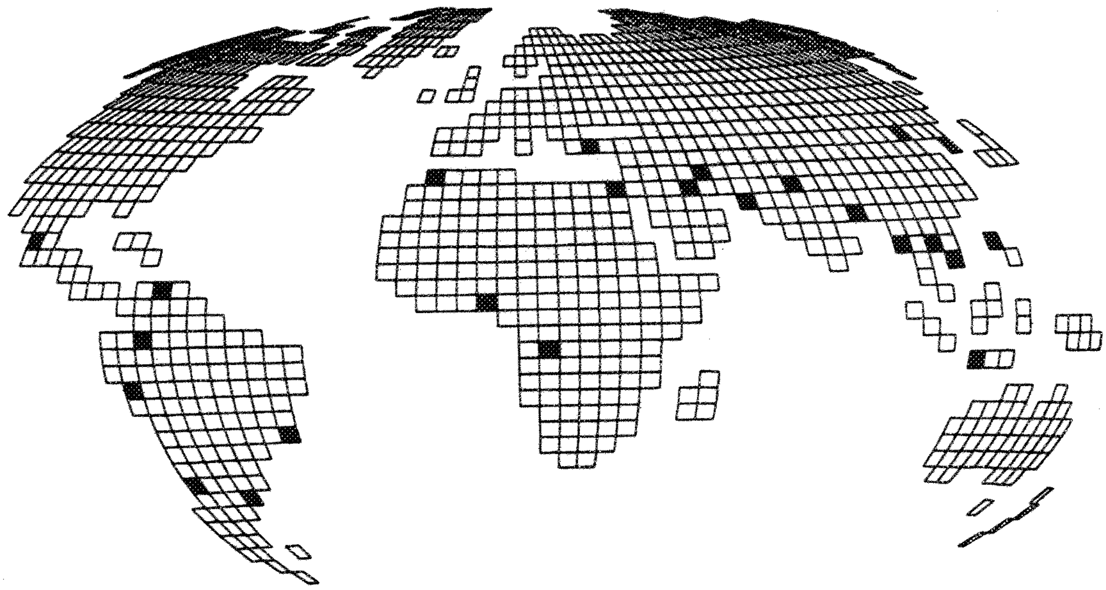
World Conference on
Natural Disaster
Reduction
Technical Committee Session C

The Effects of Disasters on Modern Societies

24 May 1994



■ Selected megacities prone to disasters

**United Nations Centre for Regional Development/
United Nations Department for Development Support
and Management Services**

World Conference on Natural Disaster Reduction

Yokohama, Japan, 23–27 May 1994

Technical Committee Session C

The Effects of Disasters on Modern Societies

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United Nations Centre for Regional Development /
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The Effects of Disasters on Modern Societies

PROGRAMME

Venue: Pacific Convention Plaza Yokohama (PACIFICO Yokohama), Yokohama, Japan
Date: 24 May 1994

Moderator: Atsushi Takeda, STC member, NIED
Rapporteur: Tsuneo Katayama, IAEE

14:00-14:05 **Introduction**
by Hideki Kaji, Director UNCRD/UNDDSMS

14:05-14:45 **Natural Disaster Risk in Modern Societies**

1) Disaster Management in Metropolitan Areas
   by Shinjiro Mizutani, Chairman of the IDNDR Aichi/Nagoya International Conference 1993 JAPAN
2) Urban Environmental Degradation and Vulnerability to Disasters
   by Mohan Munasinghe, Chief, Environmental Policy Division, the World Bank
3) Risk Management and Preventive Planning in Megacities: Scientific Approach for Action
   by Philippe Masure, IAEG, STC member, BRGM
4) Coordination and Integration of International Projects on Risk Assessment in Megacities
   by Yoshikazu Kitagawa, Director, IISEE

14:45-15:00 Comments
by Ismael A. Mathay, Jr., Chairman, Metropolitan Manila Authority
by Ibrahim Attawa, Vice Governor, City of Cairo
by Xu Jiling, Chief Engineer of Beijing Municipal Administrative Commission

