THE APPLICATION OF REMOTE SENSING TO NATURAL HAZARDS OF GEOLOGIC ORIGIN-EXPERIENCES LEARNED FROM GARS-PROGRAM OF UNESCO AND IUGS

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Abstract:

Natural hazards of geological origin have become a significant threat to a large part of the world population. Remote sensing methods can be used to assess the potential for many natural and man made geological hazards. The assessment of risks involving volcanoes, earthquakes and active faults, landslides, mudflows, floods, can be considerably improved by using remote sensing data as an additional and important source of information. The Geological Application of Remote Sensing (GARS) Programme is addressing a wide variety of these issues and invites geological and remote sensing institutes around the world to join.

Kurzfassung:

Naturgefahren geologischen Ursprungs sind eine bedeutende Bedrohung für einen großen Teil der Weltbevölkerung geworden. Fernerkundungs - Methoden können genutzt werden, um das Gefährdungspotential vieler natürlicher und durch menschliche Aktivitäten verursachten Risiken zu bewerten. Die Risiko-Abschätzung bei Vulkanen, Erdbeben und aktiven Störungen, Hangrutschen, Schlammströmen, Überflutungen kann durch die Hinzuziehung fernerkundlicher Daten als eine weitere, wichtigen Informationsquelle, erheblich verbessert werden. Das GARS-Programm widmet sich einer großen Bandbreite dieser Themen und lädt weitere geologische und Fernerkundungs - Institute der ganzen Welt ein, diesem Programm beizutreten.

1. INTRODUCTION

In recent years natural hazards - many of those of geologic origin - became an issue of increasing public awareness. There are a number of reasons, governing this development:

- rapid dissemination of news, intensive media coverage
- larger populations moving into potential risk areas
- loss of financial investments due to natural catastrophes
- unsuitable land-use and land management

There is, a on the other hand, a rapid development in the information technology sector, especially in earth observation. Earth observation satellites and remote sensing aircraft are the platforms, which are used to install sophisticated equipment designed to scan the earth in numerous wavelengths of the electromagnetic spectrum.

Modern remote sensing technology provides excellent opportunities to observe geodynamic processes. However, the sensors and platforms to be utilised have to be adequate to the problem addressed. In many cases, where fast processes are involved, a high repetition rate is essential in monitoring the event.

The data acquired is mainly in digital format. Multispectral scanners (MSS) with bands numbering from 3 to 220, covering the visible to short-wave range of the electromagnetic spectrum, are the most common instruments in space and on aircraft. The trend to improve the spatial resolution will continue and add unprecedented image data, which, when combined with selected MSS bands, will build a powerful source of information. Radar satellites with their all-weather capabilities add to the spectrum of satellites. Radar data together with the precise ranging of the satellite will add measured quantities to earth observation. For the first time we are in a position to generate an exact topographical model of the earth surface. Altitudes can thus be compared from continent to continent. Future missions will deliver data for a higher vertical resolution and will be of a more precise cartographic quality.

Powerful computers are available practical for everyone and expectations are high that automated procedures will be developed that warn authorities and organisations of disasters to come. However, their remains a lot of work to be done: Basic geologic research has to continue using conventional methods. Remote sensing application has to be intensified, since it contributes to many geological research programs essential information. The user community has to make herself heard by the sensor and satellite providers in order to have more suitable satellites in orbit.

The Geological Application of Remote Sensing (GARS) Programme is addressing a wide variety of these issues in order to have more powerful tools developed to assess potential hazards, to monitor ongoing geological catastrophes and to register and appraise the damages occurred. GARS is an international co-operation programme jointly sponsored by UNESCO and IUGS. It had been initiated 1983 with the aims

- to demonstrate the use of advanced remote sensing techniques for the solution of key geological questions

- to ensure the transfer of information and technology through co-operative research in the field in combination with educational programmes

- to ensure a wide dissemination of results

IUGS and UNESCO science and education policy asks for the promotion of new techniques in the field of earth sciences and to involve scientists from developing countries by co-operative research, training and technology transfer. Usually, research programs are initiated between two or more partners at key geological or geological / environmental problems.

