REMOTE SENSING DATA IN RISK MANAGEMENT OF NATURAL HAZARDS IN BULGARIA

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Abstract: *The main responsible agency for risk management of natural hazards in Bulgaria is the Ministry of Emergency Situations. The Aerospace Monitoring Center (ASMC) at the Ministry is the first satellite data receiving center built up in Bulgaria. The Center was opened in July 2007 and its main objectives and tasks are focused on monitoring risk and disaster analysis, as well as damage assessment. The center is equipped with two receiving satellite ground stations (one for NOAA - AVHRR and Feng-Yun - MVISR, and another one for TERRA/Aqua - MODIS) for real-time data receiving and processing. In addition, satellite images from Disaster Monitoring Constellation (DMC) are delivered to ASMC by Internet after being downloaded and processed. The ASMC uses the leading geographic information systems ArcGIS and digital maps of Bulgaria appropriate for the task.*

The paper deals with the primary results obtained from the activity of the ASMC in Bulgaria and the role of the Aerospace Monitoring Center (ASMC) in natural hazard risk management in Bulgaria.

1. Introduction

The Aerospace Monitoring Center (ASMC) at the Ministry of Emergency Situation is the first direct satellite broadcast center built up in Bulgaria and its main objectives and tasks are related to support natural hazard risk management.

The center is equipped with two satellite direct broadcast stations (one for NOAA - AVHRR and Feng-Yun - MVISR, and second for TERRA/Aqua - MODIS) for real-time data receiving and processing. In addition satellite images from Disaster Monitoring Constellation (DMC) are delivered to ASMC by Internet. The different satellites have different application in disaster studies as well as in different stages of risk management process.

ASMC has the ability for real time video monitoring. The system can be based on an Unmanned Aerial Vehicles or other vehicles. The signal transmits via telecommunication satellites Inmarsat. Because of GPS, each captured image contains information about the coordinates in real time.

The center has the leading geographic information systems for modeling, mapping and image possessing (ERDAS and ArcGIS), as well as appropriate for the task digital maps and DEM model of Bulgaria.

The paper deals with the satellite data application in risk management of natural hazards and some preliminary results obtained.

2. Remote sensing data in risk management process

2.1. Biomass fires

The extremely high temperatures in Bulgaria in the end of July 2007 contributed to hundreds of forest fires. The largest fires were near the city of Stara Zagora, where more than 30 000 hectares were affected in this mountain region.

The most severe wildfire in 2008 started in the beginning of September in the mountainous area of the national park “Rila”, around 30 km from the city of Blagoevgrad.

According to European Forest Fire Information System (EFFIS) Bulgaria is the 4th country in Europe most severely affected by fires in 2007. The total areas burned in Bulgaria are estimated around 68 160 ha until 31 August 2007 (http://effis.jrc.it/documents/2007).

Table 1 presents the distribution of the burned area by land cover type. The normally considered as forest area, i.e. including forest stands and shrubland, was burned in a total of 28 995 ha. The remaining burned area was distributed by agriculture (38 607 ha) and artificial surfaces, i.e. urban, industrial or social areas (558 ha).

Table 1. Distribution of burned area (ha) in Bulgaria by land cover types (until 31 August 2007). http://effis.jrc.it/documents/2007/EFFIS_Newsletter_2_2007.pdf

Land cover	Area burned (ha)	% of total burned
Forest land	28995	42.5
Agriculture	38607	56.6
Artificial surfaces	558	0.8
Total	68160	100

The wildfires were detected, observed and localized in ASMC by NOAA and Feng-Yun satellites. The satellite data, coupled with meteorological data, DMC data and GIS have been used about the emergency and disaster analysis, as well as damage assessment. In addition, satellite data, NDVI index obtained from satellite data and data from EFFIS and FAS-USDA was used for determination of the areas with higher probability of biomass fires**.**

Analyses show that very high fire danger was due to extreme temperatures, lack of precipitations, very low soil moisture and dry vegetation. The affected areas are located in flat country and low-mountain areas with mixed forest (coniferous and deciduous trees) and low-growing vegetation. The bigger part of the fires was placed in border between low-laying and low-mountains land and most of the fires were located near the settlements. (fig. 1,2,3).