15:00-15:30 Discussion on Natural Disaster Risk in Modern Societies

15:30-16:10 **Policies for Natural Disaster Reduction in Modern Societies**

5) Megacities: The Vulnerability of Infrastructure to Natural Disaster
   by Stuart Mustow, President of ICE/WFEO
6) The Application of Satellite Remote Sensing for Natural Disaster Reduction in Developing Countries
   by Niek Rengers, IAF/ITC
7) The Use of Mobile Satellite Communications in Disaster Mitigation
   by Eugene Staffa, Manager, INMARSAT
8) Role of Non-Life Insurance in Disaster Management Systems
   by Takashi Onoda, Chairman, The Marine and Fire Insurance Association of Japan

16:10-16:20 Comments
by Md. Hanif, Mayor, Dhaka City Corporation
by Bernardo Grau Arias, Director of the Office in Charge of Emergencies Prevention in Santafé de Bogotá

16:20-16:50 Discussion on Policies for Natural Disaster Reduction in Modern Societies

16:50-17:00 Concluding Remarks by Rapporteur

Application of Satellite Remote Sensing for Natural Disaster Reduction in Developing Countries

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The paper describes the integrated application of Remote Sensing (RS) and Geo Information Systems (GIS) in the process of monitoring and hazard assessment of natural disasters.

After a short introduction on the methodology of hazard assessment emphasis is given to the unique role which satellite Remote Sensing can play in this context.

An evaluation is made on the applicability of different types of RS-imagery, considering their spatial, spectral and temporal resolution. The capabilities of the use of RS-data in GIS for data integration and analysis of hazard occurrence specifically for conditions in developing countries are highlighted.

1. Introduction

Satellite Remote Sensing techniques can be used for the reduction of natural disasters if these techniques enable us to collect data about atmospherical conditions and/or the characteristics of the earth's surface which may lead to the occurrence of processes which may bring about natural disasters or can help us to take actions which reduce the disastrous effects of these processes.

To reduce the impacts of natural disasters with the help of satellite Remote Sensing, a complete strategy for disaster management is required (OAS, 1990 and UNDRO, 1991), involving the following aspects:

<u>Disaster prevention</u>

- *Hazard analysis*: assessing the probability of occurrence of potentially damaging phenomena.
- *Vulnerability analysis*: assessing the degree of loss expected to population, infrastructure, economic activities, as the consequence of an event of a certain magnitude.
- *Risk assessment*: assessing the numbers of lives likely to be lost, the persons injured, damage to property and disruption of economic activities caused by a particular natural phenomenon.
- *Landuse planning and legislation*: implementation of the risk map in the form of building codes and restrictions.

<u>Disaster preparedness</u>

- *Forecasts/warning/prediction* of disasters (for example, hurricane warning).
- *Monitoring*: Evaluating the development through time of disasters (for example, floods).

<u>Disaster relief</u>

- *Damage assessment* shortly after the occurrence of a disaster.
- *Defining safe areas*, to indicate possible escape areas.
- *Infrastructure monitoring*, to ensure an undisturbed supply of aid.

2. Characteristics of Satellite Remote Sensing and GIS

	LANDSAT MSS	LANDSAT TM	SPOT	
			XS	PAN
Nr. of spectral bands	4	7	3	1
Spectral resolution	0.5 – 1.1 µm	0.45 – 2.35 µm 10.4 – 12.5 µm	0.5 – 0.9 µm	0.5 – 0.7 µm
Spatial resolution	80 m	30 m 120 m in TIR	20 m	10 m
Swath width	185 m	185 m	2 x 60 km	2 x 60 km
Stereo	no	no	yes	yes
Temporal resolution	18 days	18 days	26 days 5 days off nadir	26 days 5 days off nadir

Table 1. Comparison of the specifications of different multi-spectral remote sensing products.

