AgroLife Scientific Journal - Volume 5, Number 1, 2016
ISSN 2285-5718; ISSN CD-ROM 2285-5726; ISSN ONLINE 2286-0126; ISSN-L 2285-5718

# DEVELOPMENT OF A DOWNSTREAM EMERGENCY RESPONSE SERVICE FOR DISASTER HAZARD MANAGEMENT BASED ON EARTH OBSERVATION DATA

**Gheorghe STANCALIE[1], Vasile CRACIUNESCU[1], Anisoara IRIMESCU[1], Iulia Dana NEGULA[2], Ion NEDELCU[2], Florin SERBAN[3], Delia TELEAGA[3], Stefan-Adrian TOMA[3], Daniela FAUR[4], Mihai DATCU[4], Ana VIRSTA[5]**

[1]National Meteorological Administration, 97 Bucuresti-Ploiesti Avenue, 13686, Bucharest, Romania
[2]Romanian Space Agency, 21-25 Mendeleev Street, 010362, Bucharest, Romania
[3]Terrasigna, 4 Verii Street, District 2, Bucharest, Romania
[4]Polytechnica University of Bucharest, Research Centre for Spatial Information, 313 Splaiul Independentei Blvd, Bucharest, Romania
[5]University of Agronomic Sciences and Veterinary Medicine Bucharest, 59 Marasti Blvd, 011464, Bucharest, Romania

Corresponding author email: gheorghe.stancalie@meteoromania.ro

***Abstract***

*The number of hydrological (flood, mass movement), meteorological (tropical storm, extratropical storm, convective storm, local storm), climatological (extreme temperature, drought, wildfire) and geophysical (earthquake, tsunami, volcanic activity) events continue to increases in the last decades at global level. According to different research, statistics and databases (UNISDR, EM-DAT) floods are the most frequent in the last decades worldwide and especially in Romania. On the other hand, the probabilistic hazard results for Romania indicate that, in the future, the highest damages will be produced by floods and earthquakes. In this context, it has become necessary to develop an emergency response service. The emergency service, named GEODIM, integrates the GIS geodatabases: roads, rivers, administrative units, land cover/land use, satellite data (optical and synthetic aperture radar), in-situ measurements, in order to support the disaster management.*
*The Earth Observations data offers the capabilities to monitor the disasters at a large scale, being able to identify areas where the events are not in-situ observed or to monitor large vulnerable areas potentially affected by disasters. The paper presents the downstream emergency response service for disaster hazard in Romania, based on Earth Observation data and other geo-information information.*

***Key words****: Earth Observation, Disaster, Downstream service Hazard management.*

## INTRODUCTION

The Sendai Framework for Disaster Risk Reduction 2015 - 2030 highlighted that natural disasters are of increasing frequency and severity in the modern world, with important impacts on human lives and the economy. Romania is a flood hotspot in Europe, which experienced significant human and economic losses in the last decade. Since 2000, Romania has been affected by 55 natural disasters from which 34 were floods (62%), according to the International Disaster Database.
Earth Observation data offer necessary information for emergency and disaster management. In order to mitigate the human and property losses, different programs have been developed and implemented: the International Charter on Space and Major Disasters, the Emergency Management Service (EMS), managed by the European Commission within the Copernicus Program and the United Nations Platform for Space-based Information for Disaster Management and Emergency Response (UN-SPIDER).
These programs/services offer space-based products by combining the satellite derived information with additional geospatial data (maps, statistics and reports). In this context, a downstream emergency response service is built in Romania (GEODIM), based on the users' requirements. The GEODIM geoportal is a geoinformation platform for local disaster and hazard management, which provides value-

added products (reference maps, disaster situation maps, graphics, statistics, reports on the extent of disasters and their effects) that are tailored to the specific conditions in Romania. The accent is put on floods (the most important natural hazard in Romania), landslides, ground displacements, and earthquakes. The GEODIM service is developed to provide value-added and validated products for emergency management process. The GEODIM service is the support for decision makers and responsible authorities, in order to develop and implement better policies in the field of environment, climate change, and disaster management.

