DEM generation from high resolution satellite stereopairs for hydraulic hazard analysis

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1 AIM OF THE WORK

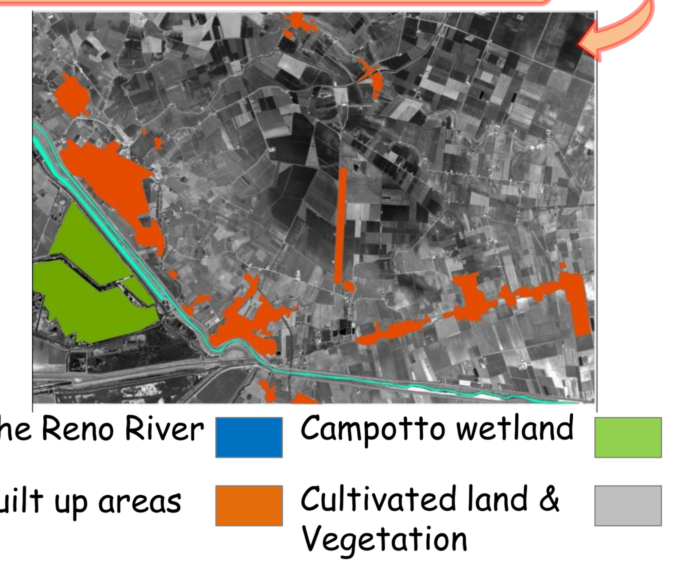
possible use of High Resolution Satellite Stereopairs to generate DSMs useful for **hydraulic hazard analysis**

alternative / integration to classic techniques:
- Aerial photogrammetry
- LiDAR
- GNSS

Pros	Cons
✓ costs reduction	✗ lower precision
✓ fast acquisition	✗ matching errors
✓ fast elaboration	✗ acquisition

2 DATASET

GeoEye-1 in-track stereopair

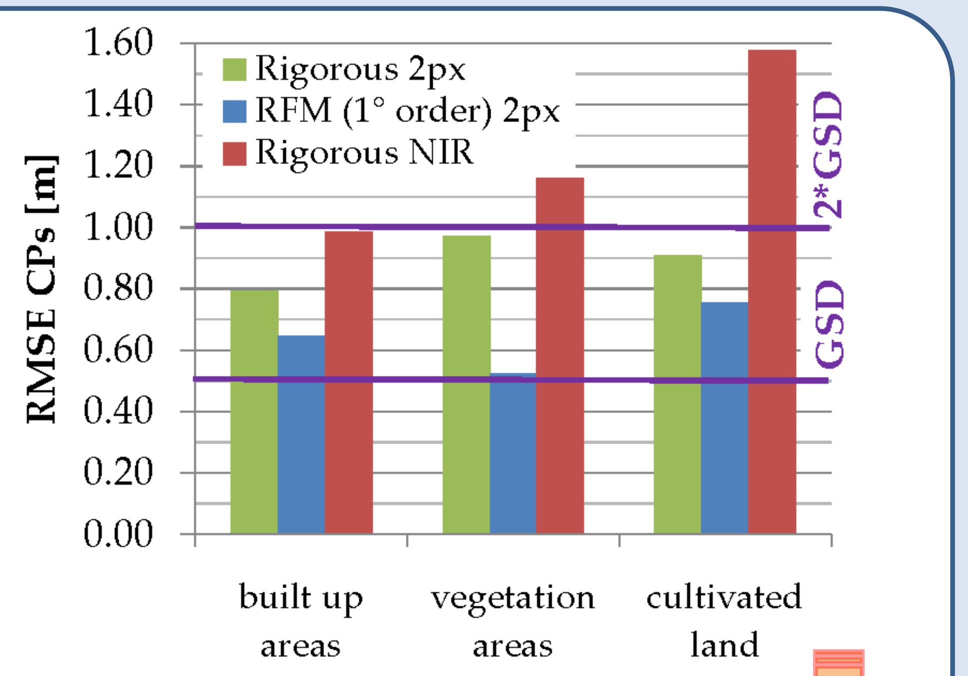


Stereopair characteristics	
Acquisition date	28-03-10
Acquisition time	11.30 GMT
GSD	0.5 m
Scan direction	Reverse
Bits per pixel per band	11bits
Intersection angle	46°.4784
B/H	0.8
Pixel (row x col)	16604x23804

