EARTHQUAKE DAMAGE ASSESSMENT USING SPACE TECHNIQUES

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ABSTRACT

The aim of this paper is to present two different methods and data which could be applied in order to map damages due to an earthquake. The similarity of these methods is that they both concern remote sensing techniques. The application areas are: i) Adapazari city suffered by the 17-8-99 earthquake (M=7.4) with severe damage on the building, and ii) the city of Bhuj in north-west India struck by the strong earthquake on 26-1-2001 (M=7.9). Two radar images of ERS-2 and a pan-sharpening Ikonos product have been used. Both Earth observation data have been processed in order to enhance and detect the potential damages.

KEY WORDS: SAR Images, Ikonos Image, Damage Assessment

1. INTRODUCTION

An earthquake is a way of releasing stress from the Earth and transferring it on its surface. When an earthquake occurs, it is very important to examine its results and effects at the damaged area. Remote sensing from satellites constitutes a unique tool for monitoring damaged areas after a seismic event. These methods are very significant as they both provide fast damage assessment using space data.

The areas examined are Sakarya-Adapazari in Turkey and Bhuj in India. For the study of Adapazari city, two SAR images where used: the first taken before the earthquake and the second one after the earthquake. The amount of backscatter signal is different before and after the earthquake, as the surfacial parameters have changed due to the earthquake. A lot of buildings have been collapsed provoking changes in the brightness of the images. For Bhuj, an IKONOS Pan-sharpening Multispectral image of high resolution has been used. This image provides very good results, as it doesn't need a lot of processing. It just shows clearly the damaged area especially in these parts of the city with a clear urban structure.

Currently, operational Earth Observation (EO) capabilities have some limited use in the mitigation (Bhatia, 1992, Buchbinder and Sarria, 1994, Gupta et al., 1995, Das et al. 1996, Tuttle and Barstow, 1996, Grigorev and Kondratev, 1997, Ferretti et al. 1999) and response phases of earthquake risk management. In mitigation, EO is useful for base mapping for emergency relief logistics, and estimation of settlement and structure vulnerability (e.g. building design) and exposure (e.g. proximity to active areas). In the response phase, EO's improving contribution is in damage mapping of prime concern to relief agencies that need to locate possible victims and structures at risk, and the insurance industry that need to assess losses.

2. STUDY AREAS

On August 17, 1999, an earthquake with a Richter magnitude of M=7.4 struck northwestern Turkey, at 3:01:37 a.m. local time, lasting about 50 seconds. The epicenter was near the town of Golcuk (40.7N - 29.9E), immediately to the south of Izmit, the capital of the province of Kocaeli. It was the result of a fault rupture on western part of North Anatolian Fault Zone. The fault rupture occurred at an east-west direction, spanning approximately 60 km between the town of Golcuk and the city of Adapazari. The most heavily damaged area was around the Gulf of Izmit and the City of Adapazari. (Fig.1)

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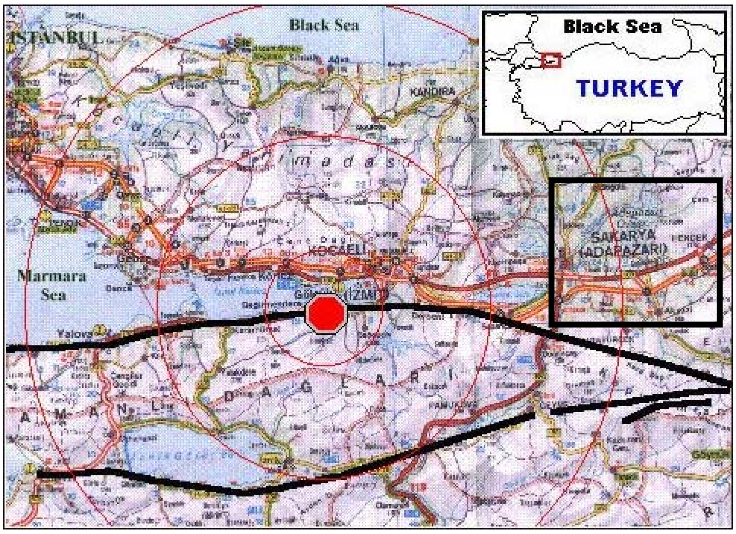

Fig.1: Location of Adapazari city and the epicenter area close to Izmit city

These urban centers were sites of massive structural destruction and extensive ground failures. Adapazari is build up on alluvial soil including old river beds. That explains the fact that aside from the direct damage caused by fault rupture and tectonic subsidence, significant ground failure, cracking, deformation and liquefaction were observed (Neugebauer, 1995, Ambraseys,1999, Scawthorn and Johnson, 2000,).