Remote sensing data derived from satellites are excellent tools in the mapping of the spatial distribution of disaster related data within a relatively short period of time. Many different satellite based systems exist nowadays, with different characteristics related to their:

— *Spatial distribution*: the size of the area on the terrain that is covered by the instantaneous field of view of a detector.
— *Temporal resolution*: the revisit time of the satellite for the same part of the earth's surface.
— *Spectral resolution*: the number and width of the spectral bands recorded.

The most frequently used systems are given in table 1.

Besides the use of conventional aerial photographs, which often remain the most useful tools in many types of disaster studies, the application of satellite data has increased enormously over the last decades. After the initial low spatial resolution images of the LANDSAT MSS (60 x 80 meters), LANDSAT is also offering Thermatic Mapper images with a spatial resolution of 30 meters (except for the thermal infrared band) and an excellent spectral resolution with 6 bands covering the whole visible and the near and middle infrared part of the spectrum and with one band in the thermal infrared. LANDSAT has an overpass every eighteen days, offering a theoretical temporal resolution of eighteen days, although weather conditions are a serious limiting factor in this respect, as clouds are hampering the acquisition of data from the ground surface. The weakest point of the LANDSAT System is the lack of an adequate stereovision. Theoretically a stereomate of a TM image can be produced with the help of a good digital terrain model (DTM), but this remains a poor compensation as long as very detailed DTM's are not currently available.

The French SPOT satellite is equipped with two sensor systems, covering adjacent paths each one with a 60 kilometers swath width. The sensors have an off-nadir looking capability, offering the possibility for images with good stereoscopic vision. The option for sidewards looking results also in a higher temporal resolution. SPOT is sensing the terrain in a wide panchromatic band and in three narrower spectral bands (green, red and infrared). The spatial resolution in the panchromatic mode is 10 meters, while the three spectral bands have a spatial resolution of 20 meters. The system lacks spectral bands in the middle and far (thermal) infrared.

Radar satellite images, available from the European ERS-1 and the Japanese JERS, are offering an all weather capability, as the system is cloud penetrating. Theoretically this type of images can yield detailed information on surface roughness and micromorphology, however, the till now applied wavelengths and looking angle have not been very appropriate for the application in mountainous terrain. The first results of the research with radar interferometry are very promising and indicating that detailed terrain models to an accuracy of around one meter can be created, which creates the possibility to monitor slight movements related to landslides, fault-displacements or bulging of volcanic structures.

Remote sensing data should generally be linked or calibrated with other types of data, derived from mapping, measurement networks or sampling points, to derive at parameters which are useful in the study of disasters. The linkage is done in two ways, either via visual interpretation of the image or via classification (Rengers et al., 1992).

A very powerful tool in the combination of the different types of data, required for disaster management, are Geographic Information Systems. A geographic information system (GIS) is defined as a "powerful set of tools for collecting, storing, retrieving at will, transforming and displaying spatial data from the real world for a particular set of purposes" (Burrough, 1986). The first experimental GIS's were developed as early as the 1960's, but the real boom came in the 1980's, with the increasing availability of "cheap" (personal) computers. It is estimated that by 1986, more than 4000 different systems have been developed around the world (Burrough, 1986). Many different GIS systems exist today, with different characteristics with regards to the type of data structure (vector versus raster), data compression techniques (Quadtrees, run-length coding), two-dimensional versus three-dimensional data storage, mainframe, mini-, and microcomputer hardware, and user interfaces (pop-up menus, mouse driven, help options, etc.).

Spatial data, used in GIS, is data with a geographic component, such as maps, aerial photography, satellite imagery and rainfall data, borehole data, etc. Many of these data will have a different projection and coordinate system, and need to be brought to a common map-basis, in order to superimpose them. GIS allows for the combination of these different kinds of spatial data, with non spatial, attribute data, and use them as input data in complex models. One of the main advantages of the use of the powerful combination techniques of a GIS, is the evaluation of several scenarios, and the analysis of the sensitivity of the models by varying some of the input data.

3. Characteristics of Geological Natural Disaster types and the Role of Remote Sensing

Widely known are the potentials of applications of data from satellites to predict weather-related disastrous phenomena such as extreme storms and rainfall.