Software used
- **OrthoEngine v.10.3** (PCI Geomatica)
- **SISAR**, developed by the team of Geodesy and Geomatic Area at La Sapienza University of Rome, Prof. M. Crespi

3 IMAGERY ORIENTATION

removal of **spatial** and **radiometric distortions** of the raw data:
- Rigorous model
- RFM
- RPC improvement using SISAR



- 78 GPs surveyed by stop&go GNSS, with 3D accuracy 3D of about 0.1m:
  - 40 GCPs used to execute orientation tests (▲)
  - 38 CPs used to validate orientation's accuracy (●)
- orthometric heights (ITALGEO99) calculated using VERTO3 software provided by IGM (Istituto Geografico Militare)

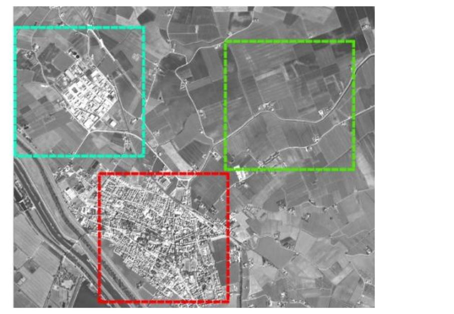
✓ good accuracy achievable
✓ accuracy stabilization with few GCPs (~20 for 100Km²)
✓ comparable results with rigorous model and RFM
✗ dependence on points' distribution
✗ dependence on GCPs' image recognition
✗ NO improvement using TPs
✗ NO improvement with RPC refinement

4 IMAGE MATCHING & DSM EXTRACTION

identification of all the corresponding features using **Area Based Matching** (cross correlation) and regular GRID creation

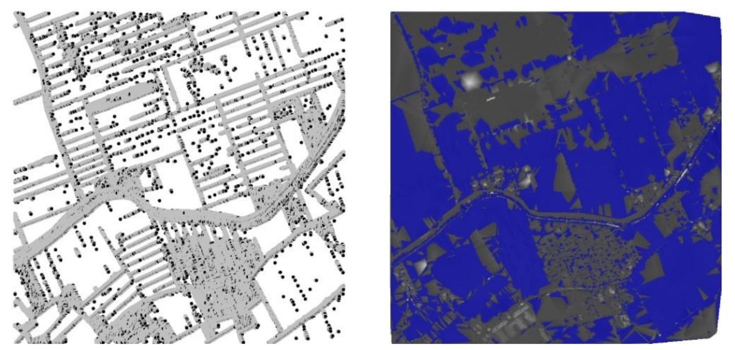
estimated parameters
- software (commercial / scientific)
- GCPs number and distribution
- TPs
- orientation model (rigorous / RFM)
- spectrum information (Pan / multispectral)
- grid spacing of the final DSM
- editing needed

using **SISAR**……
3 homogeneous tiles (urban, rural, mix)



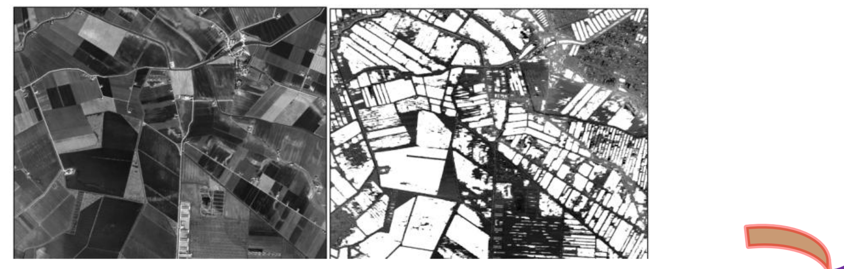
using **OrthoEngine v.10.3**……whole image

