a DEM with a vertical error of +/- 1 metre on the “z” value.

4. DEM: generation steps

Optimization and validation of the model

- Different methodologies have been integrated in order to improve the model. Some of this methodologies include photointerpretation, insertion of break lines and the use of Geographic Information System (GIS) to eliminate peaks and valleys.
- The in-situ GPS measurements (around 2000 points were collected over the coast line and along the river) have been used to improve the accuracy of the TIN.
- The table containing the GPS measurements was formatted as input file for Photomod in order to act as TIN breaklines.

4. DEM: generation steps

DEM generation (1/2)

- Pickets from which the TIN was generated were exported from the Photomod and imported into a GIS project (ESRI ArcMap 9.3)
- The objective was to analyse the height distribution of the points in order to find anomalies that could be eliminated
- In addition the software ET Geotools was used for the individuation of possible peaks or valleys.
- The results of this analysis were manually verified using photointerpretation over the satellite image.
- After the pickets were controlled and modified, they were reimported in Photomod to generate an optimized TIN.

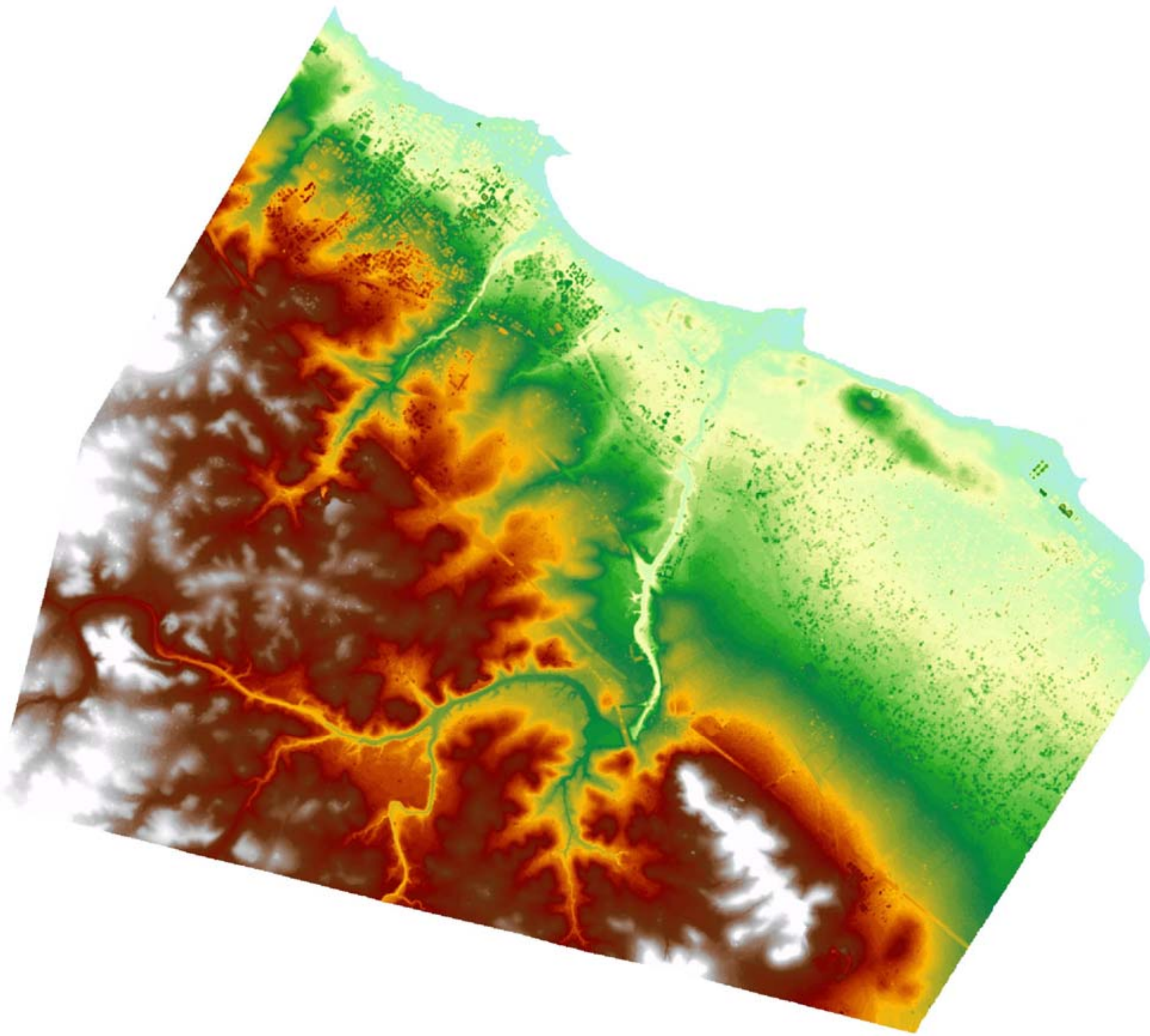
4. DEM: generation steps

DEM generation (2/2)