The wildfires were probably caused by unprecedented heat waves and mainly by human neglect. The fact that the most of burnt areas is not highly populated and the distant villages were not easily reached by the fire brigades and the high speed of the wind helped the fires to spread very quickly. Because of the lack of resources, Bulgaria requested international assistance to cope with the disaster.

On the figures 2 and 3 are presented satellite images during and after the disaster. The results of damage assessment are shown on fig. 3. The presented images show the most affected areas on the territory on the country. For this purpose DMC images have been used.

The remote sensing data used about detection and assessment of the forest fires show good correlation with the surface observations.

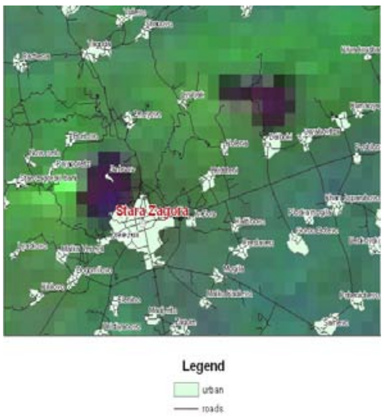

Fig. 1. Left - During disaster (Feng-Yun CHRPT, 20 July 2007, 18:52:17,)

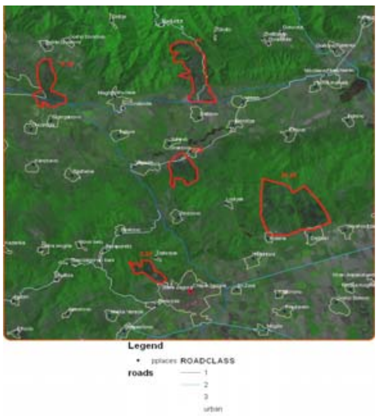

Fig. 2. After disaster – Affected regions are enclosed in red.

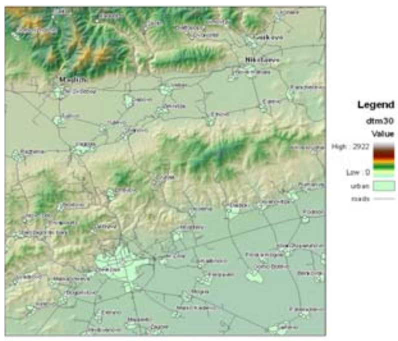

Fig. 3. Right - Topographic map of the region

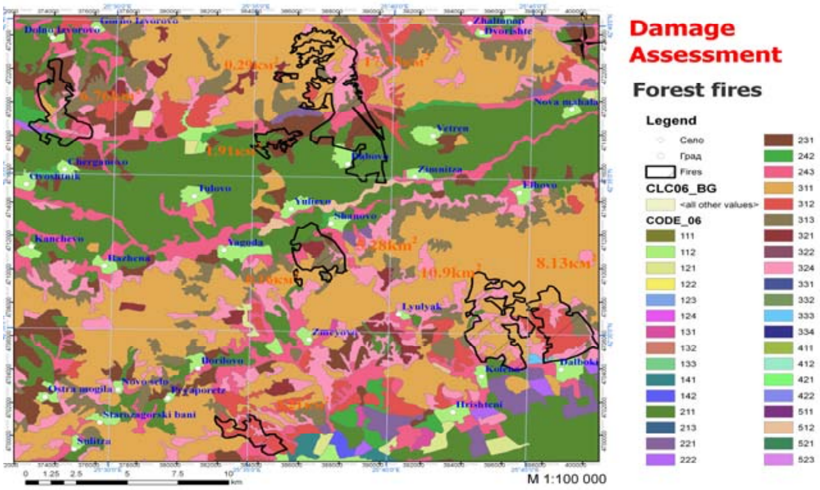

Fig. 4. Damage assessment of forest fires (Corine LandCover 2006)