The downstream service for disaster hazard is starting to be implemented on a dedicated geoportal in the framework of the GEODIM project ("Platform for Geoinformation in Support of Disaster Management": http://geodim.meteoromania.ro).

## EARTH OBSERVATION DATA SOURCES

The service is based on the acquisition, processing and analysis, in rapid mode of satellite images.

Different types of freely available satellite images, covering the disaster event time interval, were acquired and processed:

- satellite data available on public repositories (e.g. MODIS, ASTER, Landsat 5-8, SPOT VGT, PROBA-V);
- satellite data from the EMS or International Charter on Space and Major Disasters, obtained via Romanian General Inspectorate for Emergency Situations (IGSU);
- Pléiades satellite images, in order to provide data to build the relief maps of the impact of the earthquake in Ecuador, acquired during The International Charter Space and Major Disaster and Emergency Copernicus activation;
- The TerraSAR-X data, provided by courtesy of DLR and the German Commission, have been used for landslide monitoring.

Due to the good temporal frequency the MODIS data have been widely used for flood mapping, flood assessment, warning, vulnerability analysis and mitigation.

The new Sentinels mission, specifically designed for the operational needs of the Copernicus programme, can be used to assess the extent of affected areas and the impact on human, economic and environmental loss. Sentinel-1, equipped with a C-band synthetic aperture radar imaging makes it ideal for flood and ground displacements monitoring; Sentinel-2, with the high-resolution, multi-spectral imaging instrument offers valuable information to generate the reference maps.

Reference datasets were also integrated into the service platform. The datasets include: historical maps, topographical maps, aerial images (used to analyze the old landscape), reference water masks (before the event occurred), digital elevation model, soil maps, land cover/use maps, GIS layers (localities, transportation network, points of interest, etc).

Different methodologies/techniques/algorithms have been applied tailored with the disaster type: Content Based Image Annotation (CBIA) for flood reference maps, Differential InSAR (DInSAR) techniques for ground displacements monitoring and Persistent Scatterers Interferometry (PS-InSAR) for landslides monitoring, Alparone and KullbackLeibler algorithms for change detection in case of an earthquake.

## SATELLITE BASED PRODUCTS FOR DISASTER MANAGEMENT

### 1. Generation of flood reference maps

The reference maps for flood events monitoring and assessment are usually based on high spatial resolution offered by the optical images. In this respect the capabilities of the new Sentinel-2 was used to generate flood reference map for the vulnerable river basins. The image was acquired by the Multi-Spectral Instrument (MSI) from a descending orbit (no 905), on the 17$^{th}$ of April 2016. The satellite image offers an almost cloud-free view of the area of interest (2% cloud coverage), i.e. Moldova, located in the north-eastern part of Romania. Crossed my major rivers, this region is often flooded, thus it represents an excellent area for the generation of reference maps. A subset containing the city of Buzau and the Buzau River was extracted from the 13 spectral bands acquired by MSI.

Using the CBIA system and a patch based approach, the water class was successfully identified (Figure 1). The patch-based approach used to extract relevant contextual information is also described in (Faur et al., 2013). The study demonstrates the effectiveness of multi-temporal satellite data for damage assessment in case of floods or earthquakes. Considering Sentinel 2 data availability pre and post disaster the proposed processing scheme (Faur, 2015) comes to support the classical rapid mapping procedures by offering an analytical evaluation of the damages.

