5th Workshop on Remote Sensing Applications to Natural Hazards

Washington DC – 10&11 September 2007

Damage assessment on buildings using very high resolution multimodal images and GIS

Anne-Lise CHESNEL[1], *Renaud BINET*[1] *and Lucien WALD*[2]

[1]: *Commissariat à l'Énergie Atomique, France*

[2]: *École des Mines de Paris, France*

Remote sensing and damage assessment

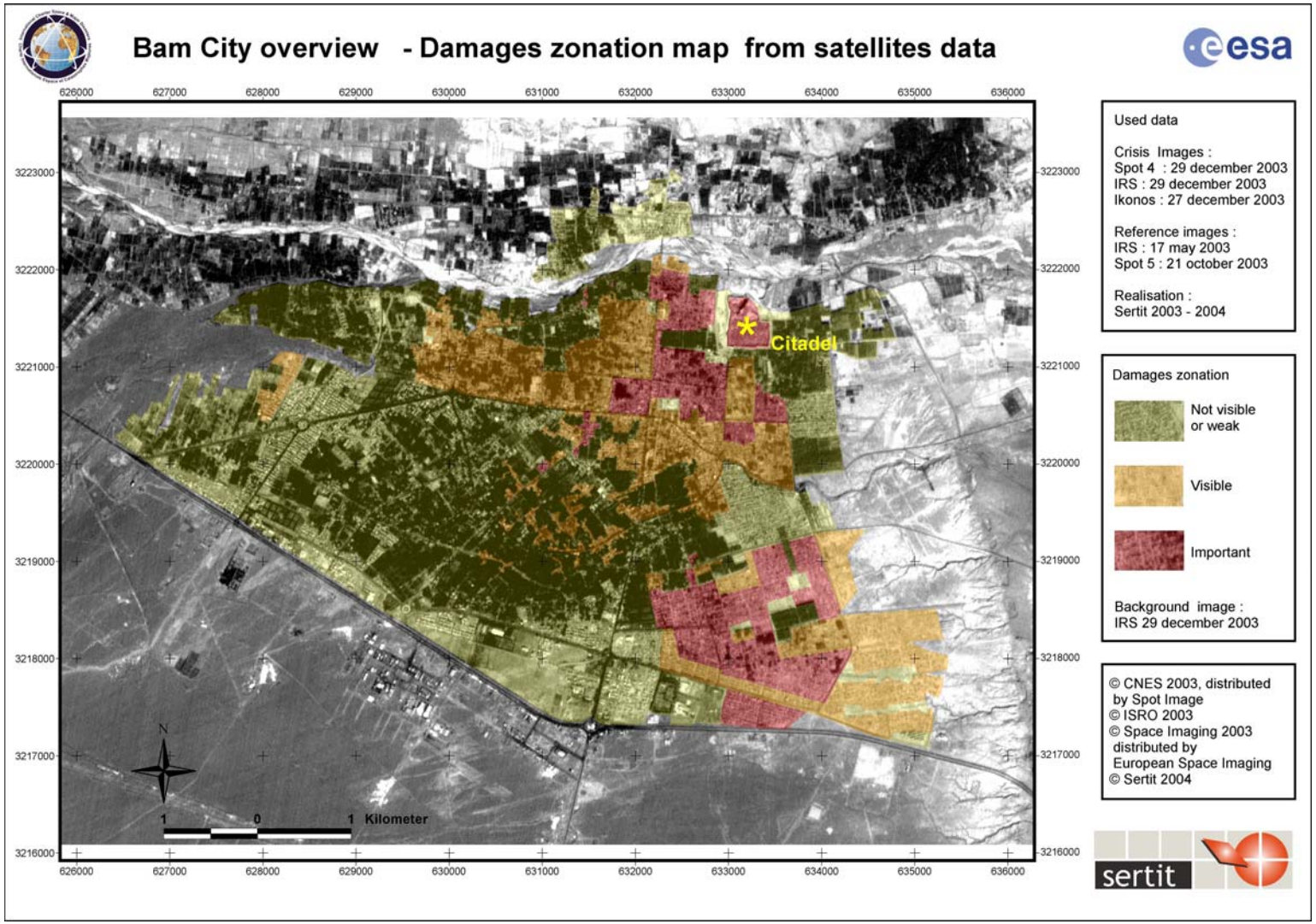
- Bam (Iran) – Extract of SPOT-5 image (res. = 2,5 m) – 16/10/2003

Remote sensing and damage assessment

- Bam (Iran) – Extract of SPOT-5 image (res. = 2,5 m) – 28/02/2004

Remote sensing and damage assessment

- Bam – International Charter product: damage map(SERTIT)



The Very High Resolution images

- Bam (Iran) – Extract of SPOT-5 image (res. = 2,5 m) – 16/10/2003

The Very High Resolution images

- Bam (Iran) – Extract of QuickBird image (res. = 0,6 m) – 30/03/2003

The Very High Resolution images

- Bam (Iran) – Extract of QuickBird image (res. = 0,6 m) – 30/03/2003

The Very High Resolution images

- Bam (Iran) – Extract of QuickBird image (res. = 0,6 m) – 30/03/2003

The Very High Resolution images

- Bam (Iran) – Extract of QuickBird image (res. = 0,6 m) – 03/01/2004

Observable changes in VHR images

- Boumerdes (Algeria) – Extract of QuickBird image (res. = 0,6 m)