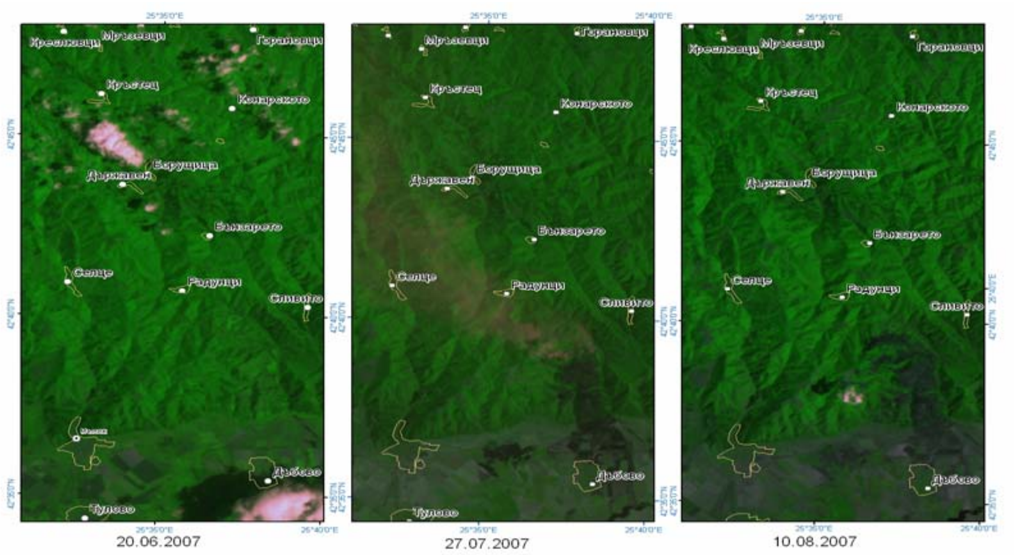

Fig. 5. Before, during and after disaster (Dubavo, Stara Zagora Municipality; DMC images)

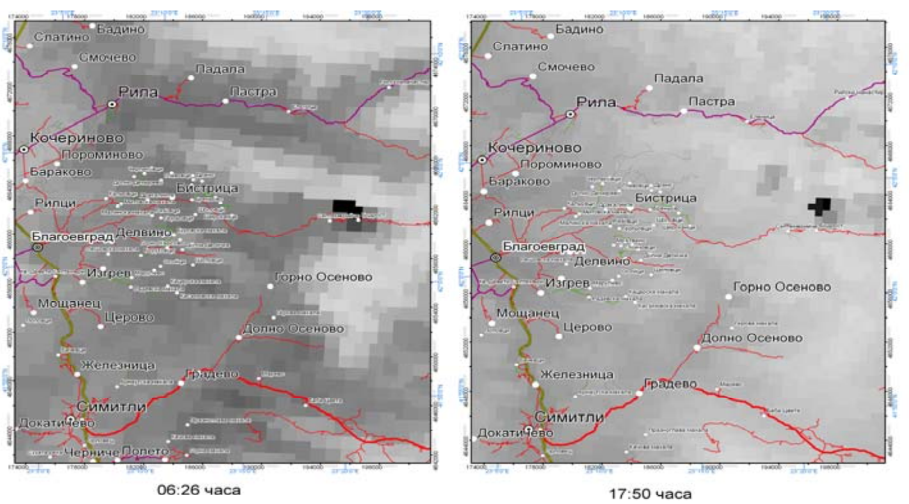

Fig. 6. *Monitoring of forest fires on the territory on the country - .Rila National Park, September 2008. Fire spread direction (from south to north and west) is clear visible*

2.2. Winter storm

During the wintertime the different parts of the country usually are subjected by severe winter storms – the temperatures fall to around minus 15 degrees Celsius, the snow cover reach over one meter in some parts of the country, dozens of villages remain without electricity and water supply.

The satellite images, coupled with meteorological information and ground data are used for risk analysis and disaster preparedness. The results of the risk analysis and monitoring of snow cover helps to determine places with higher probability of storms. In addition, the monitoring of snow cover, meteorological forecasts, together with remote sensing data serves for determination of snowmelt rates, one of the most important factors contributing to springtime flood danger. For these purposes are used satellite image from NOAA AVHRR and MODIS and image product such as albedo, temperature, density slice, NDSI etc. Taking into consideration physical and spectral characteristics of ice (snow) it was possible to determinate snowmelt rates, areas with the highest probability of severe winter storms and areas that may be subjected by floods in spring time.