✓ matching parameters optimized for each tile
✓ easy outliers filtering
✓ correct height range
✗ some problems in the rural area
✗ simple point triangulation

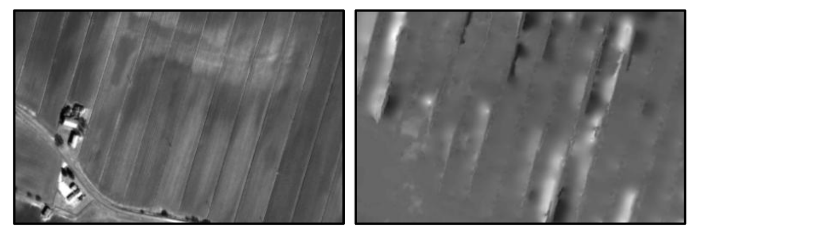


cloud points — interpolated DSM

only 40% of the image matched succesfully:
✓ streets, dirty tracks & built up areas
✗ cultivated land



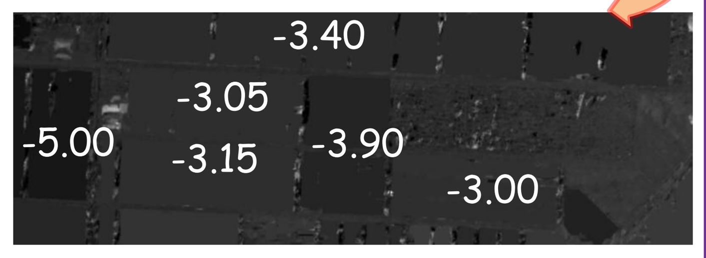
1) automatic fill procedures:
   a. OrthoEngine: Geocode DEM
   b. ArcMap: Spatial Analyst Tools | Hydrology



✗ heigth variations in already matched areas
✗ peaks & holes (>2m) due to objects near *No data* zones (OrthoEngine)

2) semi-automatic procedure implemented in ArcMap:
   - buffer of each *No data* zone
   - field height value = mean of pixels value in the buffer area

…approximation but…

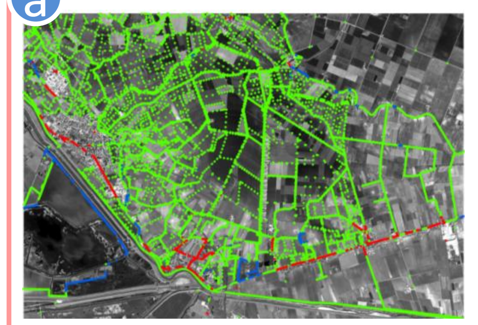


studied area: strongly flat area, differences between fields and dirty tracks < 0.5m