22/04/2002

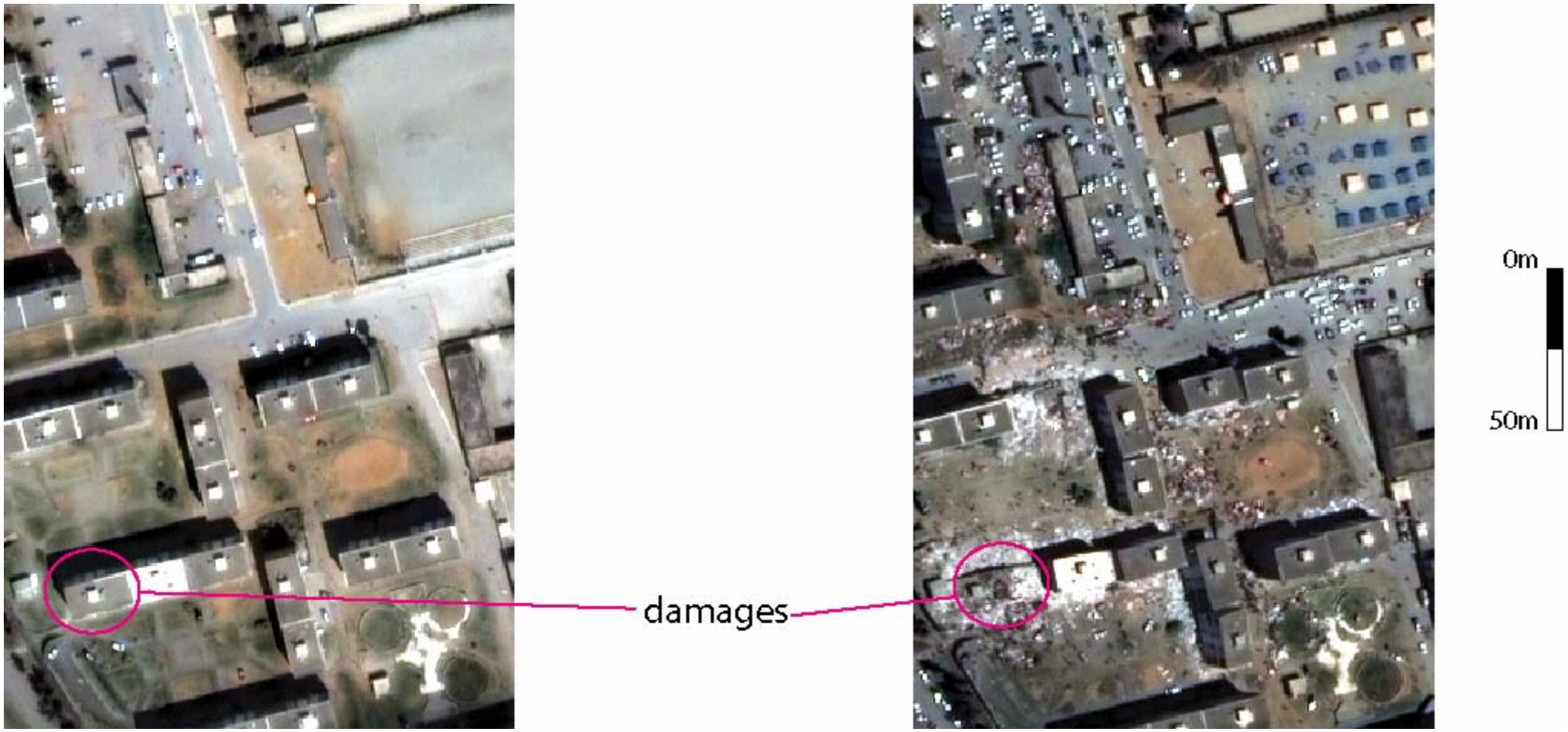
23/05/2003

Observable changes in VHR images

- Boumerdes (Algeria) – Extract of QuickBird image (res. = 0,6 m)

22/04/2002

23/05/2003

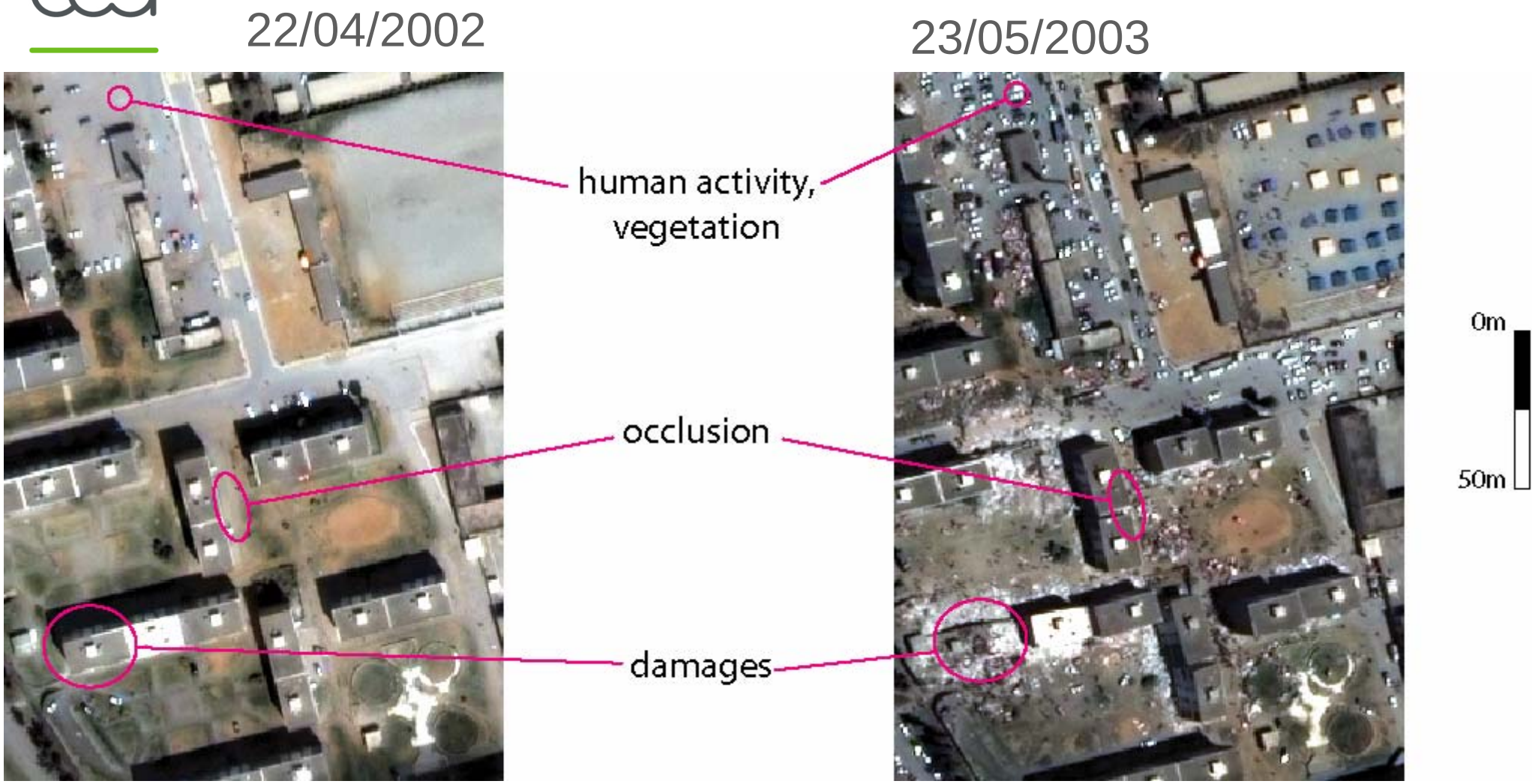


Observable changes in VHR images

- Boumerdes (Algeria) – Extract of QuickBird image (res. = 0,6 m)