The NDSI helps in distinguishing snow from similarly bright soil, rock and cloud (Dozier,1989). This has been shown to be an effective index for mapping snow cover in rugged terrain (Hall at all, 1995). A normalized difference snow index (NDSI) is calculated from reflectance in bands at wavelengths where snow is bright (AVHRR band 1) and where it is dark (AVHRR band 3):

NDSI = AVHRR band1 – AVHRR band3 / AVHRR band1 + AVHRR band3

NDSI = AVHRR band2 – AVHRR band3 / AVHRR band2 + AVHRR band3

NDSI = AVHRR band2 + AVHRR band3 / AVHRR band2 - AVHRR band3

NDSI = AVHRR band1 + AVHRR band3 / AVHRR band1 - AVHRR band3

The results show good correlation with ground observation.

Some of the results are presented on fig. 5, 6,7 and 8.

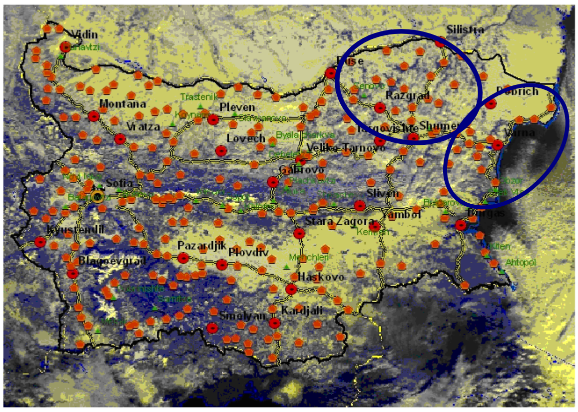

Fig. 7. Snow cover on the territory on the country. Blue circles indicates the areas with the highest probability of severe winter storms.(NOAA HRPT, 04.11.2008, 10.51.53 h,

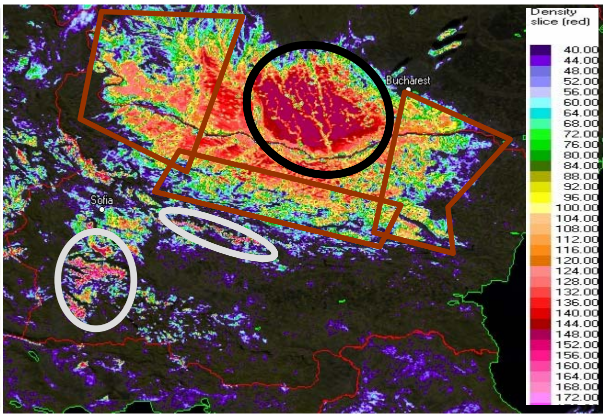

Fig. 8. Channel 2 NOAA density slice product. 26.01.2008 13:15 h The snow that going to melt first if framed in red figures, and the one that is going to hold for a longer period of time is circled in black ellipses. White circle shows the highest mountain areas

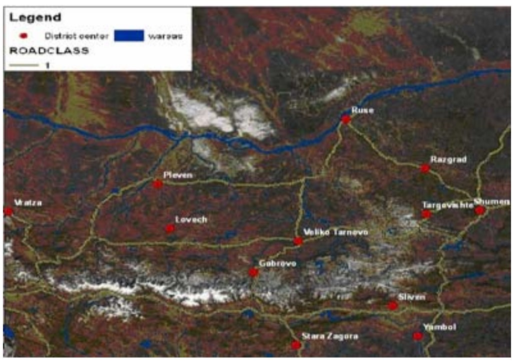

Fig. 9. Snow cover on the territory on the country, 22.02.2008. Image from USDA/PECAD integrated in GIS (*http://www.pecad.fas.usda.gov*)

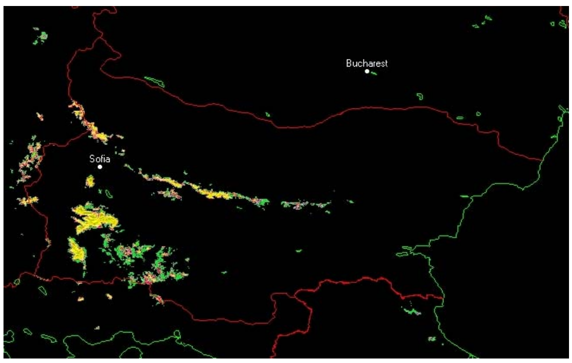

Fig. 10. Snow cover , 25.02.2008, NDSI product, NOAA image

3. Anthropogenic hazards

On the figure 11 are presented the results obtained during the explosions from a military storage facility on 3 July 2008, located in the northeast Sofia, quarter Chelopechene.

