Remote Sensing to Assessment Damages Post Earthquakes, focusing in Urban Structures

Author: Elisa Solano

Tutor: Marcelo Scavuzzo

March 27, 2013
## Contents

Abstract 1

1 Introduction 2

2 Theorical aspects 4
2.1 Remote Sensing 4
2.2 Differences between Passive and Actives systems 7
2.2.1 Passive systems 7
2.2.2 Active systems 7
2.3 Assessment Risk 8
2.4 Urban remote sensing 9

3 Latest Charter activations 11

4 Methods and techniques 14
4.0.1 Uses of remote sensing to assessment damages in the latest Earthquakes 16
4.0.2 Using optical images to detect building damages post Earthquakes 17
4.0.3 Using thermal and microwave detection of earthquakes and faulting as an alternative to mapping earthquake damage 20
4.0.4 SAR detection of earthquakes and faulting High resolution Synthetic Aperture Radar (SAR) 20
4.0.5 Prediction 26
4.0.6 Sensor, advantages and limitations 27

5 Techniques used around the world 29
5.1 Conclusions 31
5.2 Glossary 36
List of Figures

2.1 Time scale of satellite systems ................................. 6
2.2 Image where shows the main difference between passive and active sys-
tems, getting the sun energy ........................................... 7
2.3 Scale-dependent urban analysis, from [RT10] ....................... 10
3.1 This image shows the latest activations of the charter ................. 13
4.1 Visual comparison between SPOT scenes in the Fig. the town of Golcuk, demonstrates changes in reflectance due to earthquake damage, from [ES03] ............................................................... 16
4.2 Harvard MIT Data Center’s Eric Alderman studies map printed by Cen-
ter for Geographic Analysis at Harvard University for the Boston Uni-
versity mission to Haiti, with B.U. organizer Jean Lucien Ligonde. ... 17
4.3 Damage Map for Ban Nam Khem, developed using high-resolution Quick-
Bird and IKONOS imagery 2004 Indian Ocean Earthquake and Tsunami. The percentage of collapsed buildings is computed within zones at 100m intervals from the open coast and inlet shores. Source: [CW06] .......................... 18
4.4 VIEWS interface showing “before” and “after” high-resolution imagery and part of the GPS route (illustrated by the yellow and red dots) followed by the field team in Ban Nam Khem Indian Ocean Earthquake and Tsunami. The upper photograph shows an example of the rapid reconstruction that is occurring, and the lower digital video shows remaining building damage. Source: [CW06] .......................... 19
4.5 Backscattering mechanisms of different types of building: (a) flat roof building; (b) tilted roof building; and (c) collapsed building ............. 21
4.6 Schematic figure of the repeat pass satellite observation geometry and backscattering characteristics of buildings ......................... 21
4.7 Schematic figure of the backscattering characteristics of orderly uniform buildings with flat roofs and their damages. ...................... 22
4.8 Coseismic differential interferogram PALSAR 20080720–20090422, Abruzzi region, Italy. Superimposed to SAR amplitude image. Geocoded to Italian National coordinates, area 36 km × 40 km ...................... 23
4.9 Geometry of cross-track SAR interferometry. S1, S2, sensor positions;
B, baseline; Bn – perpendicular baseline; LOS – line of sight. Inset A:
pixel resolution in slant range and ground range. Inset B: illustration of
the phase difference between two beams ............................ 24
4.10 RADAR from clases Master AEARTE ................................. 25
4.11 Types of LIDAR ........................................................... 26
5.1 Pictures show damages cannot be recognized by remote sensing . . . . 32
5.2 Pictures show damages cannot be recognized by remote sensing . . . . 33
List of Tables

4.1 Summary of the characteristics of some sensors used in hazards mapping and monitoring Joyce, 2009 .......................................................... 15
4.2 Input remote sensing data. Source: Adams and Huyck, 2006 [AH06] . 27
4.3 Remotely sensed data types and image processing techniques for information extraction about natural hazards [JKE09] ...................... 28
Abstract

Background: Earthquake disaster is one of the most serious natural disasters, being the second problem in order of importance from disaster of evolution fast, just after flooding. Thus within the last one hundred years the Centre for Research on the Epidemiology of Disasters, has posted the percentage of deaths for earthquakes was around 2.2% over than storms, volcanic eruptions, landslides, avalanches and forest fires. When the disaster arises, assessment of damages is not an option it is a needed and Geomatics appear as expression of the new power and development of traditional geospatial related disciplines. It has been widely used in earthquake emergency studies. In this review we will show some technicians to assess the damages of urban infrastructure after a catastrophic event supporting on the uses of Remote Sensing.

Aims: The goal of this monographic review is to identify uses of Remote Sensing (passive and actives) to assessment damages post earthquakes, focused in urban areas.

Methods: In order to get a good information, has been collected more than a dozen articles and books, from various journals and editorials of remote sensing, geography and health, those articles are not older than ten years, because the knowledge of this technicians have been improved nowadays. After reading, the information, was discretized by topics and selected from various texts the best information in order to have quality and to know its applicability.

Results: Differential SAR interferometry is possibly one of the best techniques used for mapping ground deformation produced by earthquakes. Differential interferometry (DInSAR) calculates the phase difference between SAR images acquired before and after an event or some other period when deformation has occurred. The accuracy of this technique depends on data type and its quality: wave-band, perpendicular and temporal baselines, ground conditions (such as vegetation and snow coverage), tropospheric and ionospheric noise. In the most favourable conditions it is possible to achieve accuracy better than one quarter of SAR wavelength. Another group of technicians are the uses of high resolution optic images with good results, thus we can see the work with this kind of images on the latest earthquakes which started the charter activations.
Chapter 1

Introduction

Earthquakes and Tsunamis are second in importance from disaster of evolution fast, just after flooding i.e. within the last hundred years CRED\(^1\) has posted the percentage of deaths for earthquakes was around 2.2% over than storms, volcanic eruptions, landslides, avalanches and forest fires. As we know disaster management cycle, include reduction (mitigation), readiness (preparedness), response and recovery\(^2\), and remote sensing has a very important role to play in each of these phases, and its utility has been proven on many occasions around the world.

The use of RS within the domain of natural hazards and disasters has become increasingly common, due in part to increased awareness of environmental issues such as climate change, but also to the increase in geospatial technologies and the ability to provide up-to-date imagery to the public through the media and internet. As technology is enhanced, demand and expectations increase for near-real-time monitoring and visual images to be relayed to emergency services and the public in the event of a natural disaster [JKE09]. Recent improvements to earth monitoring satellites are paving the way to supply the demand. Techniques needed to exploit the available data effectively and rapidly must be developed concurrently to ensure the best possible intelligence reaching emergency services and decision makers in a timely manner [TWG07].