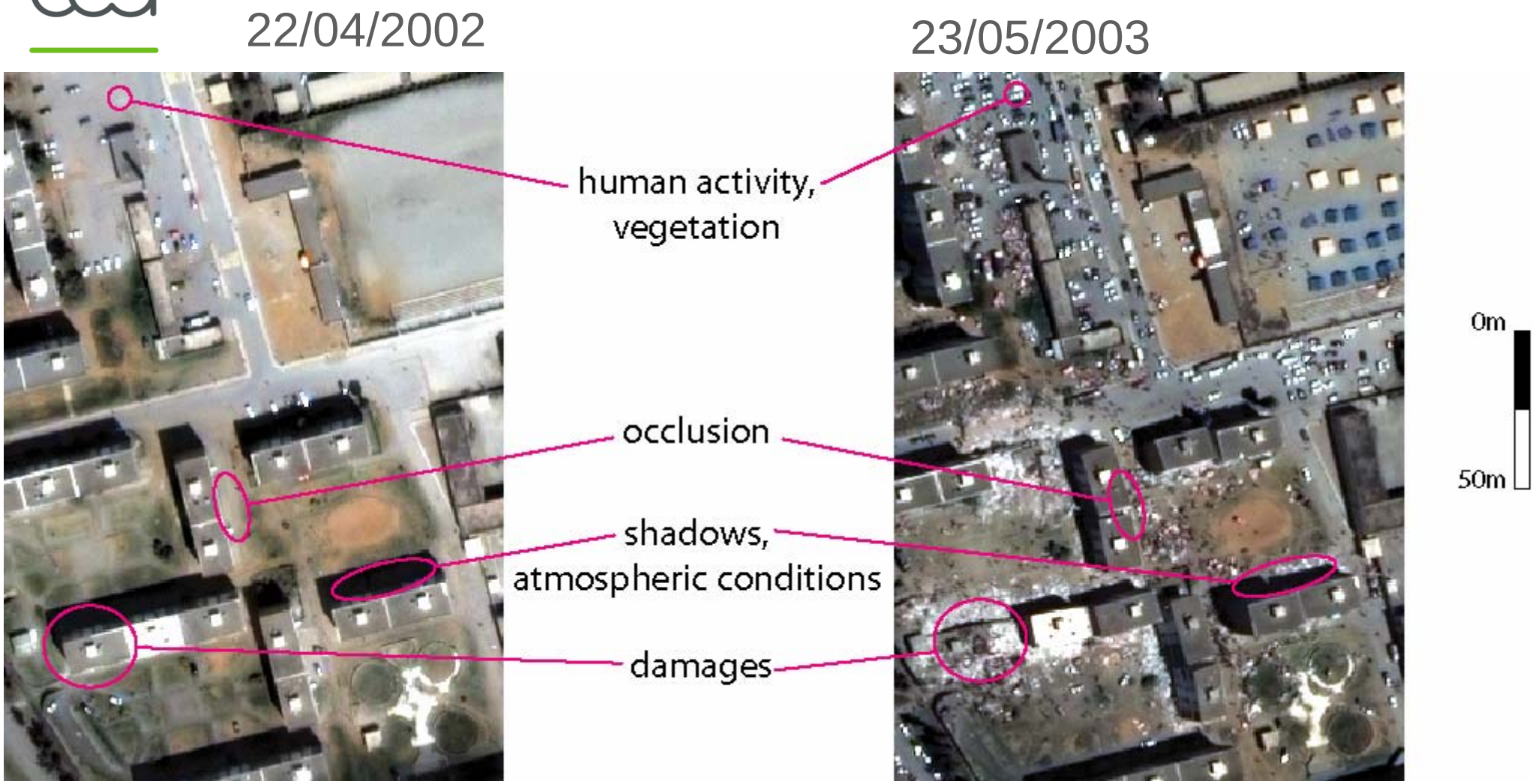
Observable changes in VHR images

- Boumerdes (Algeria) – Extract of QuickBird image (res. = 0,6 m)



Observable changes in VHR images

- Boumerdes (Algeria) – Extract of QuickBird image (res. = 0,6 m)



Observable changes in VHR images

Registration errors
of the high objects

Observable changes in VHR images

Registration errors
of the high objects

Observable changes in VHR images

Registration errors of the high objects:

Difficulty to find an archive image and a crisis image acquired with the same parameters

Object oriented damage assessment

- Definition of the regions
  - Digital Elevation Model
  - Image segmentation (auto, semi-auto, manual)
  - Geographical Information System

Object oriented damage assessment

- Definition of the regions
  - Digital Elevation Model
  - Image segmentation (auto, semi-auto, manual)
  - Geographical Information System

  → Manual segmentation of the reference image only.

Object oriented damage assessment

- Definition of the regions
  - Digital Elevation Model
  - Image segmentation (auto, semi-auto, manual)
  - Geographical Information System

  → Manual segmentation of the reference image only.
- Images registration according to the ground – Buildings are not registered (classical registration method not adapted)

Object oriented damage assessment

- Definition of the regions
  - Digital Elevation Model
  - Image segmentation (auto, semi-auto, manual)
  - Geographical Information System

  → Manual segmentation of the reference image only.
- Images registration according to the ground – Buildings are not registered (classical registration method not adapted)
- Method proposed to register the buildings roofs: subpixel measures obtained

Object oriented damage assessment

- Definition of the regions
  - Digital Elevation Model
  - Image segmentation (auto, semi-auto, manual)
  - Geographical Information System

  → Manual segmentation of the reference image only.
- Images registration according to the ground – Buildings are not registered (classical registration method not adapted)
- Method proposed to register the buildings roofs: subpixel measures obtained
- Damage assessment: computation of the correlation coefficient associated to each extracted region