Fig.2: Location of Bhuj city

On January 26, 2001, another earthquake with a magnitude of M=7.9 occurred in India, the most damaging earthquake in India's history. The earthquake epicenter (N23.399 E70.316 and a depth of 23.6 km) was located to the north of Bacchau about 250 km west of Ahmadabad (India) and about 290 km southeast of Hyderabad (Pakistan). The earthquake that struck Gujarat has left in its wake a horrifying trail of death and destruction. The epicenter in the northern province of Gujarat was a scene of devastation. The city of Bhuj (Fig.2), where 150,000 people lived was turned into rubble with hardly a building left standing. Businesses were ruined, infrastructure destroyed and basic services became insignificant. It is from this earthquake that the town of Bhuj (western India) located in the northwestern of Gujarat had as a result extensive damage in buildings. About 30.000 people died (Rastogi et al., 1997, Krinitzsky and Hynes, 2001).

3. DATA USED

3.1 THE ADAPAZARI CASE

The study area of Sakarya-Adapazari in Turkey is covered by the following SAR images:

	ERS2	ERS2
Dates	5/4/99	23/8/99
Track	293	293
Frame	2783	2783
Orbit	20688	22692

The method is based on the fact that SAR images of the same area may be different if the geometry of the surface has been changed. Different objects backscatter to different degrees, and this is described by the backscattering coefficient σ^{o}. The amount of backscatter determines the tone of backscatter on the image. Radar image represents the radar backscatters for a target area on the ground: darker areas in the image represent low backscattering while brighter areas imply high backscattering. The radar signal strength reflected from the target that determines the digital number at each pixel position, is dependent on several factors including

i. radar observation parameters, such as frequency, polarization, angle of incidence of the emitted waves, and
ii. surface parameters, such as roughness, geometric shape and the dielectric properties of the target.

The incidence angle is measured from the normal to a flat ground surface. The local incidence angle can vary from this angle, as it takes into account the local slope of the terrain at any place in the image (Fig. 3).

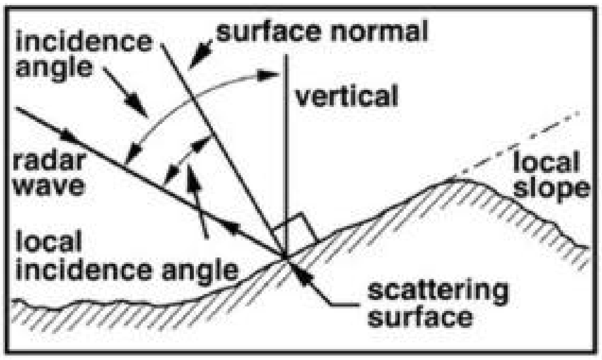

Fig.3: Incidence angle and local incidence angle

It is the local incidence angle, which in part determines the image brightness or tone for each pixel. The smallest local incident angle results in the greatest backscatter and thus the lightest tone in the image.

Before examining the area, all the above, should be taken into consideration in order to avoid possible misjudgments. The figure 4 shows four different cases. In the first one the building has no damages and so nothing will be changed in the backscattering signal; the second case is the partially collapsed buildings, containing two different subcases depending on the orientation of the part of the building that has been collapsed in respect to the radar signal; in the third case the building is totally collapsed provoking completed different backscattering signal, while in the fourth case the surface is smooth because the remained debris of the fallen building have been removed.

Another aspect is the influence of soil liquefaction at the final radar image. Liquefaction is a phenomenon that occurs in saturated soils, that is, soils in which the space between individual particles is completely filled with water. It is obvious that the "wet" soil will give a different brighter color at the image.

3.2 THE BHUJ CASE

The study area of Bhuj in India is covered by an Ikonos Pan-sharpening Multispectral image of high resolution taken on February 2, 2001. By the use of an Ikonos image, clear building blocks or buildings of large size enough is relatively easy to be seen (Fig 5).