Nevertheless, every event is distinct, and there are many different types of hazards experienced worldwide on an annual basis and their remote sensing solutions are equally varied and this mono-graphic review, within of framework of the Master Applications Spatial Early Warning and Emergency Response, leaded by Institute Mario Gulich from CONAE and the Universidad de Cordoba, has the interest on develop how to use Remote Sensing to assessment infrastructure damages post Earthquakes in technical way through of information interpretation obtained remotely, focusing in urban areas. This focus obeys two factors, one of them is because nowadays the number of urban residents is growing by nearly 60 million every year. The global urban population is expected to grow roughly 1.5% per year, between 2025-2030. By the middle of the 21st century, the urban population will almost double, increasing from approximately 3.4 billion in 2009 to 6.4 billion in 2050.[United Nations, 2011]. Thus, the urban areas of

\(^1\)CRED: The Centre for Research on the Epidemiology of Disasters www.cred.be/emdat

the world are expected to absorb all the population growth expected over the next four decades while at the same time, some of the rural population become will become cities [MY10]. The other point, is because my Thesis research, solve a problem of Geographic access in rural areas and, wish to extend my knowledge towards application on urban areas. However, most of these applications described here, can be useful for other purposes where the urban space is involved.
Chapter 2

Theoretical aspects

2.1 Remote Sensing

Remote sensing is the acquisition of information about an object or phenomenon without making physical contact with the object. In modern usage, this term generally refers to the use of aerial sensor technologies to detect and classify objects on Earth (both on the surface, and in the atmosphere and oceans) by means of propagated signals (e.g. electromagnetic radiation emitted from aircraft or satellites). Remote sensing applications include monitoring deforestation in areas such as the Amazon Basin, glacial features in Arctic and Antarctic regions, and depth sounding of coastal and ocean depths. Military collection during the Cold War made use of stand-off collection of data about dangerous border areas. Remote sensing also replaces costly and slow data collection on the ground, ensuring in the process that areas or objects are not disturbed. Orbital platforms collect and transmit data from different parts of the electromagnetic spectrum, which in conjunction with larger scale aerial or ground-based sensing and analysis, provides researchers with enough information to monitor trends such as El Niño and other natural long and short term phenomena. Other uses include different areas of the earth sciences such as natural resource management, agricultural fields such as land usage and conservation, and national security and overhead, ground-based and stand-off collection on border areas. There are two main types of remote sensing: passive remote sensing and active remote sensing.

Passive sensors, also known as optic sensors, do not have their own energy source and usually record the radiation from the sun that is reflected from the Earth’s surface. Photographic cameras and multispectral scanners are passive sensors often used in satellite remote sensing. The visible part of the electromagnetic spectrum is very small, and most satellite systems have been designed to be sensitive to other portions of the spectrum as well. This characteristic enables remote sensing analysts to see portions of the spectrum that the human eye cannot detect, thereby enhancing their ability to identify different surface materials. The spectral properties of a sensor are defined by the number, placement and width of bands within the electromagnetic spectrum that it is able to record. Panchromatic sensors measure reflected radiation in a single portion, usually located in the visible or infrared part of the electromagnetic spectrum, whereas multispectral sensors collect radiation in discrete parts of the spectrum, which are recorded as separate images called bands or channels. Today, most satellite
remote sensing systems are composed of a panchromatic sensor and a multispectral sensor. Each sensor usually has a different spatial resolution, with the resolution of the panchromatic sensor being higher than that of the multispectral sensor [Chu04].

The first aerial photographs were taken in the 1860s by Felix Tournachon in France using a camera mounted on a balloon [dSW02]. Cameras mounted on planes were first used for military reconnaissance in World War I and II. The military need for separating real vegetation from camouflage resulted in the development of remote sensing beyond the human eye’s visible range with the introduction of infrared wavelength sensors. After World War II, civilian applications of airborne remote sensing were developed for hazard mapping, vegetation mapping and planning. Space-based remote sensing started in the late 1950s with the launch of the first military intelligence satellite. A few years later, the first US meteorological satellite was launched, which was designed to aid in the production of generalized weather maps. The first Earth observation satellite was launched a decade later in 1972 and is known today as Landsat [dSW02]. Although aerial photography has been used as a tool for urban analysis since the late 1950s, the focus of remote sensing research has shifted to the use of imagery acquired by Earth-orbiting satellite sensors as a result of the lower costs and frequency of updates of this imagery [Don01]. The earliest launched satellites are known as first-generation sensors and were able to produce digital images of the Earth’s surface with relatively moderate spatial resolution (i.e., 80 m of pixel size for Landsat MSS – multispectral Scanning System) that were used primarily for regional scale studies. Second-generation satellites, such as Landsat Thematic Mapper and SPOT-HRV, increased the spatial resolution to 30 and 10 m, respectively, and enabled more detailed studies of urban systems. Third-generation satellites with very high spatial resolution (5–0.5 m), such as Ikonos and Quickbird, were launched in the last decade and have stimulated the development of newer detailed scale applications related to urban settlements, as anticipated by Donnay et al. (2001).

Active sensors have their own energy source and emit a signal that travels through the atmosphere, reflects on the Earth’s surface and returns to the sensor, which measures the signal’s travel time and strength. Synthetic Aperture Radar (SAR) is an example of an active sensor that uses long-wave-length signals and thus can penetrate clouds or bad weather conditions [PD13]. Radar is an object detection system which uses radio waves to determine the range, altitude, direction, or speed of objects. It can be used to detect aircraft, ships, spacecraft, guided missiles, motor vehicles, weather formations, and terrain. The radar dish or antenna transmits pulses of radio waves or microwaves which bounce off any object in their path. The object returns a tiny part of the wave’s energy to a dish or antenna which is usually located at the same site as the transmitter. Radar was secretly developed by several nations before and during World War II. The term RADAR was coined in 1940 by the United States Navy as an acronym for RAdio Detection And Ranging. The term radar has since entered English and other languages as the common noun radar, losing all capitalization. The modern uses of radar are highly diverse, including air traffic control, radar astronomy, air-defense systems, antimissile systems; marine radars to locate landmarks and other ships; aircraft anti-collision systems; ocean surveillance systems, outer space surveillance and rendezvous systems; meteorological precipitation monitoring; altimetry and
flight control systems; guided missile target locating systems; and ground-penetrating radar for geological observations. High tech radar systems are associated with digital signal processing and are capable of extracting useful information from very high noise levels. Other systems similar to radar make use of other parts of the electromagnetic spectrum. One example is, which uses visible light from lasers rather than radio waves.

Satellite systems can be placed in two types of orbits around the Earth. A geostationary orbit is obtained when the satellite orbits at a very high altitude and at the same speed as the Earth’s rotation, thus remaining in a stationary position relative to the Earth and directed to the same portion of the Earth’s surface. Satellites in this type of orbit are limited to a spatial resolution of 1–10 square kilometers and are used for weather and climate data collection and communications. A polar orbit is closer to the Earth’s surface, between 700 and 1000 kilometers; passes through the poles of the Earth, describing a steep inclination relative to the Equator; and orbits in the opposite direction to the Earth’s rotation. Satellites in this type of orbit can cycle around the Earth in 100–120 min, several times per day, and return to the same position after 2 weeks or more, allowing them to gather data on the same location over time. The time that elapses before a satellite returns to the same position is called the temporal resolution of the remote sensing system, and it has been defined as the capability for acquiring repetitive imagery over a certain time interval. Satellites in this type of orbit can obtain images with higher spatial resolution, ranging from 1 to 200 m (de Sherbinin et al., 2002). Thus far, most regional science research in urban settings has used imagery from polar-orbiting satellites with passive sensors with medium, high or very high spatial resolution that provide good spectral resolution with multiple bands in the visible portion of the electromagnetic spectrum, at least one band located in the infrared portion of the spectrum and a panchromatic band. Figure 2.1. shows the satellite remote sensing systems that are frequently used in urban regional science applications.

![Figure 2.1: Time scale of satellite systems](image-url)
2.2 Differences between Passive and Actives systems

2.2.1 Passive systems

- Passive systems detect radiation emitted naturally (all objects above 0 degrees Kelvin / -273 degrees Celsius emit energy) operate similarly to the thermal, and measure electromagnetic energy emanating from the Earth’s surface.

- The energy source of passive systems is an incoherent and unpolarized source (sun). We say inconsistent because the phase differences between two successive waves is not constant. In remote sensing, incoherent sources used are the sun and emissions from the Earth’s surface.

- Passive sensors work with very small amounts of radiation, so the field of view must be large enough to detect low resolution and the result is a low spatial resolution (of the order of tens of km).

- Passive sensors work with frequencies between visible and infrared (UV seldom).