- The DEM was then generated from the TIN.
- The high spatial resolution of the satellite image has enhanced the quality of the DEM
- In order to maintain a uniform representation of the territory, a "*smoothing*" technique has been applied
- The final result was compared with 2000 GPS measurements gathered along the river basin, proving the effectiveness of the methodology and validating the high degree of accuracy of the DEM.

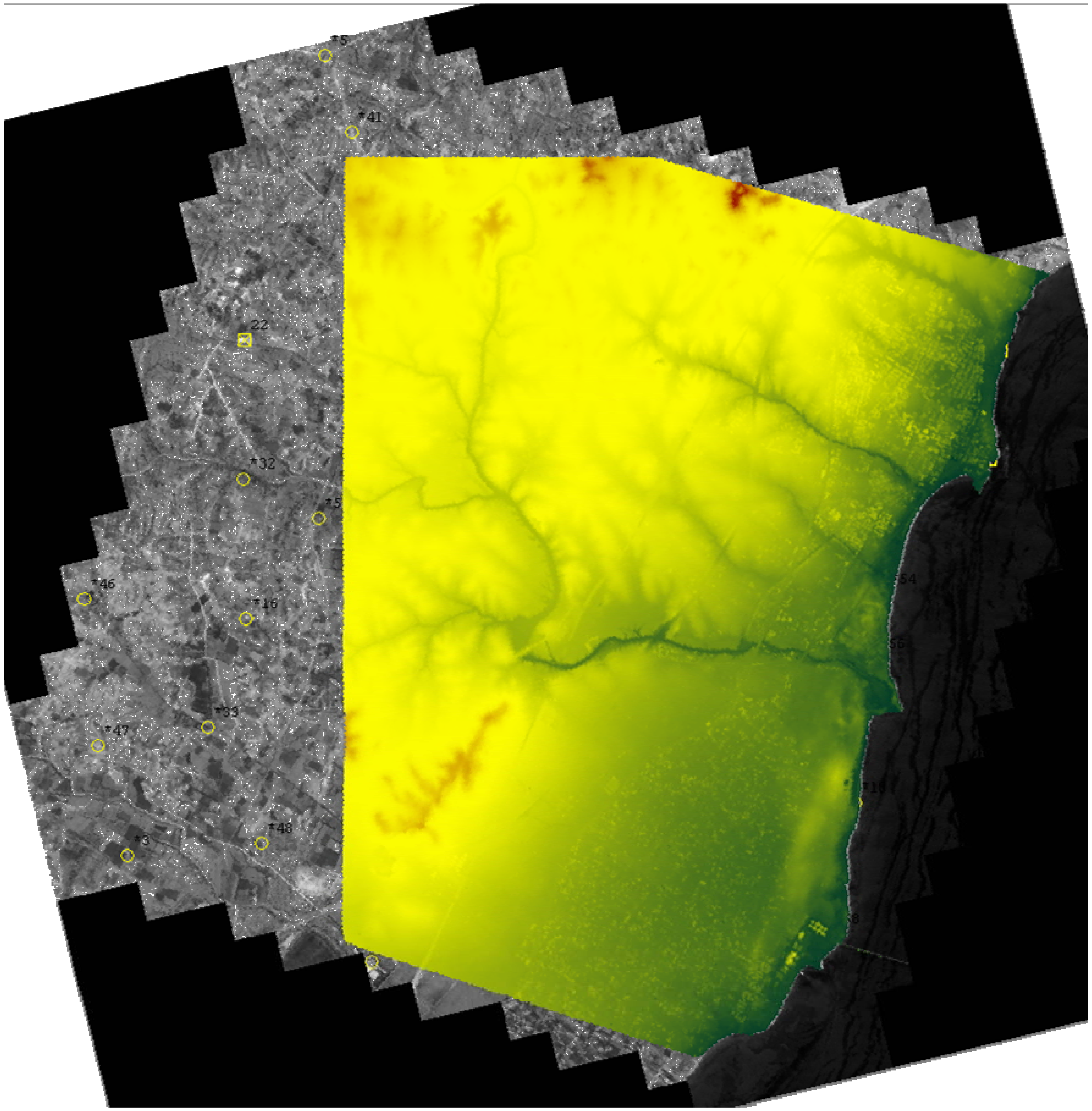
4. DEM: generation steps

DEM pictures (1/4)