The project has addressed a number of essential problems in the past:

- the development of new methods for the integration of multisensor data to improve lithologic mapping in tropical environments (East-Africa)

- landslide mapping using GIS technology based on satellite data and new
  Radar information on test sites in Colombia

- the analysis of volcanic and associate hazards in the Philippines to demonstrate the use of remote sensing, SAR in particular. During this current Phase 3 GARS institutes co-operate with the Philippine Institute for Volcanology and Seismology (PHIVOLCS).

Currently, the scope of the GARS-Program widens, as new remote sensing techniques emerge, new satellites are being launched and a growing number of organisations in developing countries and in the industrialised world apply remote sensing techniques.

2. THE APPLICATION OF REMOTE SENSING TO IDENTIFY AND MONITOR HAZARDS OF GEOLOGIC ORIGIN

In geology we identify two major forces that influence the surface of our planet. They are the endogene forces and the exogene forces. Both can result in disasters. The endogene forces, stemming from the earth interior, can cause uplifting, earthquakes, as well as volcanic activity. Among the exogene forces are erosion, flooding, desertification with all the associated disasters once larger populations are affected.

All the processes mentioned here can develop into catastrophic events in the case, the population is not prepared. Often the impact of the event is underestimated, or the event develops more rapidly than anticipated.

2.1 Erosion

Erosion and sedimentation are two processes, which are generally everywhere present on the land surface. Wind and water remove the topmost surface and the material will be deposited elsewhere. Both processes can achieve catastrophic dimensions. Landslides strike without warning and lahars, a form of volcanic sedimentation, can bury within hours whole valleys under meters of sediments.
Optical sensors, spaceborne or airborne, can be employed to map repeatable the area affected by erosion. The effects along coastlines can be very dramatic. Changes in coastline caused by erosion and sedimentation in the magnitude of several kilometres have been observed in satellite images in the vicinity of Jakarta, on the island of Java/Indonesia. Wind erosion in arid and semi-arid environments are well known and can be monitored using earth observation satellites. In the northern parts of France, Belgium, in Denmark and Germany, in the Midwest of the United States wind erosion has been found to be quite severe in places. Recently, much attention is drawn to landslides. Here again, we have to differentiate between several types of landslides. Large to medium sized landslides can be detected on SPOT, IRS and LANDSAT-TM images and in a combination of RADAR-images and Digitial Terrain Models (DTM). Smaller ones can be easily identified on air-photos. The risk of soil creep, which can accelerate during heavy rainfalls are extremely difficult to assess. Mapping using airborne laser-scan technology is still expensive and needs to be flown repeatedly. The example of subtle terrain changes in the northern part of Germany, however, demonstrate the value of this method (KÜHN et al. 1999). Radar interferometry even from satellite orbits can give excellent results in the cm-range of displacement (MASSONET et al. 1999). However, vegetation cover, which is abundant in the moderate climates and especially in the humid tropics makes it impossible so far, to detect slight topographical changes. The use of permanent corner reflectors provides only movements of the particular reflector, but this can be done in the magnitude of cm as well. Longer radar wavelengths, however, might not be affected so much by vegetation cover, but can only be used for landslides with considerable dislocations. Among all the remote sensing data, optical data, especially air-photos can provide the largest amount of information. Combined with a DTM, a thorough field survey and further geologic and climatic data, the air-photo interpretation will definitely yield the best results. There has been observed a thermal anomalous behaviour prior to sliding recently, but research has not been carried out to explain the reasons behind it.

2.2 Volcanoes

Volcanoes are distributed around the world along plate boundaries. In smaller clusters they occur also within geological plates or continents, mainly along deep seated geological graben structures and fault systems. We differentiate between active volcanoes, dormant volcanoes and extinct volcanoes. This distinction alone bears already some risk: Pinatubo, the volcano that exploded in the Philippines in June 1991 was regarded as dormant. Its last eruption dated back to the 15th century. 500 years is a very short interval in the life of a volcano with an age of more than one million years. In this regard, we even have to regard our volcanoes in Germany as a potential danger, since some of which show slight degassing and are morphological very prominent. Their last eruptions took place only 11.000 years ago.