- Optical sensors can only be used during the day (in presence of sunlight) and much better in good weather conditions.
  The optical sensor is used generally facing down (nadir).

![Image showing the main difference between passive and active systems, getting the sun energy](Sistemas Pasivos Sistemas Activos)

Figure 2.2: Image where shows the main difference between passive and active systems, getting the sun energy

2.2.2 Active systems

- Active systems provide their own light source and measuring the potential difference between the transmitted and received signal discretized.
• The source of energy is a coherent and polarized source (Radar, Lidar). We say that a wave source is coherent when successive waves have constant phase differences. Sources of coherent waves used in remote sensing is the Radar. Therefore, it is necessary to measure not only the amplitude of the received wave, but also the polarization and phase as any change in the phase includes information from the target.

• They can generate image (radar) with (spatial resolution on the order of meters)

• The active-radar sensor works with microwaves allowing penetrate clouds (X-band) to the ground (L-band).

• The active sensor operates day or night and in different weather conditions.

• The active sensor uses looking sideways (off nadir), otherwise happen glare.

• The image of the active sensor is complex and requires advanced technical analysis.

2.3 Assessment Risk

Risk assessment is the determination of quantitative or qualitative value of risk related to a concrete situation and a recognized threat (also called hazard). Quantitative risk assessment requires calculations of two components of risk (R):, the magnitude of the potential loss (V), and the probability (H) that the loss will occur. In all types of engineering of complex systems sophisticated risk assessments are often made within Safety engineering and Reliability engineering when it concerns threats to life, environment or machine functioning. The nuclear, aerospace, oil, rail and military industries have a long history of dealing with risk assessment. Also, medical, hospital, and food industries control risks and perform risk assessments on a continual basis. Methods for assessment of risk may differ between industries and whether it pertains to general financial decisions or environmental, ecological, or public health risk assessment.

As we have described, this work is concentrate in the occurrence after an event of earthquake, and how we can assess risks, the fundamental difficulty in it, is determining the rate of occurrence since statistical information is not available on all kinds of past incidents. Furthermore, evaluating the severity of the consequences (impact) is often quite difficult for intangible assets. Asset valuation is another question that needs to be addressed. Thus, best educated opinions and available statistics are the primary sources of information. Nevertheless, risk assessment should produce such information for the management of the organization that the primary risks are easy to understand and that the risk management decisions may be prioritized. Thus, there have been several theories and attempts to quantify risks. Numerous different risk formulas exist, but perhaps the most widely accepted formula for risk quantification is:

\[ \text{Rate (or probability) of occurrence multiplied by the impact of the event equals risk magnitude } R = H \times V \]
2.4 Urban remote sensing

We all know an urban place when we see it, but defining it is not as easy as it might seem. In other writings, some authors define urban as being a characteristic of place, rather than of people. Places are typically defined as “urban”, and on the basis of that definition the people living there are thought of as being part of the urban population. But, we do not usually apply the term “urban” to a person. The personal adjective “urban”, still occasionally used to describe a person, is defined \footnote{Oxford English Dictionary} as having the qualities or characteristics associated with town or city life; elegant and refined in manners, courteous, suave, sophisticated, so urban is a place-based characteristic, then we can proceed to define an urban place as a spatial concentration of people whose lives are organized around nonagricultural activities. The essential characteristic here is that urban means nonagricultural; whereas rural means any place that is not urban. A farming village of 5,000 people should not be called urban, whereas a tourist spa or an artist colony of 2,500 people may well be correctly designated as an urban place. We appreciate, then, that “urban” is a fairly complex concept. It is a function of (1) sheer population size, (2) space (land area), (3) the ratio of population to space (density or concentration), and (4) economic and social organization. As I will discuss below, the changes occurring throughout the world might well call into question this definition that relies on non-agricultural activity as a major criterion, because urban characteristics of place – especially those related to infrastructure – are increasingly (and deliberately) showing up in places that used to be strictly agricultural in nature. In other words, the urban–rural divide is becoming less obvious as the world population grows, as the fraction of humans living in cities increases, and as technology continues to transform human society \cite{RT10}.

Even though a good definition about urban area is complex, because the separability of urban an rural spacious is difficult. We can talk about the remote sensing in urban areas i.e. in recent years “Urban Remote Sensing” (URS) has proved to be a useful tool for cross-scale urban planning and urban ecological research. Remote sensing in urban areas is by nature defined as the measurement of surface radiance and properties connected to the land cover and land use in cities. Today, data from earth observation systems are available, geocoded, and present an opportunity to collect information relevant to urban and periurban environments at various spatial, temporal, and spectral scales. The urban pattern causes deterioration in air quality, the urban ecosystem processes and biodiversity. In this context URS is a necessary prerequisite to examine how urban forms modify the landscape as a complex system. it can help to detect and evaluate the distribution of impervious or, likewise, sealed surfaces, a key parameter of urban ecology (surface and groundwater availability and runoff,vegetation dynamics) and planning (storm water runoff, flooding hazards, landslides) \cite{M03} explains the development of urban landscapes being shaped by the penetration of settlement and open-space structures. Remotely sensed data will be used to detect and evaluate the physical structure and composition of urban areas, such as the structure of residential, commercial or mixed neighborhoods, green spaces or other open spaces.
The growth of “Spatial Data Infrastructures”, Geo-portals and private sector initiatives (e.g. Google Earth, Microsoft Virtual Earth, etc.) produced an increase of geographical data availability at any scale and worldwide. This growth has not been fully coupled by an increase of knowledge to support spatial decisions. Spatial analytical techniques and geographical analysis and modeling methods are therefore required in order to analyse data and to facilitate the decision process at all levels. As cities can be described as a concentration of people it is most striking to find coherence between urban land use and socio-demographic as well as socio-economic parameters [RT10]. The statistical analysis of census data infers information on the human usage of the land, the human exposure to potential hazards in the city, and the configuration of each neighborhood indicating the urban quality of life. For example, overlaying choropleth maps of socio-demographic features with land-use maps give information on gender and age distribution connected with proximity to urban green spaces, income and building density, or water consumption and level of provision of infrastructure. In this context URS aids at providing spatial information being linked to social indicators to explain the interrelations between ecological conditions and socio-spatial development.
Chapter 3

Charter activation by earthquakes, from the last five years

The Charter, emerges from an international agreement between agencies of space to provide a unified system of procurement and delivery of spatial data source in the case of emergency caused by natural or anthropogenic manner. The activation initially proposed UNISPACE-III in the conference held in Vienna (Austria), in July 1999 by the European Space Agency and the Canada. This Charter is in operation since November 2000. Since this date every activation has had images of Remote Sensing. The activation depend on damage not by intensity.