This paper concentrates on geology-related natural disasters. As these disaster types are concerned with natural phenomena with wide variations in characteristics, size, speed of development, etc., the following paragraphs will concentrate separately on the role of satellite remote sensing in the reduction of the following four types of geological hazards: flooding, earthquakes, volcanic eruptions, and landslides.

Flooding

The areas affected by flooding are generally large in size (in the order of 10^3–10^5 km^2). Many different types of flooding exist, with different requirements as to the satellite imagery. In general the following subdivisions can be used:

- *river floods*, which can be seasonal floods related to big rivers, or flash floods in smaller catchments.
- *coastal floods*, which can be related to tropical cyclones, or to high tides.

Many factors play a role in the occurrence of flooding, such as the intensity and duration of rainfall, snowmelt, deforestation, poor farming techniques, sedimentation in riverbed, and natural or man made obstructions. In the evaluation of flood hazard, the following parameters should be taken into account: depth of water during flood, the duration of flood, the flow velocity, the rate of rise and decline, and the frequency of occurrence.

Satellite data can be used in the phase of disaster prevention, by mapping sequential inundation phases, including duration, depth of inundation, and direction of current. This can be done with automated classification from SPOT, LANDSAT or NOAA images. Furthermore SPOT and LANDSAT TM can be used in the geomorphological mapping of the potential flood area. However, the most crucial data is derived from the calculation of the peak discharges and return periods, using data from gauging stations.

For the prediction of floods, promising results have been reported recently, on the use of NOAA images, combined with meteorological satellites and radar data, in the calculation of rainfall over large areas. For the monitoring of floods in large catchments, such as in Bangladesh, NOAA images are successfully applied.

For the disaster relief operations, the application of current satellite systems is still limited, due to their poor spatial resolution and the problems with cloud covers. However, SPOT data, if available, can be applied successfully in the determination of safe areas, and the planning of relief operations.

<u>Earthquakes</u>

The area affected by earthquakes are generally large (on the order of $10^2 - 10^4$ km^2), but they are restricted to well-known regions (plate contacts). Typical recurrence periods vary from decades to centuries. Observable associated features include fault rupture, damage due to ground shaking, liquefaction, landslides, fires and floods. The following aspects play an important role: distance from active faults, geological structure, soil types, depth of the water table, topography, and construction types of buildings.

In the phase of disaster prevention, satellite remote sensing can play an important role in the mapping of active faults, using neotectonic studies, with the use of LANDSAT TM/SPOT or radar, and the measurement of fault displacements, using satellite Laser Ranging (SLR), Global Positioning System (GPS), or radar inferometry. The most important data for seismic hazard zonation is derived from seismic networks. In seismic microzonation, the use of satellite remote sensing is very limited, as the data is derived from accelerometers, geotechnical mapping, groundwater modelling, and topographic modelling, at large scales.

Earthquakes cannot be predicted with the current state of knowledge, and therefore also satellite remote sensing cannot play a role in the phase of earthquake disaster preparedness.

In the phase of disaster relief, satellite RS can only play a role in the identification of large associated features (such as landslides). Structural damage to buildings cannot be observed with the poor resolution of the current systems.

<u>Volcanic eruptions</u>

The areas affected by volcanic eruptions are generally small (< 100 km^2), and restricted to well-known regions. The distribution of volcanoes is well known. However, due to missing or very limited historical records, the distribution of active volcanoes is not well known (especially in developing countries). Many volcanic areas are densely populated. Volcanic eruptions can lead to a large diversity of processes, such as explosion (Krakatau, Mount St. Helens), pyroclastic flow (Mt. Pelee, Pinatubo), lahars (Nevado del Ruiz, Pinatubo), lava flows (Hawaii, Etna), and ashfall (Pinatubo, El

Disaster type	Disaster prevention	Disaster preparedness	Disaster relief
Volcanism	++	++	++
Earthquakes	+	-	o
Landsliding	o	+	+
Flooding	++	++	++

Table 2. Usefulness of Satellite Remote Sensing for Disaster Management:
++ = very useful, + = useful, o = of limited use, – = not useful

Chincon). Volcanic ash clouds can be distributed over large areas, and may have considerable implications for air-traffic and weather conditions.