There is a number of risks involved by dwelling in the vicinity of an active volcano. Not only the eruptive products, pyroclastic flows, tuffs, lava flows and lahars are threatening life and infrastructure, but also associated earthquakes, tsunamis and the silent death of CO_2-eruptions as happened on Nyos-volcano in Cameroon in 1986. The huge methane content in Kivu-Lake at the Zaire-Burundi border is another constant threat to the population living at its shore (TIETZE 1992).

In the aftermath of volcanic eruptions the deposition of lahars can have catastrophic dimensions as could be seen on the flanks of Pinatubo in the Sto. Tomas basin and the Sacobia watershed, or on Mt. St. Helens.

Traditionally, volcanoes are best monitored by using geophysical instruments, so-called seismometers, which record the seismic events very often associated with volcanic underground movements. Remote sensing methods are suitable to observe the surface processes of volcanic eruptions. These include also processes that precede a volcanic eruption: thermal remote sensing of volcanic lakes or fumarole fields, topographic changes like bulging and collapse of the volcanic edifice could be observed in optical and radar data, including interferometric data. Gas emissions are monitored from ground stations in order to detect changes in the gas composition, which could indicate a change in the behaviour of a volcano. New instruments on LANDSAT-7 and on the EO-1 polar platform to be launched at the end of this century by NASA and NASDA will provide thermal multispectral sensors with a foot-print of 60m X 60m on the ground. They will be much more capable of thermal mapping than the current thermal sensors on NOAA and other weather satellites.

To assess the local impact of a volcanic eruption, radar and optical sensors have been proven to be very cost-effective, especially when combined with digital terrain models.

Volcanic hazard prediction includes the application of the above mentioned sensors, as well as precise digital terrain models in order to predict possible eruption centres and the possible distribution of volcanic products downhill.

2.3 Active faults and earthquakes

Optical as well as radar satellite imagery are excellent tools to map active faults. They occur in regionally different patterns, and the knowledge of these patterns, the reconstruction of the kind of movements along the faults, and their connection with active volcanoes will greatly help in the assessment of geological hazards. If compared with information on the location of seismic hypo- and epi-centres areas prone to earthquakes can be more precisely delineated. Observations from LANDSAT-TM images in the Himalayan mountains of Nepal and China revealed a clear connection between of active faults, associated with earthquakes, and the occurrence of large landslides. Effects of earthquakes of the kind, which devastated Mexico City in 1986 can be predicted by mapping large basins and analyse the underground sediments with conventional geological methods.

The delineation of active faults becomes an urgent necessity. Many damsites in the world have been constructed on active faults and the knowledge of the distribution of such faults, especially when they are associated with earthquake hypo-and epi-centres might help to mitigate larger losses due to dam collapses and landslides, as well as by direct earthquake damage.

2. THE ROLE OF UNESCO/IUGS GARS-PROGRAM IN NATURAL HAZARD PREDICTION AND MONITORING

The GARS-Program during the outgoing IDNDR, devotes its future emphasis to the mitigation and monitoring of natural hazards in the broadest sense. It is determined to transfer the knowledge of remote sensing applications of experienced institutes and laboratories to those institutions, which need to apply these methods. The program has currently 13 active institutes and is open to any institute and laboratory that wishes to participate and exchange their experiences with others

The GARS-Program is not funding projects, but it supports the exchange of knowledge through seminars and workshops. It emphasises the wider use of remote sensing techniques for hazard mitigation and monitoring.

The GARS-Program is a member of the CEOS advisory group and wishes to propose to the space industry and funding agencies to plan future space missions in closer contact with the user community. The network of operational earth observing satellites still leaves much to be desired: special radar-interferometric missions with dual receiving antennas, continuous spatially high resolution thermal sensors with high repetition rates and vegetation instruments with free access to local users would be among those missions, which are urgently needed, in order to cope with the challenges of the third millennium.

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