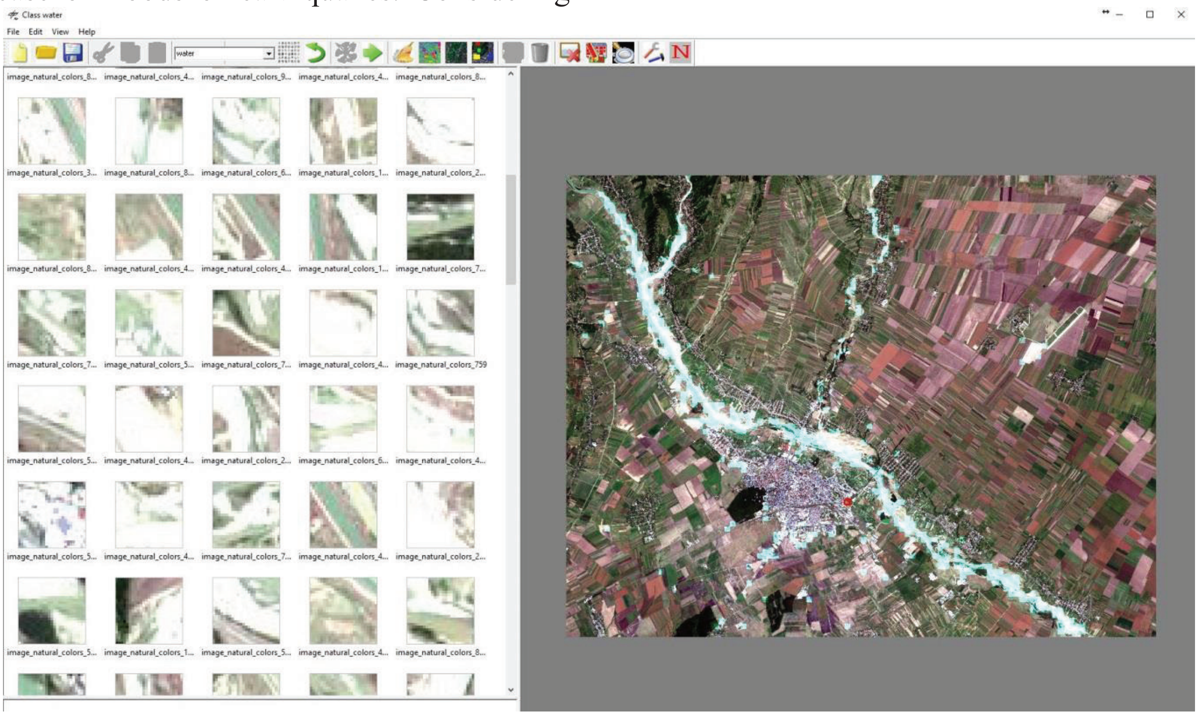



Figure 1. Instant of CBIA system - Patch level processing - Water class highlighted

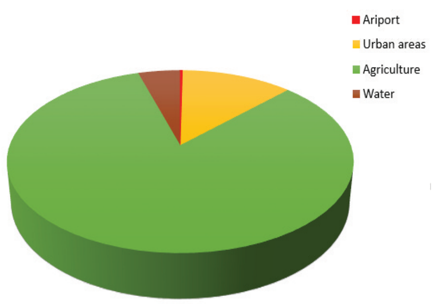



Figure 2. Semantic classes distribution in the studied area


Figure 3. Samples of classes' distribution in the studied area a) - airport, b) agriculture fields, c) water and d) inhabited areas

The semantic classes' distribution within the area of interest is illustrated in Figure 2. Four classes were considered for the analysis, namely airport, agriculture field, water, and urban areas (Figure 3).

Another approach to generate a reference map is to highlight scene's physical features at pixel level. The linear dimensionality reduction technique-PCA (Mateen, 2009) transforms the 13 spectral bands- the high dimensional data set of Sentinel 2, in a 3 dimensional space aiming to describe as much as possible the existing data variance.

The procedure is followed by a K-means classification of the result. Figure 4 shows a preliminary result.

Through trails, supplemented by human interpretation of the image, the considered number of classes to describe this scene is seven. The watercourse is clearly highlighted in the classification map and so is the river basin (Figure 4).

The envisaged approaches represent complementary techniques designed to be used as a reference data for a further evaluation of the disaster impact on a region. The patch based procedure will deliver quantitative semantic annotations of the scene before and after disaster while the land cover map provides additional data for scene understanding.