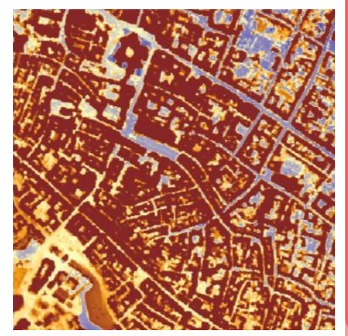
5 DSM VALIDATION

REFERENCE DATA

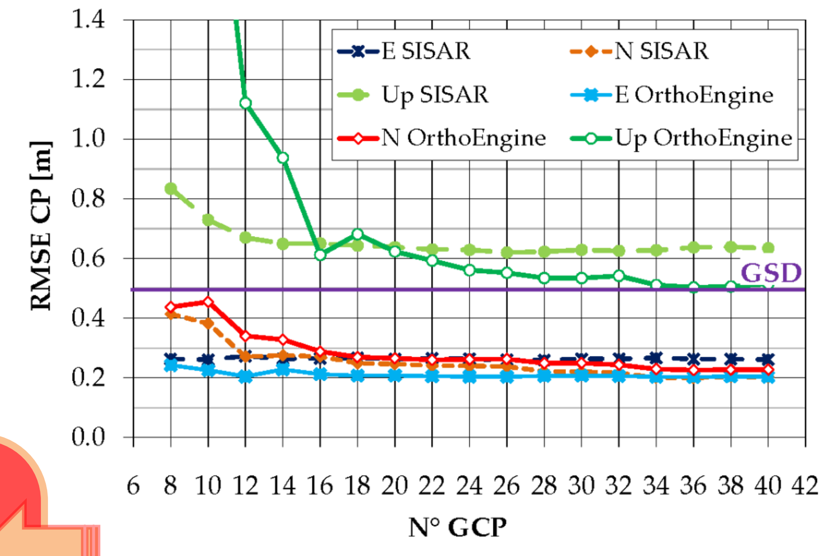
a



- ~12000 **points** collected with kinematic GNSS with 3D accuracy of about 0.3m:
  - cultivated land (~10000)
  - built up areas (~500)
  - vegetation (~1250)
- orthometric heights (ITALGEO99) computed using VERTO3
- **grid of x2m** derived by a photogrammetric flight executed in July 2008 (GSD of each image about 0.43 m)
- manual editing of areas with low correlation
- validation by sample comparison with a kinematic GNSS survey
- change detection analisys

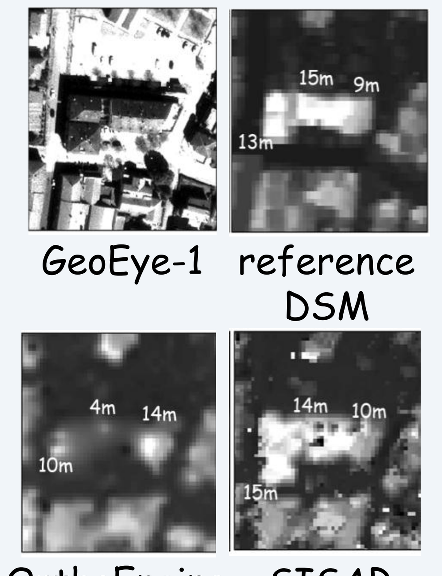


b
- comparisons with GNSS check points (LE95): RMSE Up (OrthoEngine)



RasterValue - PointValue

buildings detection



GeoEye-1 — reference DSM
OrthoEngine DSM — SISAR DSM

- comparisons with the reference DSM (LE95): RMSE Up

DSM	rural area			urban area			mix area		
	Bias [m]	σ [m]	RMSE Up [m]	Bias [m]	σ [m]	RMSE Up [m]	Bias [m]	σ [m]	RMSE Up [m]
SISAR	-0.17	0.97	**0.98**	-0.78	1.27	**10.49**	-0.14	1.53	**1.53**
OE Pan	-0.39	0.62	**0.73**	0.69	1.69	**1.82**	0.75	1.15	**1.37**
OE NIR	-0.15	2.17	**2.17**	0.53	2.22	**2.28**	0.69	2.01	**2.13**

better results with semi-automatic procedure

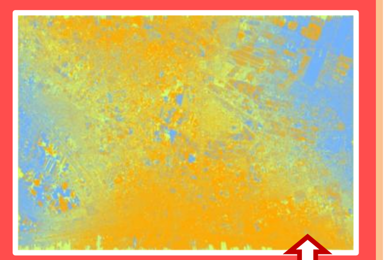
RasterValue - ReferenceValue

✓ accuracy of about 2 pixel in the open area
✓ accuracy of 3 pixel in the urban area (SISAR)
✓ good results with matching in homogeneous areas
✓ possible use of NIR band (NO RGB)

advantages with GSD reduction

SISAR
✗ matching errors
✗ points interpolation

OrthoEngine v.10.3
✗ matching errors
✗ too much noise
✗ problems in buildings recognition
✗ dependence on GCPs distribution
✗ NO advantages using TPs
✗ RFM: high dependence on polynomial's order