Satellite remote sensing can be used in the phase of disaster preparedness in the mapping of the distribution and type of volcanic deposits, using LANDSAT TM, SPOT, or Radar. For the determination of the eruptive history, other data are required, such as morphological analysis, tephra chronology, and lithological composition. Volcanic eruptions occur within minutes to hours, but are mostly preceded by clear precursors, such as fumarolic activity, seismic tremors and surface deformation (bulging). The thermal band of LANDSAT TM can be used to monitor the thermal characteristics of a volcano, and radar inferometry in the measurement of surface deformation. NOAA-AVHRR data can be used to monitor lava flows or ash plumes. Meteosat, GOES or TOMS (Nimbus-7) can be used to monitor the extent of volcanic ash clouds and the SO_2 content.

Landslides

Individual landslides are generally small (0.001 – 1 km^2), but they are very frequent in many mountain regions. Landslides occur in a large variety, depending on the type of movement (Slide, Flow, Fall), the speed of movement (mm/year – m/sec), the material involved (rock ⇔ soil), and the triggering mechanism (earthquake/rainfall/human interaction).

In the phase of disaster prevention, satellite imagery with sufficient spatial resolution and stereo capability (SPOT) can be used to make an inventory of the past landslides, and to collect data on the relevant parameters involved (soil, geology, slope, geomorphology, landuse, hydrology, rainfall, faults, etc.).

In the phase of disaster preparedness, use could be made of the same systems used in the prediction of floods (see Flooding). Monitoring of displacements of large landslides could be done with radar inferometry.

The assessment of damage using satellites is only possible if the spatial resolution is very good, or if the individual landslides are large.

4. Conclusions

In table 2, a summary is given of the usefulness of satellite remote sensing in the different phases of disaster management for flooding, earthquakes, volcanic eruptions and landslides. From this table it can be concluded that most promising results can be expected in the fields of volcanic eruptions and flooding, as both types of disasters result in features that are clearly recognizable with the use of satellite imagery. Earthquakes and landslides generally result in damages to objects that are too small to recognize on the current imagery.

Table 3 lists the current satellite remote sensing imagery that could be used in disaster

Disaster type	Disaster prediction	Disaster preparedness	Disaster relief
Volcanism	TM/SPOT (radar)	TM/NOAA	TM/SPOT/GOES TOMS
Earthquakes	TM/SPOT (radar)	—	TM/SPOT
Landsliding	SPOT	radar NOAA	TM/SPOT
Flooding	TM/SPOT NOAA	NOAA Meteosat	TM/SPOT

Table 3. Current satellite remote sensing data which can be used in disaster management.

management.

Finally the following conclusions can be stated:

— The existing tools can generally be considered adequate. Current SPOT and LANDSAT TM are the most used systems.

— Temporal resolutions (& spatial resolution) should be improved. There is however, a clear need for certain types of disasters (earthquakes, landslides) to have stereoscopic data with a larger spatial resolution.

— In many applications, weather conditions are the most important drawback. In the near future, however, it is expected that many applications will be possible from the use of multispectral satellite data is seriously limited by the nearly continuous cloud coverage.

— New tools should be analyzed:
  - Satellite radar: ERS-1, ERS-2
  - EOS programme

— The application of the satellite data is seriously limited by the lack of funding. Funding of research in applications is in no relation to funding for space technology research.

— Accessibility of data is a problem. Applications in real time are usually only possible on paper, as the time needed for ordering and acquiring satellite images is usually excessively large.

— Satellite remote sensing can only give part of the answer to Geological Disaster Management. It will always have to be combined with other types of data.

— Policy decisions are required to make operational use of satellite remote sensing in the following fields:
  - Investments in hardware and software.
  - Compatibility and continuity of systems.
  - More training.
  - Improved awareness among decision makers.

5. References

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