Fig.5: Ikonos Pan sharpening image (True color) of Bhuj city.In the right part of the image a very dense build up area could be recognized and in the lower left part it is a relatively open urban structure.

On the contrary, in dense built-up areas without a clear road-network the recognition is almost impossible.

4. PROCESSING AND ANALYSIS

4.1 SAR IMAGES PROCESSING

The ERDAS version 8.5 has been used for the image processing of the radar images at Adapazari. The first step includes the coregistration of the two SAR images, image to image method, which has been made by selecting a set of 44 ground points, and a polynomial transformation of third order has been used. The error was: x:0,48, y:0,45 and total:0,66. A composite image has been created using the above images: the red band has been used for the image taken on April 5,1999, while for the image of August 23, 1999 the green band. The composite image consists basically of three colors: The yellow, the greenish and the reddish colors. The areas on the image with yellow color are those who have not changed before and after the earthquake. They represent the areas in the natural and man-made environment, the contribution thus of backscatter is equal for both dates. The greenish colors correspond to changes mainly in the natural environment (vegetation, grass, etc), also due to the liquefaction phenomenon provoking strong backscattered signal, and, finally, maybe to the reorientation of the buildings (without collapsing) resulting at a new local incidence angle. The reddish areas on the image could correspond to changes in the natural environment, as well as to the reddish pixels in the urban areas correspond to collapsed buildings or partially collapsed buildings, but with their collapsed part facing the radar (Fig.6).

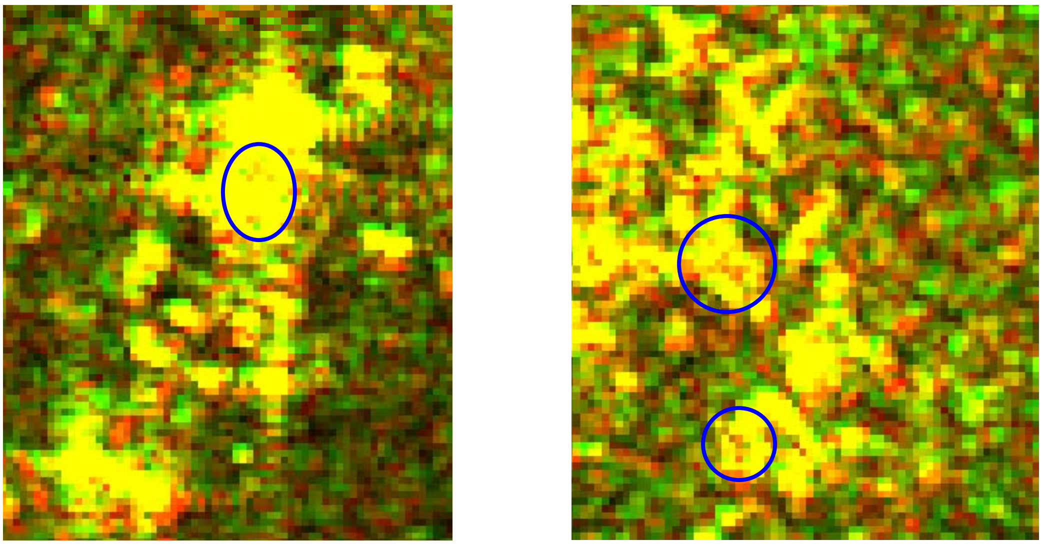

Fig.6: Subscenes of the full radar image: The yellow areas correspond to the densely build up areas with no changes in the backscattering of the signal. Inside these areas reddish pixels can be recognized corresponding to lower backscattering signal in the image acquired immediately after the seismic event probably due to building damages.

4.2 IKONOS IMAGE ANALYSIS AND INTERPRETATION

The used IKONOS image of high resolution shows the town of Bhuj after the earthquake, taken on February 2, 2001. Structure buildings that have fully collapsed with alternate rooflines could be detected in well-developed urban, while, on the contrary, recognition is almost impossible when a building has partially been collapsed. In the northern part of the city of Bhuj, areas, which have obviously been collapsed, as the area is build up with very dense building blocks cannot be determined. In the center and the southern part of the city the recognition of the damages is easier as it is shown in the image (Fig.7). This type of imagery could be used to assist authorities with immediate mediation activities such as major infrastructure damage assessment.

Fig.7: In the middle of the Ikonos image are clearly two collapsed buildings.