6 HYDRAULIC HAZARD APPLICATION

analysis of the outflow of water after **the Reno river flood**

collaboration with the land reclamation consortium of Ferrara

accuracy levels for digital models (italian guidelines)

level 0 1 2 3 4 5 6 7 8

level of OrthoEngine DSM — level needed for hydraulic analysis

suitable for:
- environmental analysis (of cultivated land and low density built up areas)
- ortophotos (1:5000)

- hydraulic analysis:
  - critical rate of flow
  - characteristics of the banks
  - position and formation of the gap
- reference model:
  - GNSS survey of land and reliefs
  - land points from Regional Maps (analysis of the subsidence)
  - drains network

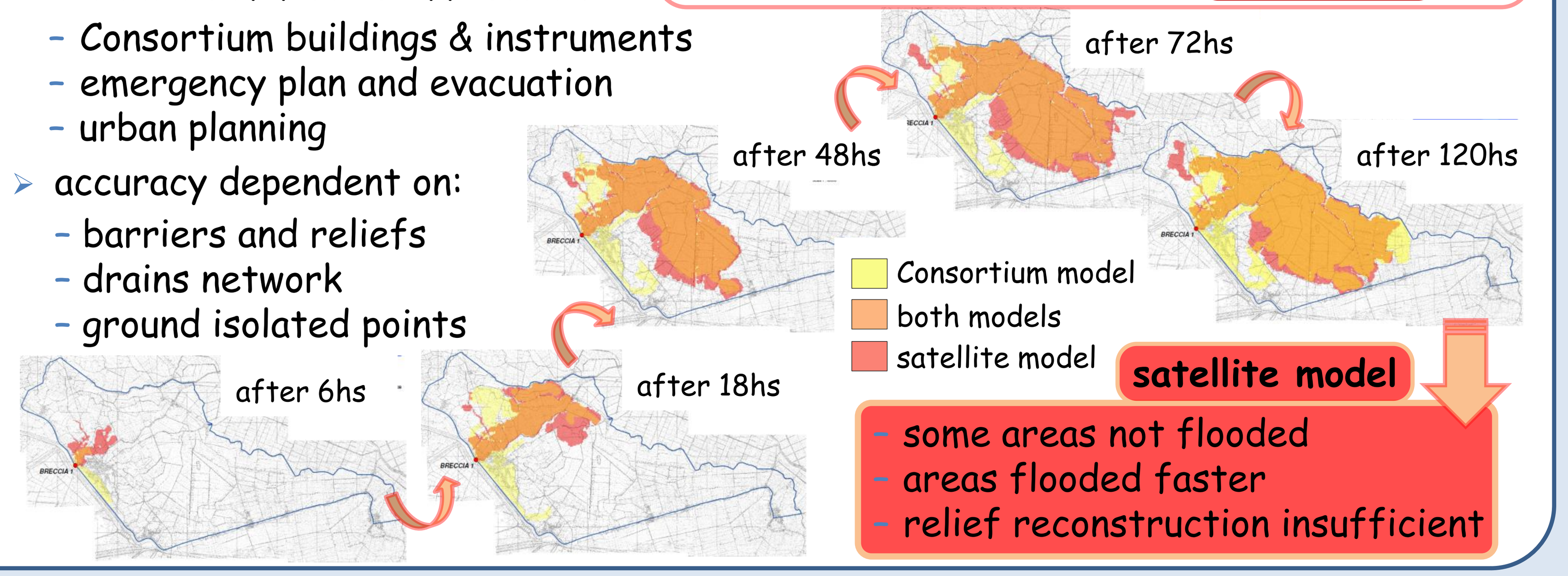
2 technicians for 6 months

- GeoEye-1 DSM:
  - PAN 4px OrthoEngine

1 technician for 10 days

model implementation and simulation run with **Mike FLOOD** (DHI)

- evaluation of flood's effects on:
  - Consortium buildings & instruments
  - emergency plan and evacuation
  - urban planning
- accuracy dependent on:
  - barriers and reliefs
  - drains network
  - ground isolated points



satellite model
- some areas not flooded
- areas flooded faster
- relief reconstruction insufficient