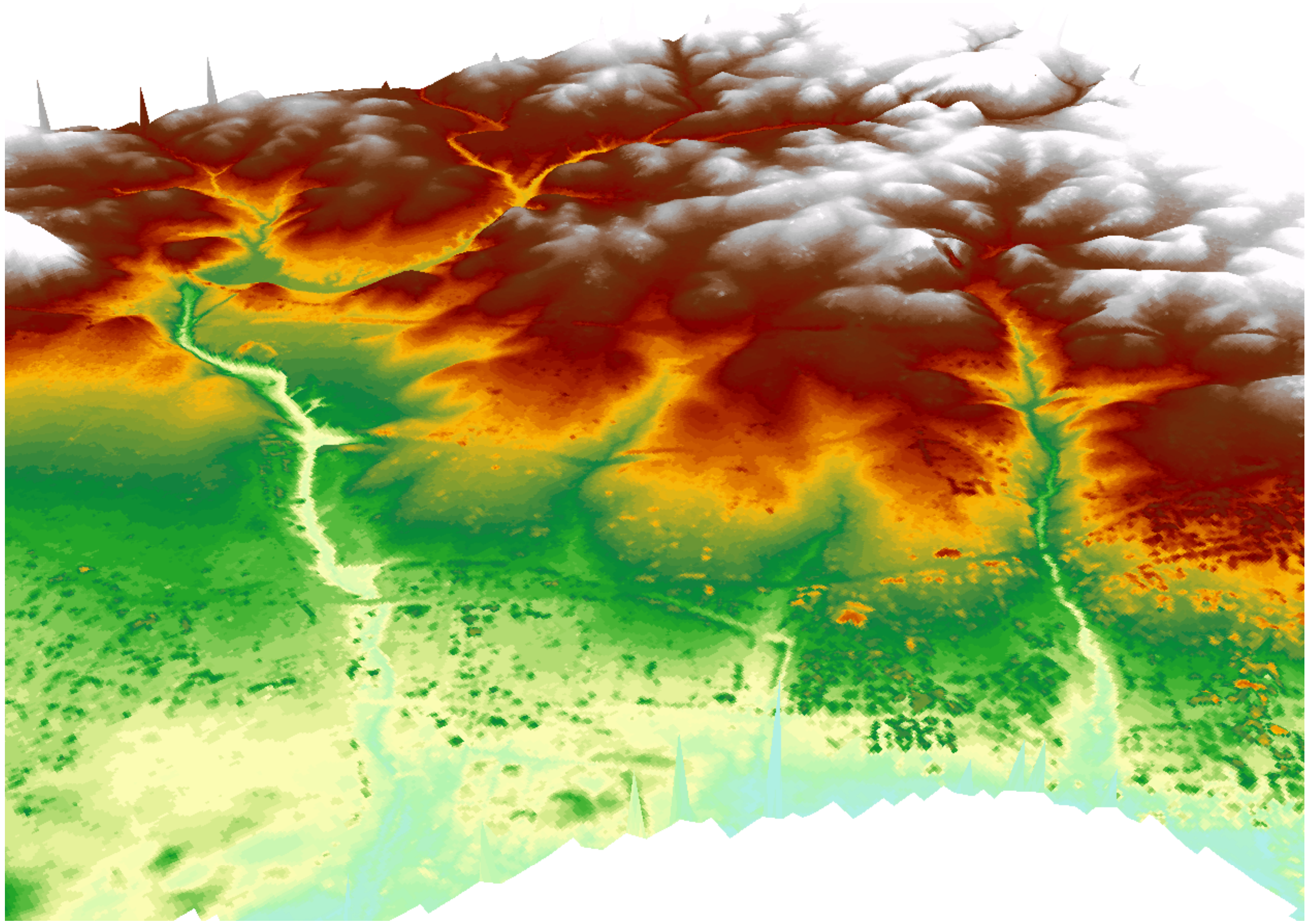
4. DEM: generation steps

DEM pictures (2/4)