2012
8 November Earthquake Guatemala
7 September Earthquake in southern China
15 August Earthquake in Iran

2011
24 October Earthquake in Turkey
18 September Earthquake, Landslide, Sikkim - North East India
11 March Earthquake in Japan
22 February Earthquake in New Zealand
19 January Earthquake in Pakistan

2010
14 April Earthquake in China
8 March Earthquake in Turkey
27 February Earthquake and tsunami in Chile M 8.3
13 January Earthquake in Haiti
5 January Earthquake in Solomon Islands

2009
30 September Earthquake in Indonesia
16 September Earthquake in Indonesia
8 June Earthquake in Saudi Arabia
9 January Earthquake and landslide in Costa Rica
CHAPTER 3. LATEST CHARTER ACTIVATIONS

2008
3 November Earthquake in Pakistan
23 July Earthquake in Hirono, Japan
11 May Earthquake in China
5 February Earthquake in Rwanda

2007
22 November Earthquake in Chile M 7.7
16 August Earthquake in Peru M 8.0
26 April Earthquake, landslides, exceptional waves in Chile M 6.2
4 April Earthquake in Afghanistan
3 April Earthquake, Tsunami in the Solomon Islands
6 March Earthquake in Indonesia

2006
27 May Earthquake on the island of Java, Indonesia
21 March Earthquake in Algeria

2005
8 October Earthquake in India
8 October Earthquake in Pakistan
22 February Earthquake in Iran

2004
28 December Tsunami, Indonesia and Thailand
26 December Earthquake, Tsunami in Southern Asia
26 December Tsunami, Sri Lanka
28 May Earthquake in northern Iran
18 May Earthquakes in Tenerife
7 April Earthquake in the Hindu Kush region of Afghanistan
24 February Earthquake in Morocco
6 February Earthquake in Indonesia (Papua province)
28 January Earthquake in Iran

2003
26 December Earthquake in Iran (Bam)
22 May Algeria Earthquake
7 May Turkey Earthquake

2002
27 March Earthquakes in Afghanistan

2001
14 February Earthquake and Landslides in El Salvador
29 January Earthquake in India
15 January Earthquake and Landslide in El Salvador
Figure 3.1: This image shows the latest activations of the charter
Chapter 4

Methods and techniques of Earthquake assessment using Remote Sensing

As we know, every event is distinct, and there are many different types of hazards experienced worldwide on an annual basis, and their remote sensing solutions are equally varied even in Earthquakes, there are many technicians to assess the damage after earthquakes.

Since 2000, there have been a number of spaceborne satellites that have changed the way we assess and predict natural hazards. These satellites are able to quantify physical geographic phenomena associated with the movements of the earth’s surface (earthquakes, mass movements), water (floods, tsunamis, storms), and fire (wildfires). Most of these satellites contain active or passive sensors that can be utilized by the scientific community for the remote sensing of natural hazards over a number of spatial and temporal scales. The most useful satellite imagery for the assessment of earthquake damage comes from high-resolution (0.6 m to 1 m pixel size) passive sensors and moderate resolution active sensors that can quantify the vertical and horizontal movement of the earth’s surface. High-resolution passive sensors have been used successfully to assess flood damage while predictive maps of flood vulnerability areas are possible based on physical variables collected from passive and active sensors. Recent moderate resolution sensors are able to provide near real-time data on fires and provide quantitative data used in fire behavior models. Limitations currently exist due to atmospheric interference, pixel resolution, and revisit times. However, a number of new microsatellites and constellations of satellites will be launched in the next five years that contain increased resolution (0.5 m to 1 m pixel resolution for active sensors) and revisit times (daily more than 2.5 m resolution images from passive sensors) [TWG07] that will significantly improve our ability to assess and predict natural hazards from space. In this chapter, we will see some technicians and uses and the summary of the characteristics of some sensors used in hazards mapping and monitoring.
Table 4.1: Summary of the characteristics of some sensors used in hazards mapping and monitoring

<table>
<thead>
<tr>
<th>Satellite</th>
<th>Sensor</th>
<th>Swath (km)</th>
<th>Nadir spatial Res (m)</th>
<th>Revisit capability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Airborne sensors</td>
<td>variable</td>
<td>variable</td>
<td>&gt;0.1</td>
<td>Mobilized to order</td>
</tr>
<tr>
<td>CASI</td>
<td>variable</td>
<td>1-2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hymap</td>
<td>100-225</td>
<td>100-225</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Worldview</td>
<td>Panchromatic</td>
<td>16.4</td>
<td>0.46</td>
<td>1.1 days</td>
</tr>
<tr>
<td></td>
<td>Multispectral</td>
<td>16.4</td>
<td>1.85</td>
<td></td>
</tr>
<tr>
<td>Quickbird</td>
<td>Panchromatic</td>
<td>16.5</td>
<td>0.6</td>
<td>1.5 - 3 days</td>
</tr>
<tr>
<td></td>
<td>Multispectral</td>
<td>16.5</td>
<td>2.4</td>
<td></td>
</tr>
<tr>
<td>Ikonos</td>
<td>Panchromatic</td>
<td>11</td>
<td>1</td>
<td>1.5 - 3 days</td>
</tr>
<tr>
<td></td>
<td>Multispectral</td>
<td>11</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Rapideye</td>
<td>Multispectral</td>
<td>77 x 1500</td>
<td>6.5</td>
<td>1 day</td>
</tr>
<tr>
<td>EO-1</td>
<td>ALI</td>
<td>60</td>
<td>30</td>
<td>Every 16 days</td>
</tr>
<tr>
<td></td>
<td>Hyperion</td>
<td>7.5</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>Terra/Aqua</td>
<td>MODIS</td>
<td>2300</td>
<td>250, 500, 1000</td>
<td>At least twice daily for each satellite</td>
</tr>
<tr>
<td>ALOS</td>
<td>PRISM</td>
<td>35</td>
<td>4</td>
<td>Several times per year</td>
</tr>
<tr>
<td></td>
<td>AVNIR</td>
<td>70</td>
<td>10</td>
<td>as per JAXA acquisition</td>
</tr>
<tr>
<td></td>
<td>PALSAR (Fine)</td>
<td>40</td>
<td>70</td>
<td>plan</td>
</tr>
<tr>
<td></td>
<td>PALSAR (ScanSAR)</td>
<td>250-300</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>SPOT-4</td>
<td>Panchromatic</td>
<td>60-80</td>
<td>10</td>
<td>11 times every 26 days</td>
</tr>
<tr>
<td></td>
<td>Multispectral</td>
<td>60-80</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>SPOT-5</td>
<td>Panchromatic</td>
<td>60-80</td>
<td>10</td>
<td>11 times every 26 days</td>
</tr>
<tr>
<td></td>
<td>Multispectral</td>
<td>60-80</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Kompas</td>
<td>Panchromatic</td>
<td>15</td>
<td>1</td>
<td>2-3 days</td>
</tr>
<tr>
<td></td>
<td>Multispectral</td>
<td>15</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Kompas</td>
<td>TM Multispectral</td>
<td>185</td>
<td>30</td>
<td>Every 16 days</td>
</tr>
<tr>
<td></td>
<td>TM Thermal</td>
<td>185</td>
<td>120</td>
<td></td>
</tr>
<tr>
<td>Landsat-7*</td>
<td>ETM + Panchromatic</td>
<td>185</td>
<td>15</td>
<td>Every 16 days</td>
</tr>
<tr>
<td></td>
<td>ETM + Multispectral</td>
<td>185</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ETM + Thermal</td>
<td>185</td>
<td>60</td>
<td></td>
</tr>
<tr>
<td>NOAA</td>
<td>AVHRR</td>
<td>2399</td>
<td>1100</td>
<td>Several times per day</td>
</tr>
<tr>
<td>Envisat</td>
<td>MERIS</td>
<td>575</td>
<td>300</td>
<td>2-3 days</td>
</tr>
<tr>
<td>Radarsat-2</td>
<td>Ultra-fine</td>
<td>20</td>
<td>3</td>
<td>Every few days</td>
</tr>
<tr>
<td>Radarsat-1/-2</td>
<td>Fine</td>
<td>50</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Radarsat-2</td>
<td>Quad-pol fine</td>
<td>25</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Radarsat-1/-2</td>
<td>Standard</td>
<td>100</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>Radarsat-2</td>
<td>Quad-pol standard</td>
<td>25</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>Radarsat-1</td>
<td>Wide</td>
<td>150</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>Radarsat-1/-2</td>
<td>ScanSAR narrow</td>
<td>300</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>Radarsat-1/-2</td>
<td>ScanSAR wide</td>
<td>500</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Radarsat-1/-2</td>
<td>Extended high</td>
<td>75</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>Radarsat-1</td>
<td>Extended low</td>
<td>170</td>
<td>35</td>
<td></td>
</tr>
<tr>
<td>ERS-2</td>
<td>100</td>
<td>30</td>
<td></td>
<td>35-day repeat cycle</td>
</tr>
<tr>
<td>Envisat</td>
<td>ASAR standar</td>
<td>100</td>
<td>30</td>
<td>36-day repeat cycle</td>
</tr>
<tr>
<td></td>
<td>ASAR Scan SAR</td>
<td>405</td>
<td>1000</td>
<td></td>
</tr>
<tr>
<td>TerraSAR-X</td>
<td>Spotlight</td>
<td>10</td>
<td>1</td>
<td>11-day repeat cycle</td>
</tr>
<tr>
<td></td>
<td>Stripmap</td>
<td>30</td>
<td>3</td>
<td>2.5-day revisit capability</td>
</tr>
<tr>
<td></td>
<td>ScanSAR</td>
<td>100</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>Cosmo-Skymed*</td>
<td>Spotlight</td>
<td>10</td>
<td>&lt;1</td>
<td>~ 37 hours</td>
</tr>
<tr>
<td></td>
<td>Stripmap</td>
<td>40</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ScanSAR</td>
<td>100-200</td>
<td>30-100</td>
<td></td>
</tr>
</tbody>
</table>