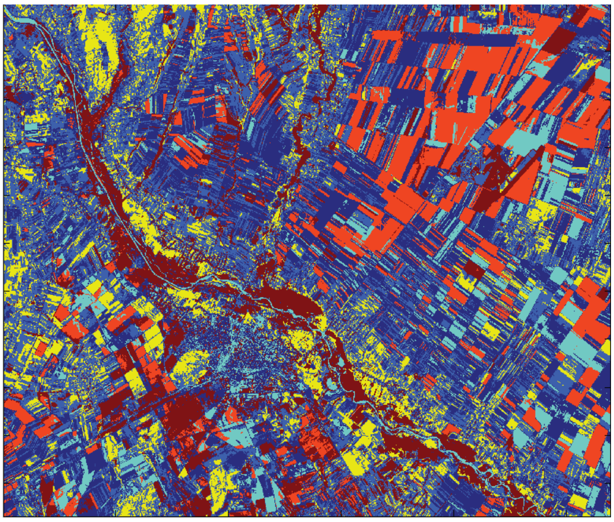


Figure 4. Land cover classification of the Sentinel 2 scene considering a dimensionality reduction technique

## 2. Landslides and ground displacement monitoring

As a growing number of EO satellites are launched every year, EO has become a valuable tool for land monitoring services that allow the generation of complete, consistent, accurate and timely information.

The Synthetic Aperture Radar (SAR) interferometry is the state-of-art technology used for landslide detection and subsidence determination, providing millimetre-scale monitoring of changes in ground elevation.

The development of the spaceborne SAR interferometric techniques started in 1992, after the launch of the ERS-1 mission of the European Space Agency. Since then, it continuously advances and gains importance in geosciences. Until now, Differential InSAR (DInSAR) techniques have been successfully applied for measuring the effects of a large spectrum of phenomena, such as: landslides, mining or groundwater related subsidence, deformation induced by the volcanic activity, co-seismic and post-seismic motions, or glaciology (Crosetto, 2005; Poncos, 2008, 2010; Teleaga, 2012). The advantage of this DInSAR technique is that it reduces the main errors specific to the conventional DInSAR processing, namely temporal and geometrical decorrelation, and atmospheric artefacts (Yu et al., 2008).

### *2.1 Landslides monitoring*

Based on multitemporal SAR data, Persistent Scatterers Interferometry (PS-InSAR) uses radar reflectors that remain stable within a time series and are identified on phase interferograms. PS-InSAR was applied for a series of 18 TerraSAR-XHigh Resolution Spotlight images acquired between March and October 2014. The test area is represented by the residential houses of the Vasile Lucaciu street in Sighisoara (Mures County), located to the west of the City Hill and along the Saes Stream (Figure 5).


Figure 5. Area affected by landslides in Sighisoara (left); Landslides monitoring using PS-InSAR (right), (© Google Earth - background images)

Since many years ago, Sighisoara has been affected by landslides triggered in most of the cases by heavy precipitation.
The most active landslide area is located between the south-western slope of the City Hill and the north-eastern part of the Stejeris Hill, along the both banks of the Saes Stream. The result of the PS-InSAR processing consists in a map showing ground and structural displacement over the analysed time interval. The map comprises of 215 persistent scatterers that reveal a mean displacement velocity that ranges between -22.9 mm/year and +8.7 mm/year, with a mean value of +1.1 mm/an. Relatively high displacements that indicate a downshift are in case of 33 persistent scatterers (Figure 5 - red points). A compact group of persistent scatterers (Figure 5 - yellow circle) can be observed at the base of the Stejeris Hill, on the right bank of the stream.

*2.2 Ground displacement monitoring*

The DInSAR technique was applied on two Sentinel-1 scenes, SLC format, acquired on 26.10.2014 and 31.01.2015, in order to demonstrate the capabilities of Sentinel-1 data to detect and monitor ground displacements, especially landslides.
The test area is located in Bacau County, Romania, the ground elevation varies between 80 - 1650 m, and two rivers (Siret and Trotus) cross the area.
This area was chosen based on historical landslides and favourable landforms for ground instabilities.
In Figure 6, the deformation map for the time interval 26.10.2014 - 30.01.2015 is presented.
Analyzing the DInSAR map, active landslides may be detected (Figures 7 to 9) and the displacement speed estimated.