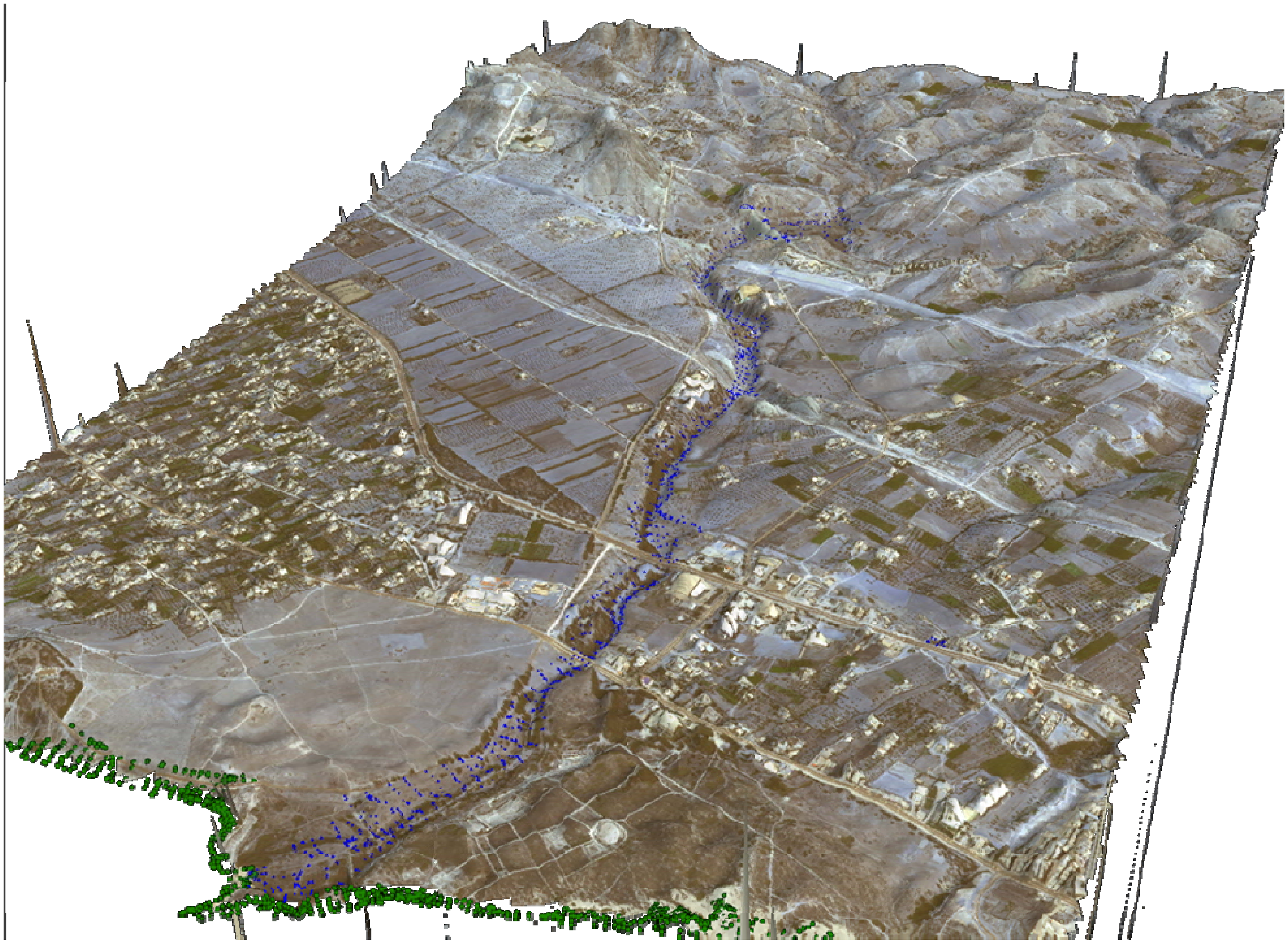
4. DEM: generation steps

DEM pictures (3/4)



4. DEM: generation steps

DEM pictures (4/4)



5. Conclusion

- Until today there are very few studies on the stereo capabilities of satellite data to generate accurate digital elevation models
- This study demonstrates the high potential of high resolution satellite technology like GeoEye-1 which increases the accuracy of image georeferencing in situation where there is no cartography or with only a few GCPs available.
- The project provided a great technical and scientific result in terms of the vertical accuracy obtained (RMS = 0.910)
- Last but not least this project also demonstrated a valuable and cost effective technology providing accurate data in less than three weeks.

6. Project Team

- **Thetis S.p.A.**

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  Irene D’Urso

  Matteo Ombrelli

  Paolo Telaroli

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  Cesar Urrutia

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