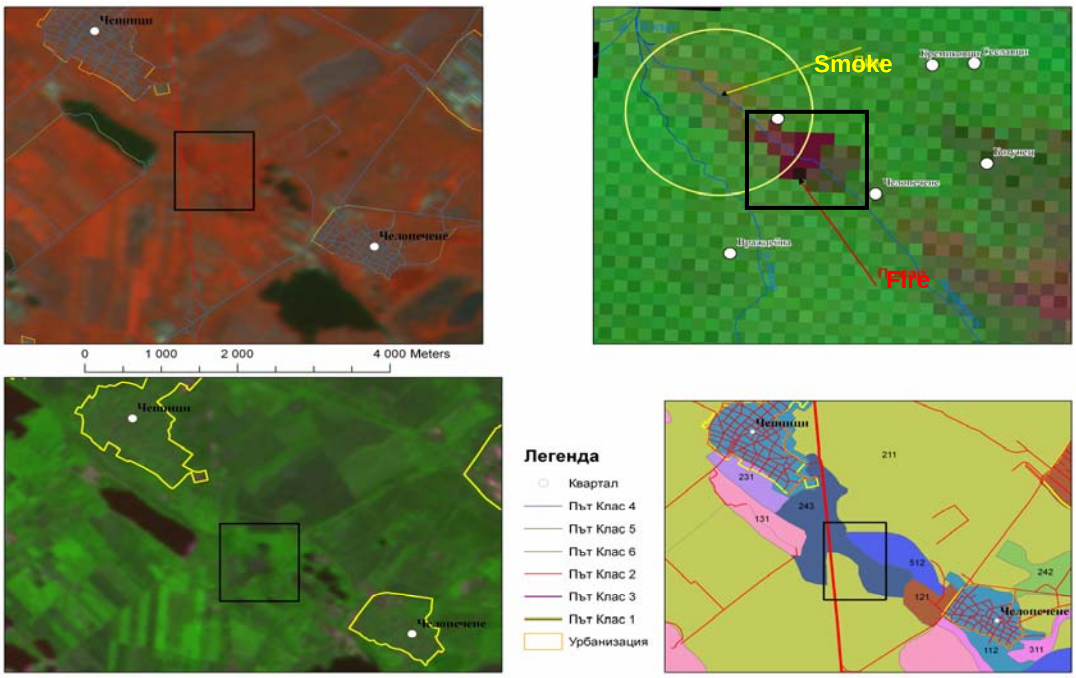

Fig. 11. Explosions from a military storage facility located in the northeast Sofia, quarter Chelopechene, 03.07.2008.

Upper left –northeast Sofia, quarter Chelopechene before accident ; Upper right – during accident. Explosion, location as well as smoke spread direction are clear visible and are enclosed in black square and yellow circle.
Bottom left – affect area is visible in the black square;
Bottom right – affect areas and land cover (Corine Land cover codes: 112. Discontinuous urban fabric, 121. Industrial or commercial units, 131. Mineral extraction sites, 211. Non-irrigated arable land, 231. Pastures, 242. Complex cultivation patterns, 243. Land principally occupied by agriculture with significant areas of natural vegetation, 311. Broad-leaved forest, 512. Water bodies)

4. Applicability of ASMC data in risk management process

The potential of the remote sensing for the monitoring of the Earth environment, risk application and their key role in risk management process are well known and largely used. Unfortunately, most of the remote sensing data are used in general by a few people - mostly specialists of the observation and monitoring systems. Some of space units have combined applications, but, it's clear that for some natural hazards the remote techniques are high effective, for others not so, for the rest - not at all.

The effectiveness of the remote sensing and technologies depends on several parameters - complexity, simultaneous use of the earth data and remote sensing data, frequency band, sensitivity, high/low resolution, sampling frequency of the measurements, reliability of the communication and data transfer, software tools and velocity of the data processing, etc.

The different effectiveness of the registrations, monitoring and warning systems depends strongly on the technologies and sensors used. The main parameters according to the classifications are the bands, sensitivity, resolution, physical principles and methods used, etc. The accuracy of the data collected depends on the resolution, purposes of the measurements, practical applications they have to be used.