*Landsat-7 nearing the end of its useful life; problems with scan line corrector resulting in data gaps.*

Figures quoted for one satellite in constellation.
4.0.1 Uses of remote sensing to assessment damages in the latest Earthquakes

When a disaster arises, effective incident response demands a rapid overview of damage sustained by numerous elements, spread over a wide geographic area. Given the magnitude and complexity of transportation systems, near-real time field-based assessment is simply not an option. Taking the recent Indian Ocean earthquake and tsunami (2004) centered near Sumatra, the media reported damage to roads and bridges, with a number of villages cut off. Considering the critical 48 hour period that urban search and rescue teams have to locate survivors, accessibility must be quickly and accurately determined, in order to reroute response teams and avoid life threatening delays. Irrespective of whether the event occurred in Indonesia or the US, earth orbiting remote sensing devices like IKONOS and QuickBird present a high-resolution, synoptic overview of the highway system, which can be used to monitor structural integrity and rapidly assess the degree of damage.

At a city-wide scale, comparative analysis of Landsat and ERS imagery collected before and after the 1995 Hyogoken-Nanbu (Kobe) earthquake, suggested a trend between spectral change and ground truth estimates for the concentration of collapsed buildings [MY10]. Similar qualitative and quantitative methods were used to evaluate damage in various cities affected by the 1999 Marmara earthquake in Turkey [ES03]. Visual comparison between SPOT scenes in the Fig. the town of Golcuk, demonstrates changes in reflectance due to earthquake damage. Areas of pronounced change are highlighted by circles.

Figure 4.1: Visual comparison between SPOT scenes in the Fig. the town of Golcuk, demonstrates changes in reflectance due to earthquake damage, from [ES03]
4.0.2 Using optical images to detect building damages post Earthquakes

Urban environments are characterized by different types of materials and land cover surfaces than found in natural landscapes. The analysis of remote sensing data has to consider these unique spectral characteristics. Although the variables of interest for regional scientists are not directly measured from the air, remote sensing can measure the context of social phenomena and their effects on the land surface. The unique characteristics of remotely sensed data, such as wide area coverage and repeat cycle, provide a means for exploring and testing hypotheses and models about urban areas and for constructing new theories that can help in the analysis and response by policy makers of problems that involve urban processes. The description of patterns of the urban landscape is a fundamental question in urban analysis. As in many urban applications, land-cover/land-use maps generated by the thematic classification of satellite images can be considered the starting point for further analyses to assess damages post Earthquakes.

Figure 4.2: Harvard MIT Data Center’s Eric Alderman studies map printed by Center for Geographic Analysis at Harvard University for the Boston University mission to Haiti, with B.U. organizer Jean Lucien Ligonde.
In case of post-earthquake urban damage assessment, remotely sensed data offers profound advantages over traditional methods of field survey; it is low-risk, and offers a rapid overview of building collapse across an extended geographic area. Accordingly, damage detection techniques are now appearing in the literature, employing either indirect or direct methodological approaches. For example, urban damage is inferred from a surrogate measure such as night-time lighting levels. In the latter, building damage is recorded directly, based on its distinctive signature within the imagery Matsuoka and Yamazaki. Direct approaches may be categorized as mono and multitemporal. Monotemporal analysis detects damage in imagery acquired after the disaster has occurred. The multitemporal technique instead assesses damage based on spectral changes between images acquired at several time intervals; typically “before” and “after” an extreme event [ES03] presents a multitemporal change detection algorithm for determining the location and severity of post-earthquake building damage. So, it is most effective for extreme damage states, where buildings have collapsed or are severely damaged.

Figure 4.3: Damage Map for Ban Nam Khem, developed using high-resolution QuickBird and IKONOS imagery 2004 Indian Ocean Earthquake and Tsunami. The percentage of collapsed buildings is computed within zones at 100m intervals from the open coast and inlet shores. Source: [CW06]
Optical detection of earthquakes and faulting, the technique of choice in the use of remote sensing for fault mapping with optical data is manual interpretation, regardless of the data source [Wal06, WB07]. Frequently, the effects of earthquake activity and faulting are not manifested in spectral variations within image data, but in topographical changes. Image interpretation therefore relies on the expertise of the analyst, rather than spectral classifiers. It is possible that this field could benefit from the use of filters specifically designed to detect linear features. Note that fault detection is more of an exercise in preparedness than rapid response.
4.0.3 Using thermal and microwave detection of earthquakes and faulting as an alternative to mapping earthquake damage

Were first used in Russia. Such studies were carried out in Russia, Japan and China. Prior to an earthquake, crustal deformation is due to a stress field. It is a known fact that increases in pressure leads to an increase in temperature. There are microcracks, the gases trapped in these pores escape and create a localized greenhouse effect and thus create a thermal anomaly near earth’s surface.

The anomalies appeared a few days to a few hours before the earthquakes. The increase in temperature ranges between 4-10°C. These anomalies are seen to disappear after the earthquakes.

Thermal and microwave detection of earthquakes and faulting as an alternative to mapping earthquake damage, several studies have sought to characterize short-term temperature increases immediately prior to earthquakes. While the detection of thermal anomalies has thus far been conducted retrospectively, refinement of this technique and routine investigation may hold information key to earthquake prediction and warnings. A “normal” temperature for a region can be calculated using a time series of image data and an image of interest compared with this to determine areas of anomaly.

This technique, as well as the split-window method, can be used with various multi-band thermal sensors. Temperature anomalies have been observed over both land and sea in this manner [OT06]. Recently, attempts were undertaken to measure the microwave signal produced by rock failures during earthquakes with passive microwave sensors such as Advanced Microwave Scanning Radiometer for Earth Observation System (AMSR-E) aboard the satellite Aqua. Some initial results are promising but more work needs to be done in this direction.

4.0.4 SAR detection of earthquakes and faulting High resolution Synthetic Aperture Radar (SAR)

Bad weather conditions usually limit the acquisition of optical remote sensing images, while all day and all weather synthetic aperture radar (SAR) shows the ability of providing timely remote sensing data for emergency response and rescue works after earthquake. Because SAR is sensitive to the surface changes caused by earthquake, the modified electromagnetic behaviour by geological disasters and the collapse of buildings can be recorded in SAR images as backscattering intensity changes. Conventional radar is mostly associated with aerial traffic control, early warning, and certain large scale meteorological data. Doppler radar is used by local law enforcement monitoring of speed limits and in enhanced meteorological collection such as wind speed and direction within weather systems. Other types of active collection includes plasmas in the ionosphere. Interferometric synthetic aperture radar is used to produce precise digital elevation models of large scale terrain (See RADARSAT, TerraSAR-X, Magellan). Laser and radar altimeters on satellites have provided a wide range of data. By
measuring the bulges of water caused by gravity, they map features on the seafloor to a resolution of a mile or so. By measuring the height and wavelength of ocean waves, the altimeters measure wind speeds and direction, and surface ocean currents and directions.