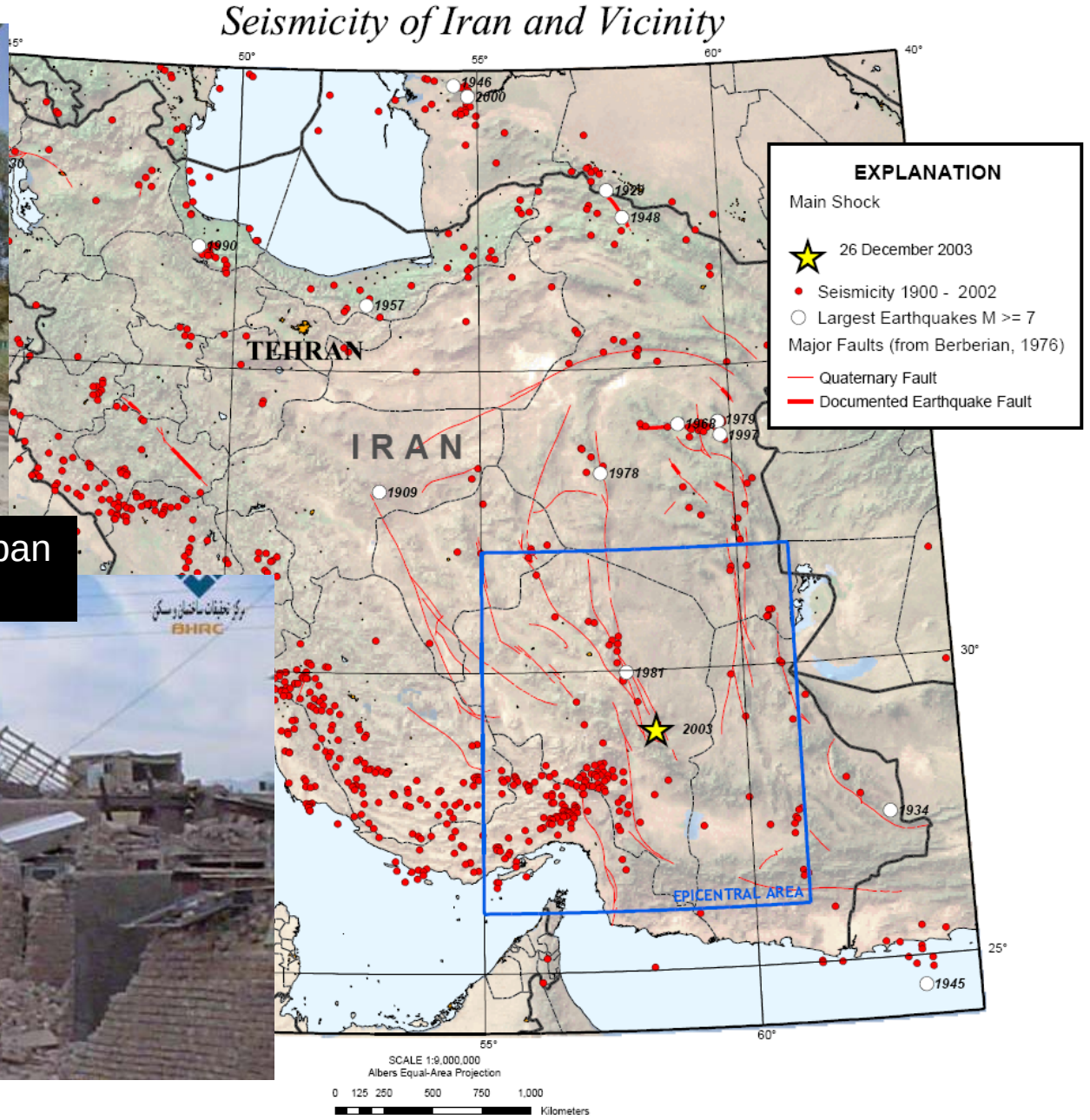
Object oriented damage assessment

- Definition of the regions
  - Digital Elevation Model
  - Image segmentation (auto, semi-auto, manual)
  - Geographical Information System

  → Manual segmentation of the reference image only.
- Images registration according to the ground – Buildings are not registered (classical registration method not adapted)
- Method proposed to register the buildings roofs: subpixel measures obtained
- Damage assessment: computation of the correlation coefficient associated to each extracted region
- Supervised classification of the buildings (SVM) according to their correlation coefficient (5 training samples per class)

Application to a natural disaster: the Bam (Iran) earthquake

[Chesnel *et al.*, 2007] – Proc. of the Urban Remote Sensing Joint Event 2007



Available data

- A pair of QuickBird image acquired before and after the earthquake
- *Geographical Information System*

  Footprints of the roofs of the buildings in agreement with the reference image (and an associated damage degree)

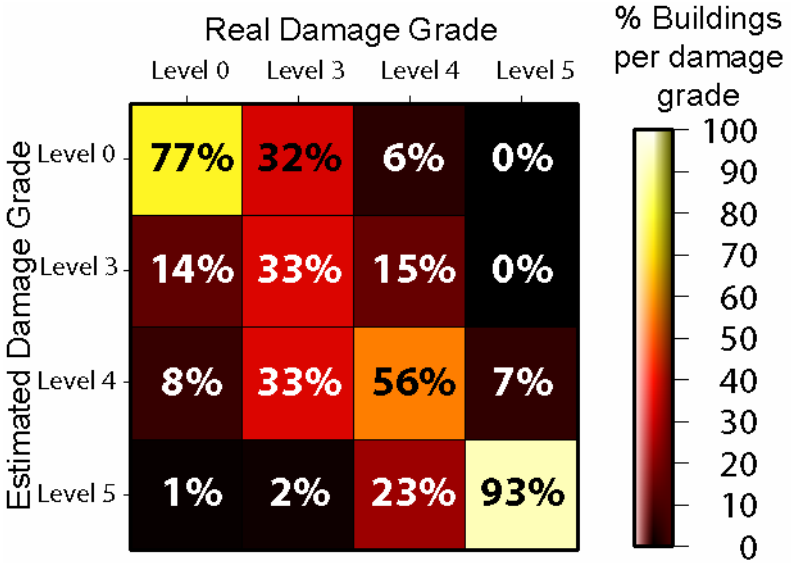
Intact / Non detectable damage
Light damage / EMS 3
Serious damage / EMS 4
Destroyed buildings / EMS 5

Reference image (extract)

Crisis image (extract)

Damage assessment results

	Level 0	EMS 3	EMS 4	EMS 5	Total
Level 0	366	64	23	0	453
EMS 3	68	67	60	3	198
EMS 4	37	67	230	71	405
EMS 5	4	3	94	1011	1112
Total	475	201	407	1085	2168



Kappa=0.66

	4 classes	3 classes {0|3|4-5 }	2 classes {0|3-4-5 }
Global performances	77 %	78 %	91 %
Kappa	0.66	0.57	0.74

Robustness of the method

- Is this method efficient for other cases of disasters ?