Below two tables are presented. In tab.2 some technical characteristics of remote sensing units and technologies is shown. The table includes only satellite and equipment on board from which SMC receive data, although each satellite caries on board a several apertures for earth observation. For each type satellite some orbital parameters, instruments carried on board, frequency band, spatial resolution and instrument swath are shown. Most of those sensors have applications in disaster mitigation practice, though depending of the physical properties of the objects on Earth and the nature of the disaster itself.

Table 3 is created on the basis of table 2. In the table the different instruments and their usefulness and applicability in risk management process of natural hazards/disaster are described. The tables show that different instruments, depending on their type, band and resolution are applicable for different hazards at the different stage of the hazards observations and the risk management process.

Thee levels of applicability (low, medium and high) and 15 hazards had been selected including global phenomenon as climate change, El Nino and La Nina. The classifications are based on the philosophy "before", "during" and "after" the disaster occurrence. "Before" means - preparatory stages, early warnings, vulnerability and risk assessment; "During" means - disaster monitoring in real or near-real time when it is possible; "After" means - damage assessment, modelling the negative effects of the past of future events.

Tabl. 2 Typology and description of the satellites and sensors

Satellite	Orbit	Repeat cycle	Instrument / Sensor	Frequency/band	Spatial Resolution	Swath (km)
AQUA (EOS-NASA) (A-Train)	Sun-Synchronous Near polar, Altitude: 705 km, Inclination: 98^{0} ,Period: 99 min	16 day	MODIS	36 band (21 within 0.4-3.0 µm; 15 within 3-14.5 µm.)	250 m, 500 m 1000 m	2330
TERRA (USA, Canada, Japan)	Sun-Synchronous Near polar Altitude: 705 km, Inclination: 98,2 Period: 99 min	14 day	MODIS	36 band (21 within 0.4-3.0 µm; 15 within 3-14.5 µm.)	250, 500 1 km	2330
DMC	Sun-synchronous Altitude - 686 km, Inclination - 98^{0} Period - 98 min	4 day	ESIS	3 band/6 channel 0,52-0,9 µm	32 m	600
NOAA/ POES series (NOAA, NASA, CSA, CNES, UK, EumetSat)	Sun-Synchronous near-polar, Alt. 804-854 km Inclination - 98.7^{0} Period -102 min	12 hr	AVHRR/3	0.58 - 0.68 µm 0.725 - 1.00 µm 1.58 - 1.64 µm 3.55 - 3.93 µm 10.30 - 11.30 µm 11.50 - 12.50 µm	1,1 km	2900

Tabl.3.Typology and applicability of the different satellites to the stages of the natural hazards

Satellite	Instrument	Before	During	After
DMC	ESIS	1,(2),(3),8,9,(11)	1,8,9,(12),14	1,3,8,9,10,11
AQUA	MODIS	1,((2)),(4),((6)),(7),(8),((10)),(11))	1,6,8,9,(12),14,(13),15	1,8,9,(10),(11)
TERRA	MODIS	1,((2)),(4),((6)),(7),(8),((10),((11))	1,6,8,9,(12),14,(13),15	1,8,9,(10),(11)
NOAA	AVHRR/3	1,((7)),(8),(9), 10, (11)	1,8,6,(9),10,12,(14),((13)),15	(1),(8)

Legend: 1 - Volcano activity; 2 - Earthquakes; 3 - Tsunamis; 4 - Climate change, research and modelling; 5 - Ozone hole; 6 - El Nino, La Nina (ENSO) - SST; 7 - Landslides; 8 - Forest fires; 9 - Droughts; 10 - Storms, hurricanes (incl. high rain rates, flash floods, strong winds); 11 - Floods (river), flash floods (incl. snow melt); 12 - Winter storms; 13 - Polar ice sheet; 14 - Global land coverage (incl. deforestation and desertification); 15 – Snow cover; (( )) - low applicability; ( ) - medium applicability; without bracket - high applicability

5. Conclusion

The climate change is probably bringing Bulgaria even closer to the Mediterranean climate, so strongly characterized with frequent forest fires in summertime and devastating flash floods. The remote sensing data could be of a great importance in risk management of natural hazards. As is stated above, for one type of disaster the ASMS data are applicable and useful (such as winter storms, fires) for other not so. The case studies and first results obtained in Aero Space Monitoring Centre show the applicability and usefulness of satellite data and GIS for monitoring of natural and man-made hazards, risk and disaster analysis, as well as for damage assessment.