Figure 4.5: Backscattering mechanisms of different types of building: (a) flat roof building; (b) tilted roof building; and (c) collapsed building

Figure 4.6: Schematic figure of the repeat pass satellite observation geometry and backscattering characteristics of buildings
Differential SAR interferometry is possibly one of the best techniques used for mapping ground deformation produced by earthquakes. Differential interferometry (DInSAR) calculates the phase difference between SAR images acquired before and after an event or some other period when deformation has occurred. The accuracy of this technique depends on data type and its quality: wave-band, perpendicular and temporal baselines, ground conditions (such as vegetation and snow coverage), tropospheric and ionospheric noise. In the most favourable conditions it is possible to achieve accuracy better than one quarter of SAR wavelength, about 0.5–1 cm for X-band, 1–2 cm for C-band, and 2–3 cm for L-band. This accuracy is sufficient for mapping ground deformation of a moderate earthquake (M5 and up) depending on the depth of the epicentre. The success of DInSAR depends on the degree of phase correlation between the various scenes, which in turn depends on the relative timing and geometry of the various scenes, as well as decorrelation due to the atmosphere, the relative accuracy of the orbit knowledge, and the precise conditions of image acquisition. Decorrelation occurs when surface conditions are significantly different between two acquisitions, or when they appear different in case of large spatial baselines. The effect of decorrelation is less significant for L-band than for C- and X-band.
Over the last decade, radar interferometry has gained a prominent position as a remote sensing tool in geoscience and environmental monitoring. Although the development of techniques for interferometric analysis and processing will still go on for years, in tandem with the improvement of sensors, there are already some well-established techniques available for operational use. Geospatial services, based on the InSAR techniques, are offered by private companies and remote sensing institutions in many countries, addressing applications in natural hazard monitoring, topographic mapping, monitoring of surface deformation, ecology, and the exploration of natural
resources. Nevertheless, the applications in science clearly exceed the operational use of InSAR products. The Sentinel-1 satellite series, to be deployed in 2011 by ESA in cooperation with the European Union, is dedicated to operational applications of SAR with interferometry being a main driver.

![Figure 4.9: Geometry of cross-track SAR interferometry. S1, S2, sensor positions; B, baseline; Bn – perpendicular baseline; LOS – line of sight. Inset A: pixel resolution in slant range and ground range. Inset B: illustration of the phase difference between two beams.](image)

SAR detection of earthquakes and faulting high resolution Synthetic Aperture Radar (SAR) intensity data is used for mapping ground changes and infrastructure damages by calculating a ratio or difference between multitemporal images and then applying supervised or unsupervised classification in the same way as is done with optical data (Matsuoka and Yamazaki, 2005). The main limitation of this approach is a significant variability of backscatter intensity for different regions, lack of quantitative estimations and dependence on incidence angle. A few modern SAR satellites such as TerraSAR-X, Radarsat-2 and ALOS PALSAR are capable of providing data of various polarizations simultaneously. Phase shift and intensity difference between images of
various polarizations are dependent on land cover and, therefore, can be successfully used for its classification [CK03]. For example, due to side-looking acquisition geometry, urban constructions often produce distinct signal caused by the double bounce mechanism [GP05] and this pattern changes when buildings are damaged by an earthquake. For this particular case and many other applications, SAR polarimetry will produce valuable results and complement optical observations.

Another active sensor is LIDAR, Light detection and ranging. LIDAR is used to detect and measure the concentration of various chemicals in the atmosphere, while airborne LIDAR can be used to measure heights of objects and features on the ground more accurately than with radar technology. Vegetation remote sensing is a principal application of LIDAR. Detection of faulting Airborne LiDAR surveys are increasingly useful for mapping surface expressions of faulting. The extremely high vertical and horizontal resolution is ideal for observing previously undetected faults. [CK06] demonstrated the utility of mapping active faults after applying a tree removal algorithm to the derived digital elevation model (DEM). Subsequent analysis was completed manually by visual interpretation. Manual interpretation was also used in New Zealand to extend the length of known faults and identify and map new faultscars. Topograph-
ical profiles were used to assist analysis and quantify vertical deformations. However, this technique of hazard mapping and monitoring is not appropriate for providing information in a rapid-response emergency situation due to the time it takes to acquire and process the data to a point where it can be manually interpreted.

Figure 4.11: Types of LIDAR

In other words, there are several aspects involved in the detection of earthquakes, faulting, and damages associated with each. RADAR and LIDAR are examples of active remote sensing where the time delay between emission and return is measured, establishing the location, speed and direction of an object. Remote sensing makes it possible to collect data on dangerous or inaccessible areas.

4.0.5 Prediction

Generally, prediction capabilities of spaceborne satellites remain poor given the unpredictable nature of earthquakes. However, vulnerability of landscapes to earthquake hazards can be quantified with fault and demographic data [MK06] explored the potential utility of satellite images to determine the vulnerability of buildings to earthquakes using IKONOS and QuickBird imagery. Examined features such as building characteristics (material, height, shape), geologic and edaphic conditions, and context (the position of a house in relation to its surroundings). Ouzounov demonstrated the potential capabilities of remote sensing technologies to predict an earthquake up to a week before its occurrence based on mid-infrared emissions from the earth’s surface. MODIS imagery provides per-pixel temperature and emissivity values that enable researchers
to detect land and sea surface temperature anomalies ranging up to 5° C. from mean values. Before the Bhuj earthquake in Gujarat, India, 2001, MODIS imagery was able to detect a land surface temperature anomaly of 4° C. five to six days before the earthquake hit. This thermal anomaly was hypothesized to occur due to high levels of rock stress prior to the earthquake [TWG07]. The prediction of mass movements such as landslides, avalanches, and debris flows is significantly easier to predict than earthquakes. [MG05] provide an excellent review of satellite imagery and landslides. They show how satellite data on topography and slope collected from active sensors and high-resolution data on vegetation cover and geologic substrate from passive sensors can be used in models to predict slope failures.

### 4.0.6 Sensor, advantages and limitations

<table>
<thead>
<tr>
<th>Sensor</th>
<th>Advantage</th>
<th>Limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optical images</td>
<td>Images are easy to understand and to interpret</td>
<td>Obscured by cloud and smoke</td>
</tr>
<tr>
<td>e.g. Spot, Landsat, Ikonos</td>
<td>Images is comparable</td>
<td>Limited to daylight hours</td>
</tr>
<tr>
<td>SAR</td>
<td>Day and night images capability</td>
<td>Image interpretation is complicated</td>
</tr>
<tr>
<td>e.g. ERS</td>
<td>Penetrate clouds and smoke</td>
<td>Subject to considerable noise</td>
</tr>
<tr>
<td>Radarsat</td>
<td>High revisit frequency</td>
<td>Sideways looking sensor</td>
</tr>
<tr>
<td></td>
<td></td>
<td>causes layover issues</td>
</tr>
</tbody>
</table>