Robustness of the method

- Is this method efficient for other cases of disasters ?
- **What is the influence of the acquisition angles difference between the archive and the crisis images ?**

Robustness of the method

- Is this method efficient for other cases of disasters ?
- **What is the influence of the acquisition angles difference between the archive and the crisis images ?**

  Application to another case of study: Beirut (Lebanon)

Robustness of the method

- Is this method efficient for other cases of disasters ?
- **What is the influence of the acquisition angles difference between the archive and the crisis images ?**

Application to another case of study: Beirut (Lebanon)

- 2 references images + 3 crisis images
- Binary classification: intact/destroyed

Images acquisition angles

Date	Sat. elevation angle above the horizon	Sat. azimuth (clockwise due North)
12 July 2005	66.0^o	58.0^o
19 June 2006	84.6^o	244.0^o
22 July 2006	45.8^o	279.2^o
9 August 2006	44.6^o	274.4^o
12 August 2006	63.6^o	208.0^o

B/H ratio

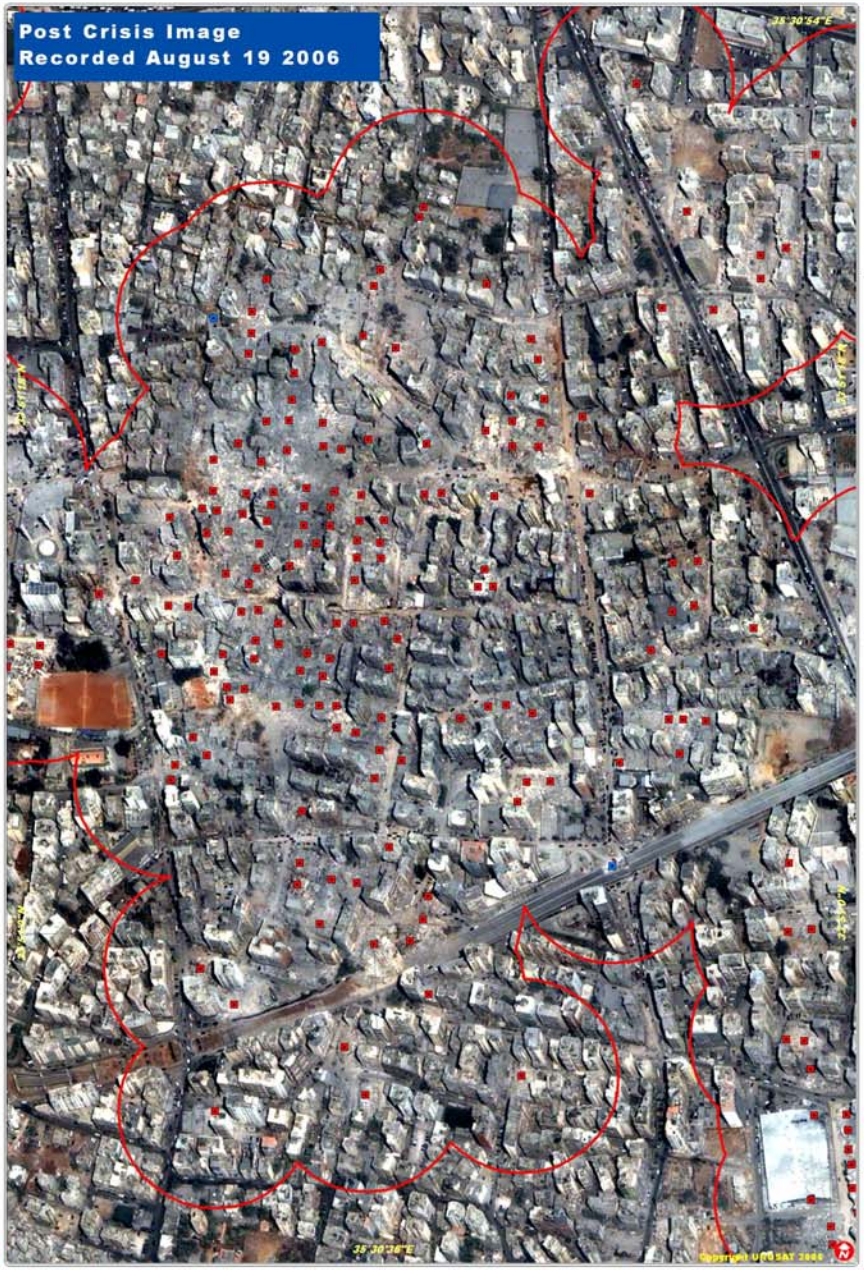
		Crisis images		
		22 July 2006	9 August 2006	12 August 2006
Reference images	12 July 2005	1.34	1.40	0.91
	19 June 2006	0.90	0.93	0.42

Satellite Identification of Damage in Beirut, Lebanon

Example of Before and After Satellite Image of Bomb Attacks on Beirut

29 September 2006

Version 1.0



Crisis Background Information

Following the 12 July 2006 abduction of two Israeli soldiers by Hezbollah, the Israeli Defense Force (IDF) launched a large scale military operation in Lebanon. Simultaneously, Hezbollah launched rocket attacks into Israel. This crisis resulted in hundreds of deaths and injuries on both sides, massive population displacement and extensive damage to civilian infrastructure. The United Nations Security Council Resolution 1701 (2006), calling for an immediate cessation of hostilities, was passed on 11 August 2006. A cease fire based on the creation of a buffer zone free of armed personnel other that UN and Lebanese forces consequentially came into effect on Monday 14 August 2006.