5. DISCUSSION

The damage assessment after an earthquake should take into consideration the following parameters:

i. The spatial resolution of the data used in relation to the urban characteristics,
ii. Temporal resolution of the system; a system presents high temporal resolution but the data could not be provided in less than 24 hours (the real time or near real time provision of the data)
iii. The detection and recognition capabilities of the system used; high capabilities of detection and recognition especially in area with clear urban structure.

Concerning the use of SAR images in damage assessment it is obvious that the information necessary is not possible to be captured due to the nature of SAR images (signal backscattered transform to image), the spatial resolution, the coefficient of the backscatter signal which depends on many parameters that affect the surfacial features in the imagery. Finally, the SAR data exhibits low operational capabilities due to time consuming for processing (two images, preprocessing of the data, co registration) and the temporal resolution.

Using a change detection composite SAR image, it is possible to detect possible changes in the build up areas, but not the recognition. An advantage of the SAR data is the detection of liquefaction areas due to the sensitivity of the system to the ground moisture.

On the contrary, the Ikonos data is an ideal tool for damage assessment taking into consideration the following:

i. Resolution (1m) sufficient for identification of building damaged
ii. Some confusion in localized areas
iii. Interpretation difficult in dense urban areas
iv. The TDI (Temporal Difference Image) Ikonos data would overcome the difficulties but need identical incident angles between the before/after images. Applying the change detection method, the two images should have the same incidence angle and the same sun conditions (sun elevation and azimuth) otherwise misjudgments in the interpretation could be arise.
v. High temporal resolution, so a high operational value as it does not require complicated processing, and the assessment could simply be by visual interpretation.

Generally, and in order to improve the accuracy of the damage assessment the following should be considered:

- Change detection: based on radiometry, texture and geometry
- Identification: need of fielding knowledge or high certainty in the interpretation
- Complementary between sensors: optical+radar
- Ground truth validation in order to enhance algorithms
- At least one day of temporal separation in the case of multitemporal images

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REFERENCES

[1]Ambraseys N., (1999). The earthquake of 10 July 1894 in the Gulf of Izmit (Turkey) and its relation to the earthquake of 17 August, Journal of Seismology 5(1), pages 117-128.

[2]Bhatia, S., Chetty, T., Filimonov, M., Gorshkov, A., Rantsman, E., Rao, M., (1992). Identification of potential areas for the occurrence of strong earthquakes in Himalayan arc region. Proceedings of the Indian academy of sciences-earth and planetary sciences 101, pages 369-385.

[3]Buchbinder, G., Sarria, A (1994). A satellite-based seismic and volcanic monitoring-system for Colombia. Bulletin of the seismological society of America 84, pages 1670-1674.

[4]Das, J., Saraf, A., Jain, A., (1996). A satellite picture reveals seismically potential tectonic structures in north-east India. International journal of remote sensing 17, pages 1433-1437.

[5]Ferretti, A. Rocca, F. Prati, C. (1999) Non-uniform motion monitoring using the permanent scatterers technique. FRINGE ’99: Second ESA international workshop on ERS SAR interferometry: Advancing ERS SAR interferometry from applications towards operations.

[6]Grigorev, A., Kondratev, K., (1997). *Satellite monitoring of natural and anthropogenic disasters*. Earth observation and remote sensing 14, pages 433-448.

[7]Gupta, R., Chander, R., Tewari, A., Saraf, A., (1995). Remote-sensing delineation of zones susceptible to seismically induced liquefaction in the Ganga plains. Journal of the Geological Society of India 46, pages 75-82.

[8]Krinitzsky E. L. and Hynes M. E.,(2001). The Bhuj, India, earthquake: lessons learned for earthquake safety of dams on alluvium, Engineering Geology, In Press.

[9]Neugebauer J., (1995). Structures and kinematics of the North Anatolian Fault zone, Adapazari-Bolu region, northwest Turkey, Tectonophysics, Volume 243, Issues 1-2, pages 119-134.

[10]Rastogi B.K., Grigorev, A., Kondratev, K., (1997).The deadliest stable ontinental region earthquake occurred near Bhuj on 26 January 2001. Journal of Seismology 5(4), pages 609-615, Satellite monitoring of natural and anthropogenic disasters, Earth observation and remote sensing 14, pages 433-448.