Digital imagery of study site, acquired “before” and “after” the earthquake. Coverage may include optical and SAR imagery at varying spatial resolution.
<table>
<thead>
<tr>
<th>Data type</th>
<th>Sensor examples</th>
<th>Techniques</th>
<th>Advantage</th>
<th>Disadvantage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multispectral</td>
<td>Ikonos, Quickbird</td>
<td>manually or visually interpreted or knowledge</td>
<td>Non-repeatable</td>
<td></td>
</tr>
<tr>
<td>high to</td>
<td>SPOT, ASTER, ALOS</td>
<td>interpretation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>moderate resolution</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>resolution</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spectral classification</td>
<td></td>
<td>Rapid interpretation over large area to detect debris</td>
<td>Non-unique response</td>
<td>Needs algorithm to have best results</td>
</tr>
<tr>
<td>Semivariogram analysis</td>
<td>other textural classifiers</td>
<td>Can be useful even if the scale is less than desired</td>
<td>Returns relative estimation of damages</td>
<td></td>
</tr>
<tr>
<td>Image differences.</td>
<td></td>
<td>Location and extend debris</td>
<td>Requires before-after imagery co-registered and radiometrically balanced</td>
<td></td>
</tr>
<tr>
<td>Thermal</td>
<td>ASTER, MODIS, AVHRR</td>
<td>Split window</td>
<td>Precursor to earthquake activity</td>
<td>Relatively low spatial resolution of thermal sensor</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dual band</td>
<td>Like split window</td>
<td>Assumes only two thermal sensor</td>
</tr>
<tr>
<td>SAR</td>
<td>JERS-1, ERS, 1/2, ENVISAT, ALOS, PALSAR, Terra SAR-X, Radarsat 1/2, Cosmo-SkyMed</td>
<td>Differential interferometry</td>
<td>Surface deformation</td>
<td>Depend on DEM accuracy</td>
</tr>
<tr>
<td>DEM</td>
<td>PALSAR, LiDAR, Terra SAR-X, Ikonos, Quickbird, SPOT</td>
<td>Volumen of landslide by earth movement and elevation displacement</td>
<td>Quantitative estimation of volumetric depositions and ground change</td>
<td>Requires both before and after imagery to be accurately co-registered</td>
</tr>
<tr>
<td>Airborne</td>
<td>LiDAR sensors, SEASAT</td>
<td>Manual interpretation</td>
<td>Very high horizontal and vertical resolution</td>
<td>Acquisition of LiDAR can be expensive</td>
</tr>
</tbody>
</table>
A number of different techniques have been reported in the literature to map the extent of earthquake damage, particularly in urban areas. Image differencing of multidate spectral ratios demonstrated better results than synthetic aperture radar (SAR) in Turkey and Iran, though a combination of optical and SAR coherence was reported to give the most accurate result\cite{ST06}. \cite{SC07} used semivariogram analysis of SPOT panchromatic imagery obtained both before and after the Izmit earthquake in Turkey. This technique demonstrated the possibility of mapping earthquake severity based on changes in the shape of semivariograms, although further research was suggested before the relationship to a quantifiable amount of damage could be determined. It may also be of use where the spatial resolution of the image data is sufficient to detect textural changes, though insufficient to detect specific damages. for details of landslide mapping as a result of earthquake damage.

Absolute radiometric calibration was performed to SAR products to derive backscattering coefficient sigma nought from image digital number (DN). Based on change detection methods, Advanced Land Observing Satellite (ALOS) Phased Array type L-band Synthetic Aperture Radar (PALSAR) data and TerraSAR-X data acquired for the Ms 8.0 Wenchuan earthquake were used to extract earthquake damage information. This study revealed that landslides showed stronger backscattering and barrier lakes showed lower backscattering in post-earthquake 10m ALOS PALSAR images comparing to pre-earthquake, and collapsed buildings showed lower backscattering compared to un-collapsed buildings in 1 m TerraSAR-X image. Results showed that SAR data with different spatial resolutions are useful for different earthquake damage information extraction: medium spatial resolution SAR data, e.g. 10 m ALOS PALSAR data, were efficient for secondary geological disaster extraction; high-resolution SAR data, e.g. 1 m TerraSAR-X data, with the help of ancillary GIS data or high-resolution optical data, could be used to extract building collapse information in urban areas. This study indicates that SAR remote sensing data can provide earthquake damage information at early emergency stage and assist the field surveying, further damage assessment and post earthquake reconstruction.

- Comparative analysis of Landsat and ERS imagery collected before and after the 1995 Hyogoken-Nanbu (Kobe) earthquake, suggested a trend between spectral change and ground truth estimates for the concentration of collapsed buildings
Matsuoka and Yamazaki [MY10], similar qualitative and quantitative methods were used to evaluate damage in various cities affected by the 1999 Marmara earthquake in Turkey [ES03].

- At a regional scale, Matsuoka and Yamazaki [MY05] detect damaged settlements within Marmara and Gujurat provinces, following 1999 and 2001 earthquakes in Turkey and India. This approach provides a quick-look as assessment of the damage extent, and directs responders to the severely hit areas.

Mono-temporal analysis detects damage from imagery acquired after a disaster has occurred. It is particularly useful where “before” data is unavailable. The methodology relies on direct recognition of collapsed structures on high-resolution coverage, through either visual recognition or diagnostic measures. As with the multi-temporal approach, it is most effective for extreme damage states, where buildings have collapsed or are severely damaged.

- Ogawa [OY00] employ mono- and stereoscopic photo interpretation of vertical aerial photography to determine the damage sustained by wooden and non-wooden structures in Kobe. A “standard of interpretation” was devised to distinguish between collapsed, partially collapsed, and nondamage structures, based on: the occurrence of debris; level of deformation; and degree of tilt. Success of this methodological approach is judged in terms of correspondence with ground truth observations. Chiroiu 2002 use similar criteria to interpret building damage from high-resolution IKONOS satellite imagery of the city of Bhuj, which sustained extensive damage during the 2001 Gujurat earthquake. Similar work was done by Saito 2005 for the Bam, Iran earthquake.

- An indirect method of mono-temporal building damage assessment is also documented in the literature. In this instance, damage to building stock is inferred using a surrogate measure. Hashitera et al., (1999) and Kohiyama et al. (2001) compare night-time lighting levels in US Defense Meteorological Satellite Program Operational Linescan System (DMSP-OLS) imagery acquired before and after the Marmara and Gujurat earthquakes. In both cases, areas exhibiting the greatest reduction in intensity corresponded with damaged settlements, supporting the hypothesis that fewer lights shine where buildings are severely damaged. Operating under the cover of darkness, this damage assessment tool is a useful supplement to optically-based methodologies that are limited to daylight hours.

- Li and Tao (2005) used SPOT imagery to undertake pre and post-earthquake damage of the 2003 Xinjiang Bachu-Jiashi earthquake in China and developed
a probabilistic model for earthquake intensity. Fu et al. (2004) utilized threedimensional pre- and post-earthquake ASTER imagery to identify the fault in the 26 December 2003 Bam earthquake in Iran that caused over 40,000 deaths. They determined that the fault extended 65 km and potential damage from this earthquake could have been identified in advance. Fu and Lin (2001) examined surface rupture zones after an 8.1 magnitude earthquake in northern Tibet using Landsat, SPOT, and ASTER imagery before and after the earthquake to detect the spatial distribution of the surface rupture zone. These sensors identified a surface rupture zone of at least 400 km long, the longest surface rupture zone ever reported world wide. Their remote sensing analysis was consistent with ground data and provided a rapid assessment for the detection of seismic surface ruptures.

5.1 Conclusions

This review describes about of a group of selected papers on applications of Remote Sensing damages after Earthquakes. The use of remote sensing for mapping and monitoring natural hazards has diversified in recent years owing to an increase in data availability and technological advances in their interpretation. Remote sensing has proven useful for a range of applications.