In support to the United Nations Office for the Coordination of Humanitarian Affairs (UN OCHA), UNOSAT activated its 24/7 Rapid Mapping service to quickly provide the international humanitarian community and local actors with detailed satellite map atlases and damage assessments of key affected villages.

Map Information

Damage assessment has been done using photo-interpretation of pre and post-crisis Ikonos satellite imagery recorded 17 June 2006 and 19 August 2006 respectively. The depiction and use of boundaries, geographic names and related data shown here are not warranted to be error-free nor do they imply official endorsement or acceptance by the United Nations. This map was produced by the United Nations Institute for Training and Research (UNITAR) Operational Satellite Applications Programme (UNOSAT). UNOSAT provides satellite imagery and related geographic information to UN humanitarian and development agencies and their implementing partners.

Damage Assessment Summary

On the adjacent subscene a total of 180 damage sites were identified. Of this total, the following 178 sites were either destroyed or severely damaged:

- 176 Buildings (general)
- 0 Towers / Antennas
- 0 High-rise apartment buildings
- 0 Bridges
- 0 Irrigation canals
- 0 Agricultural buildings

The remaining 2 impact sites were located as follows:

- 2 on roads
- 0 in cultivated fields
- 0 in uncultivated fields

An additional 718 buildings (all types) were identified as within the 100 meter blast radius of the 180 identified impact sites, and may be lightly to severely damaged.

NOTE: Sites classified as "Building (general)" may include residential, business, industrial or agricultural building types that could not be classified further with the available satellite imagery.

Map Legend *Site locations of identified damage*

- Bridge
- Road
- High-rise apartment building
- Agricultural building
- Building (general)
- Field (cultivated)
- Irrigation canal
- Field (uncultivated)
- Industrial building
- Airport Runway
- 100m Blast Radius

Scale (overview map) 1:2,500 for A1 Print

0 50 100 150 200 Meters

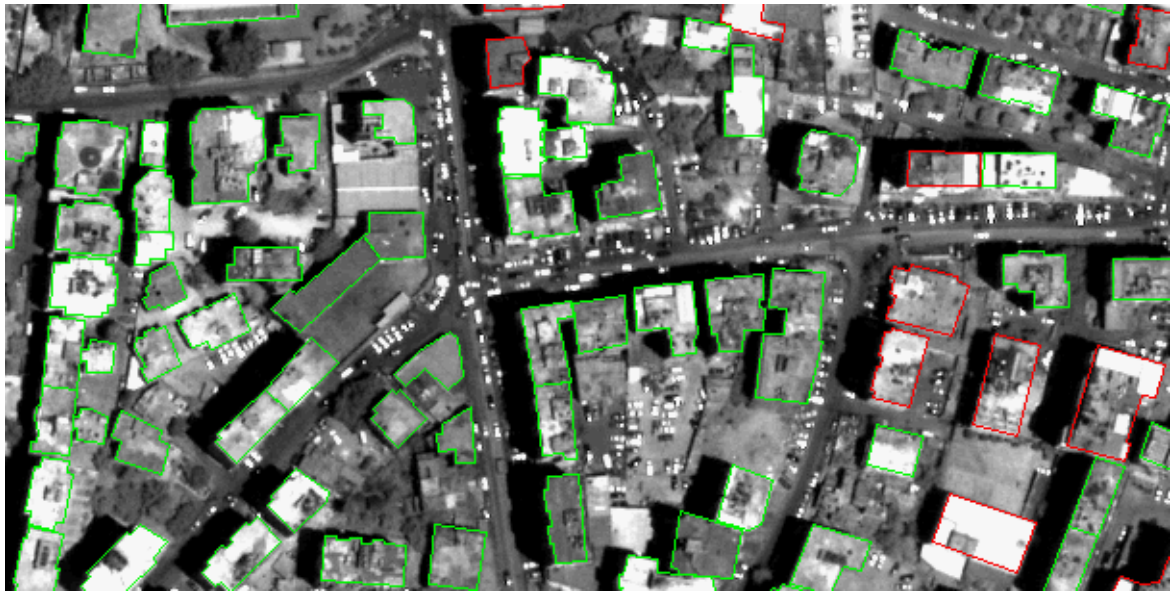
0 100 200 300 400 500 600 Feet

Satellite image	Ikonos (1m)	Data Sources	GIST, UNOSAT
Pre Image Date	17 June 2005	Datum	WGS 1984
Post Image Date	19 August 2006	False Easting	500000.00
Image Copyright	European Space Imaging	False Northing	00.00000
Map Production	UNOSAT (29 Sept. 2006)	Central Meridian	33.00000
Projection	UTM Zone 36N	Scale_Factor	0.999000

UNOSAT
satellite imagery for all
www.unosat.org
Contact Information: info@unosat.org 24/7 Hotline: +41 76 487 4998