[11]Scawthorn C. and Johnson G. S (2000).Preliminary report; Kocaeli (Izmit) earthquake of 17 August 1999, Engineering Structures, Volume 22, Issue 7, pages 727-745.

[12]Tuttle, M; Barstow, N (1996). Liquefaction-related ground failure: a case study in the new Madrid seismic zone, central United States. Bulletin of the seismological society of america86, pages 636-645.

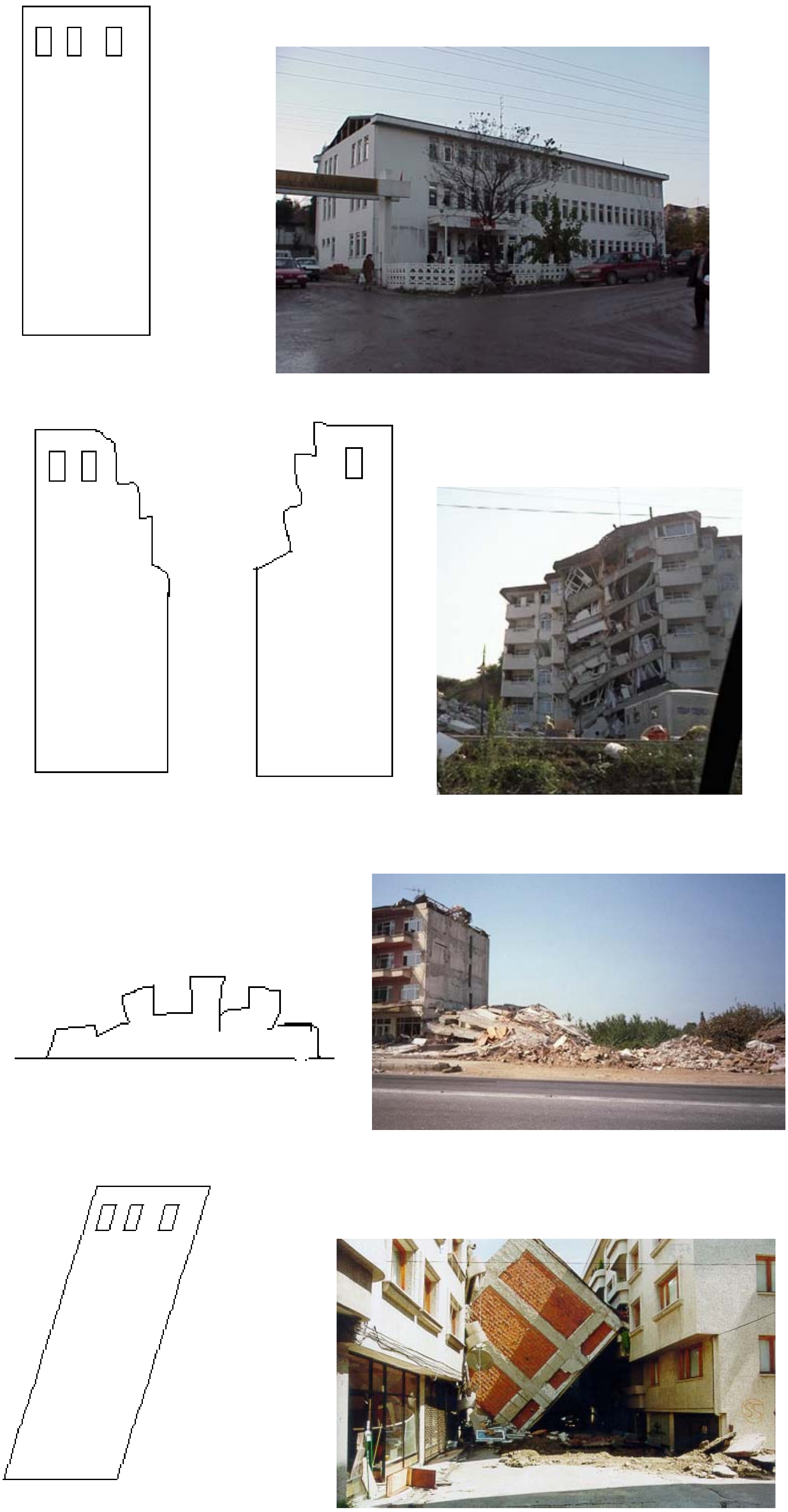

Fig.4 The four cases of building condition that could affect in different mode the backscattering signal.