Remote sensing techniques provided information about fault zone, rupture zone and earthquake damage map, which are important considerations should be taken at post-earthquake reconstruction stage. Proper designed building should be reconstructed to minimize the effect of future earthquake. Furthermore, safer areas away from the active fault and ruptures should be taken into consideration for reconstruction. Remote sensing techniques can provide useful information for quick damage assessment immediately after the earthquake, and further information extracted from remote sensing images can also attributed to post-earthquake reconstruction.

As the importance of good spatial data is becoming increasingly recognized, remote sensing in the field of hazard assessment and disaster management is likely to grow in the future. New earth observation satellites are continually being launched, recognizing the prospective market in disaster management, but the provision of acquired image data in a rapid response situation remains a challenge both technically and financially. There is also the potential for increased use of airborne platforms to provide the first level of image data in an emergency situation by acquiring, processing and serving imagery in near-real-time to the end-user.

It is not possible to recommend a single data type or processing solution that will work under all conditions. This is a broad field of applications where some techniques will work better under some circumstances than another. Optical data offers some advantages over SAR, but is inherently affected by cloud cover, smoke or haze at the time of satellite overpass. The flexibility provided by a multisensor, multi-platform approach is likely to give the most comprehensive coverage of a disaster event.

Although the use of satellite imagery in natural hazards damage assessment and
prediction can be very cost and time effective, some limitations still exist. Atmospheric interferences in the form of clouds, haze, and smoke present a significant problem in passive optical imagery analysis because they block parts of the image and can cause distortions. Often, these clouded and shadowed areas must be excluded from damage assessment analyses, resulting in gaps in the data. Active sensors can avoid this problem but there are still significant limitations due methods of classification accuracy, and revisit times. The temporal resolution of active and passive sensors can also pose a problem for the damage assessment of natural hazards in near real-time. Although sensors such as MODIS have a daily revisit time, other sensors on satellites such as QuickBird and IKONOS have longer revisit times. Earthquakes, landslides, and floods can occur very rapidly and the peak of the disaster may only persist for a few hours, so the most severe point of a disaster may not be captured.

Although open access satellite images are significantly changing our response to natural hazards, the resolution on these images can be high enough to be a national security risk. In an effort to help disaster relief after the 8 October 2005 earthquake in Kashmir, Pakistan, numerous international aid agencies posted high-resolution satellite images on the web. However, the Pakistan government forced the removal of these images because they feared the security of the Kashmir region might be compromised. Finally, there is still a need to increase the ability of disseminating data that can be integrated with demographic and socioeconomic data for risk mitigation planning and disaster response.

To assess structural level damages is very difficult (maybe less than grade V of intensity in Mercalli), from images of Remote Sensing. In these images we can found the difference between damages up to level V in Mercalli it is possible to detect by remote sensing of high resolution.

Figure 5.1: Pictures show damages can not be recognized by remote sensing.
Figure 5.2: Pictures show damages cannot be recognized by remote sensing
Bibliography


5.2 Glossary

Magnitude / Intensity Comparison Magnitude and Intensity measure different characteristics of earthquakes. Magnitude measures the energy released at the source of the earthquake. Magnitude is determined from measurements on seismographs. Intensity measures the strength of shaking produced by the earthquake at a certain location. Intensity is determined from effects on people, human structures, and the natural environment.

Richter scale:

<table>
<thead>
<tr>
<th>Magnitude in Richter Scale</th>
<th>Energy Released in Joules</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.0</td>
<td>$1.3 \times 10^8$</td>
<td>Smallest earthquake detectable by people.</td>
</tr>
<tr>
<td>5.0</td>
<td>$2.8 \times 10^{12}$</td>
<td>Energy released by the Hiroshima atomic bomb.</td>
</tr>
<tr>
<td>6.0 - 6.9</td>
<td>$7.6 \times 10^{13}$ to $1.5 \times 10^{15}$</td>
<td>About 120 shallow earthquakes of this magnitude occur each year on the Earth.</td>
</tr>
<tr>
<td>6.7</td>
<td>$7.7 \times 10^{14}$</td>
<td>Northridge, California earthquake January 17, 1994.</td>
</tr>
<tr>
<td>7.0</td>
<td>$2.1 \times 10^{15}$</td>
<td>Major earthquake threshold. Haiti earthquake of January 12, 2010 resulted in an estimated 222,570 deaths</td>
</tr>
<tr>
<td>7.4</td>
<td>$7.9 \times 10^{15}$</td>
<td>Turkey earthquake August 17, 1999. More than 12,000 people killed.</td>
</tr>
<tr>
<td>7.6</td>
<td>$1.5 \times 10^{16}$</td>
<td>Deadliest earthquake in the last 100 years. Tangshan, China, July 28, 1976. Approximately 255,000 people perished.</td>
</tr>
<tr>
<td>8.3</td>
<td>$1.6 \times 10^{17}$</td>
<td>San Francisco earthquake of April 18, 1906.</td>
</tr>
<tr>
<td>9.0</td>
<td></td>
<td>Japan Earthquake March 11, 2011</td>
</tr>
<tr>
<td>9.1</td>
<td>$4.3 \times 10^{16}$</td>
<td>December 26, 2004 Sumatra earthquake which triggered a tsunami and resulted in 227,898 deaths spread across fourteen countries</td>
</tr>
<tr>
<td>9.5</td>
<td>$6.3 \times 10^{16}$</td>
<td>Most powerful earthquake recorded in the last 100 years. Southern Chile on May 22, 1960. Claimed 3,000 lives.</td>
</tr>
</tbody>
</table>

Mercalli scale:

i. Not felt except by a very few under especially favorable conditions.

ii. Felt only by a few persons at rest, especially on upper floors of buildings.
iii. Felt quite noticeably by persons indoors, especially on upper floors of buildings. Many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibrations similar to the passing of a truck. Duration estimated.

iv. Felt indoors by many, outdoors by few during the day. At night, some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably.

v. Felt by nearly everyone; many awakened. Some dishes, windows broken. Unstable objects overturned. Pendulum clocks may stop.

vi. Felt by all, many frightened. Some heavy furniture moved; a few instances of fallen plaster. Damage slight.

vii. Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable damage in poorly built or badly designed structures; some chimneys broken.

viii. Damage slight in specially designed structures; considerable damage in ordinary substantial buildings with partial collapse. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned.

ix. Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb. Damage great in substantial buildings, with partial collapse. Buildings shifted off foundations.

x. Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations. Rails bent.

xi. Few, if any (masonry) structures remain standing. Bridges destroyed. Rails bent greatly.

xii. Damage total. Lines of sight and level are distorted. Objects thrown into the air.

**Variogram** In spatial statistics the theoretical variogram $2\gamma(x, y)$ is a function describing the degree of spatial dependence of a spatial random field or stochastic process $Z(x)$. It is defined as the variance of the difference between field values at two locations ($x$ and $y$) across realizations of the field:
\[2\gamma(x, y) = \text{var}(Z(x) - Z(y)) = E \left( |(Z(x) - \mu(x)) - (Z(y) - \mu(y))|^2 \right).\]

**Split window** The current methods for land surface temperature retrieval are mainly single window algorithm, split window algorithm, multiple channels and multiple angle algorithm. The single window algorithm is only using a land surface temperature inversion method of thermal infrared channel, originally according to the Landsat TM6 band to design, and then there is the single channel algorithm is universal, suitable for thermal infrared band of almost all. Split window algorithm is a method using two thermal infrared channels adjacent to the surface temperature inversion, is by far the fastest algorithms for retrieving land surface temperature of mature, in international has published dozens of split window algorithm. Multi-channel algorithm is with the development of multi-channel sensor and developed, is more representative of the Wan and Li algorithm, using the multiband characteristic of MODIS, research and design of the can for retrieving land surface temperature and emissivity method, used for NASA surface temperature product production.