Example: input data

19 June 2006

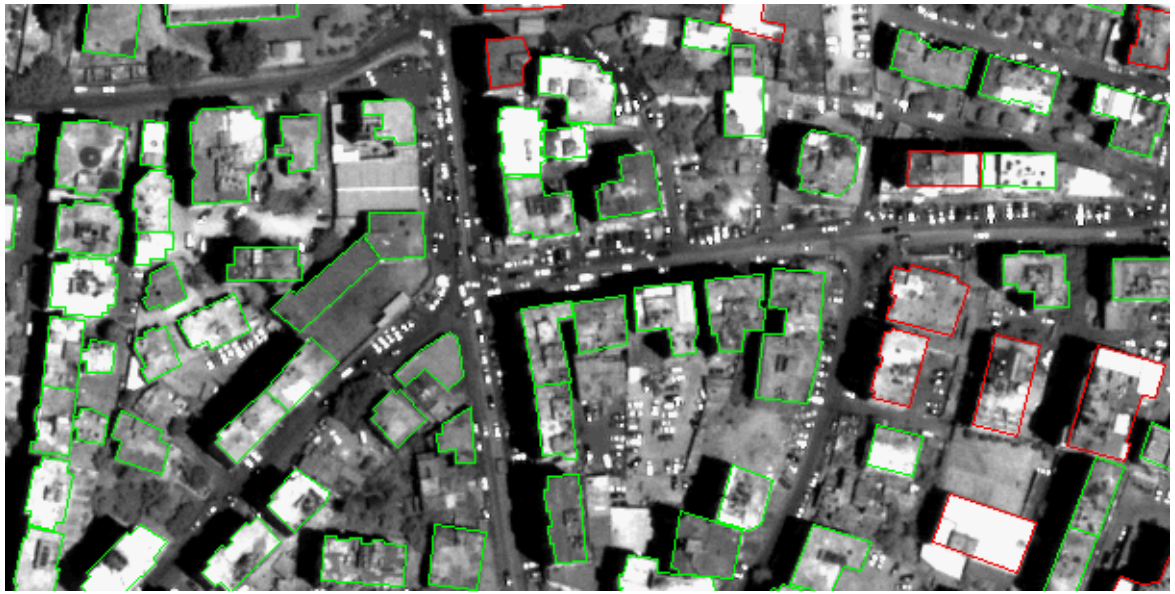


Images registered according to the ground

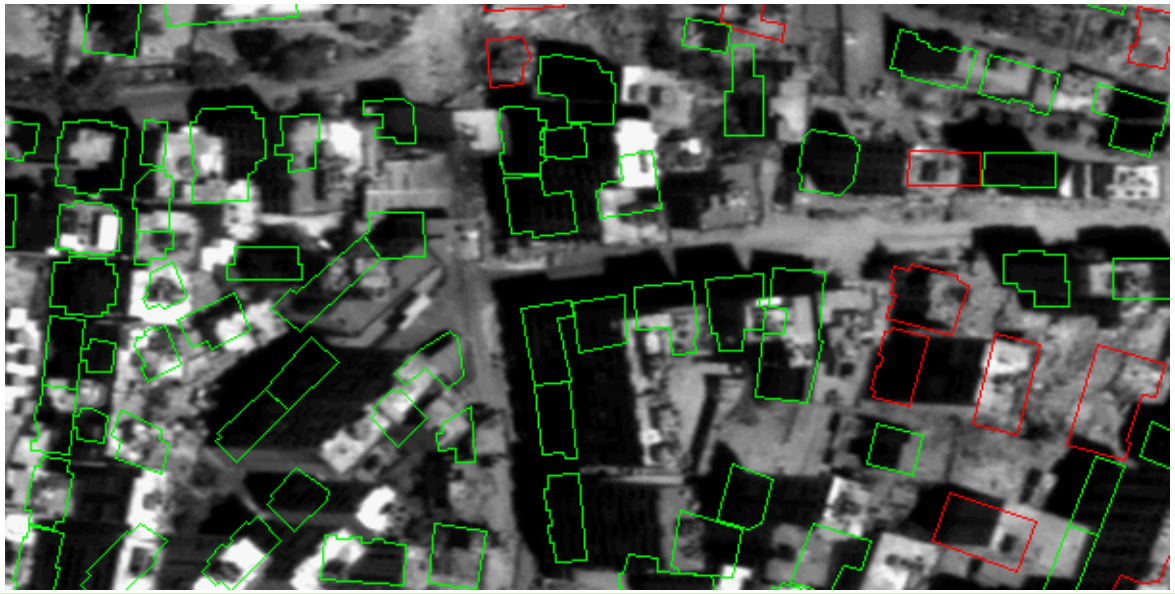
9 August 2006

Example: Unregistered buildings roofs

19 June 2006

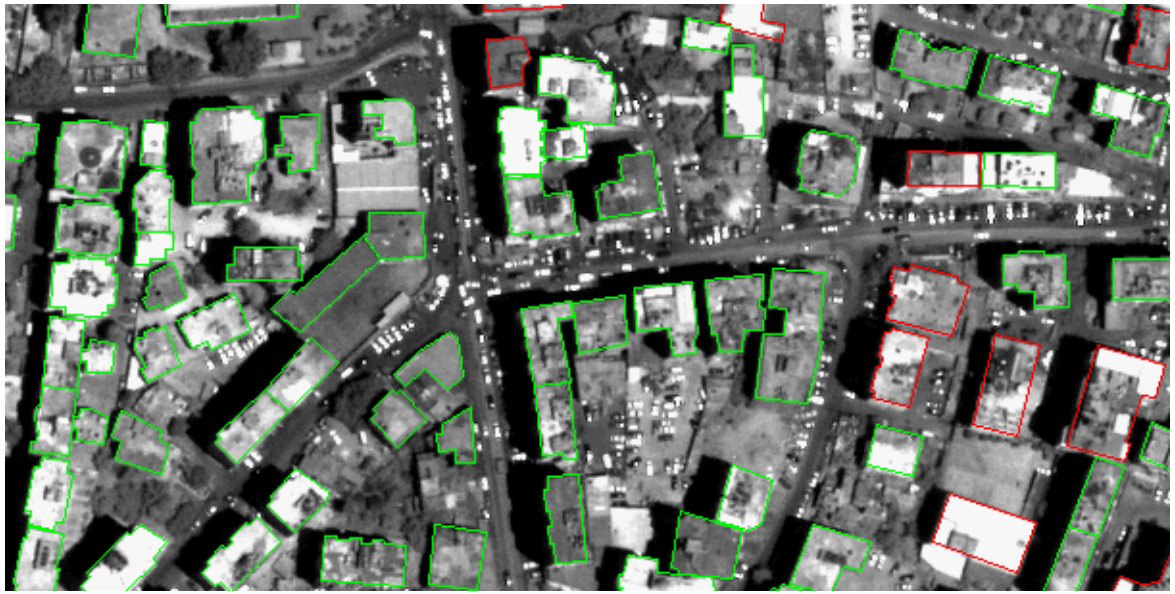


9 August 2006

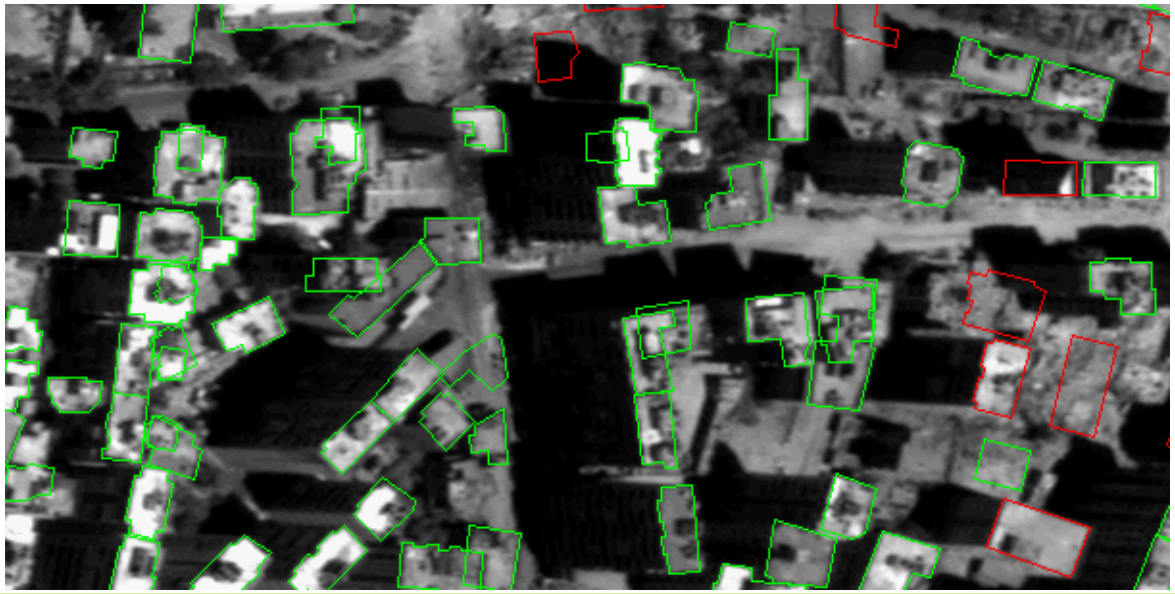


Example: registration of the roofs

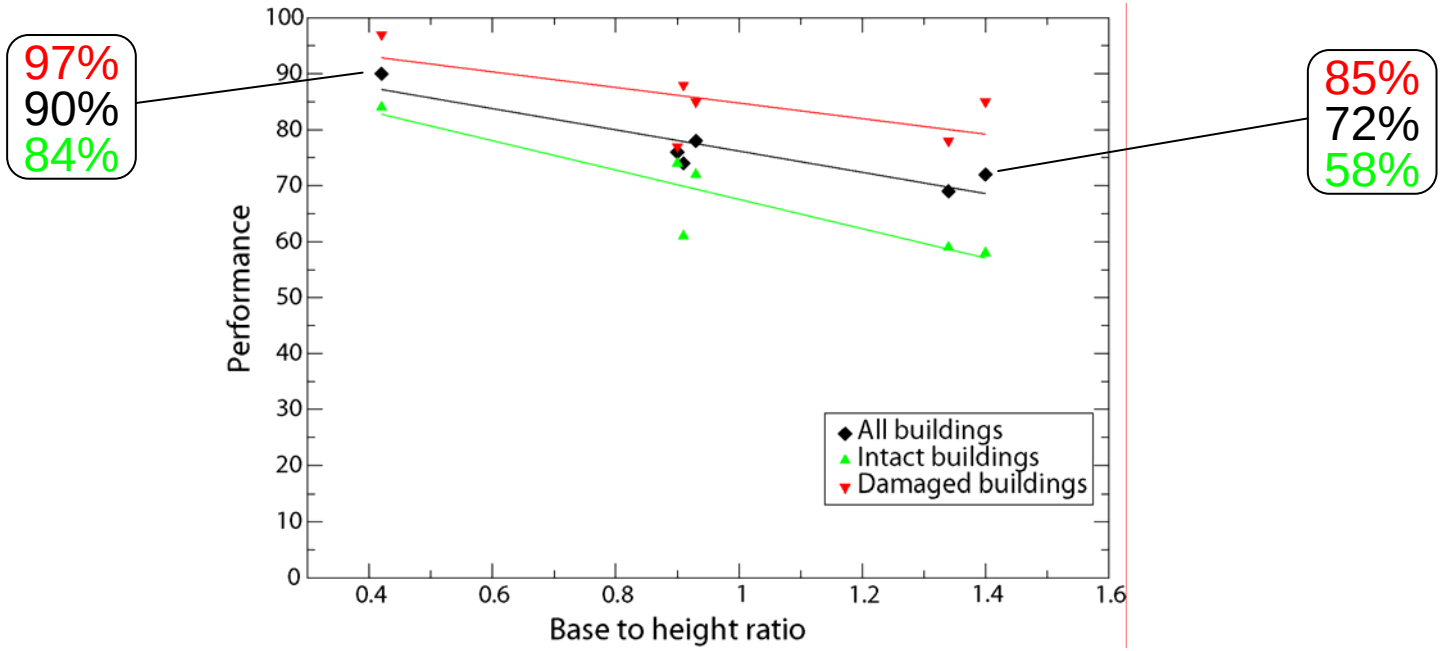
19 June 2006



9 August 2006

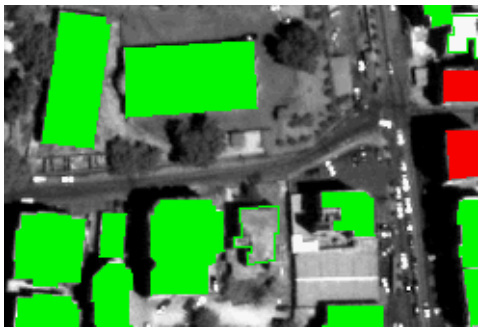


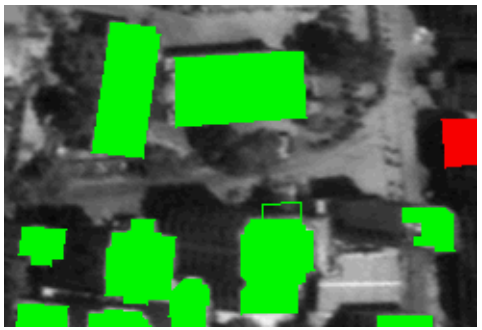
Damage assessment – Results with the 6 images pairs



Classification errors:

- Mainly false-alarms (intact buildings classified as destroyed)
- Due to registration errors: occluded buildings and buildings in shadow





Conclusion

- A solution for analysis of images with different acquisition angles is proposed.
- It is efficient for moderate B/H ratio
- Especially efficient for damaged buildings, even in “extreme situations” (diff. angle = 80°)
- Difficulty: false-alarms, due to registration errors
  - Occluded buildings
  - Buildings roofs in shadow

  No change information for these buildings…
- Methods that take into account the relation with neighboring buildings have to be tested.