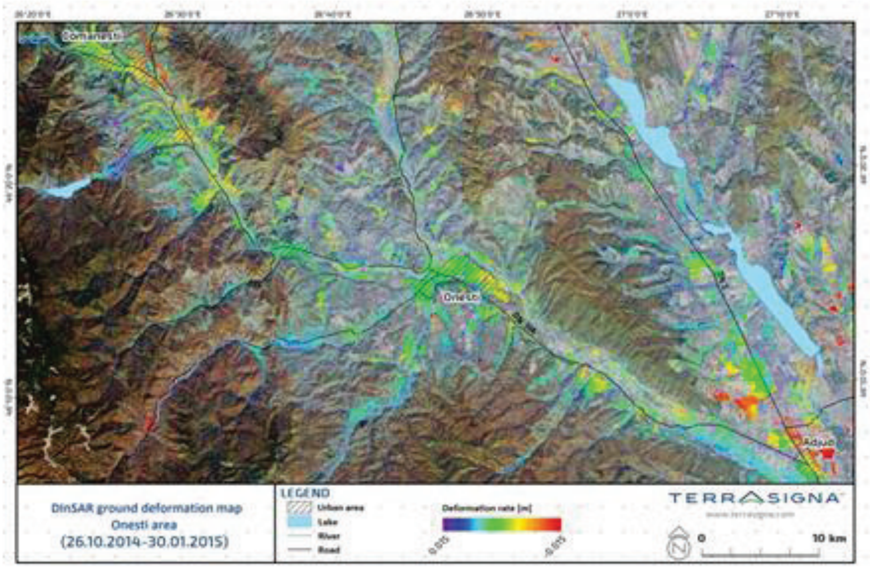



Figure 6. DInSAR deformation map for Onesti area, computed using Sentinel-1 data from 26.10.2014 and 30.01.2015. The map shows displacements [mm] for the interval 26.10.2014 - 30.01.2015

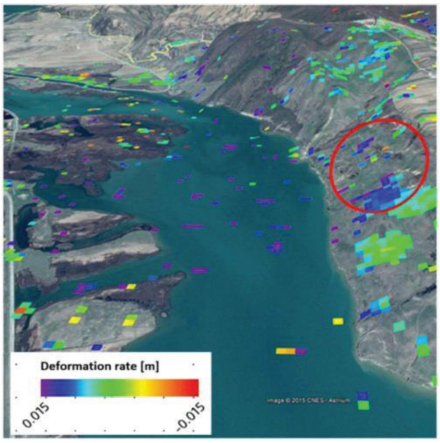



Figure 7. DInSAR deformation values visualized in Google Earth, showing active landslide on steep shore of Lake Beresti


Figure 8. Closer look at the active landslide area identified in Figure 2, showing clear evidence of ground instability in Google Earth imagery

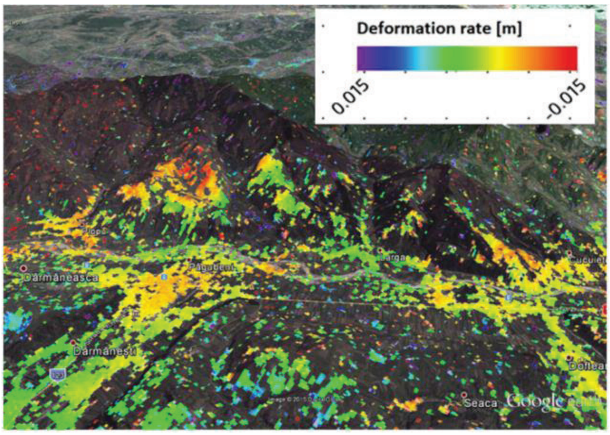



Figure 9. Instable slopes near Darmanesti area, Bacau County, identified by DInSAR

## 3. An earthquake post disaster assessment scenario

The damages caused by the earthquake over a region can be quantitatively assessed based on multitemporal high resolution optical satellite images, as previously demonstrated (Faurand Datcu, 2015).

Recently, on April 16 2016 the town of Pedernale, Ecuador was affected by an earthquake measuring a 7.8 magnitude. The International Charter Space and Major Disaster and Emergency Copernicus have been activated, in order to provide data to build the relief maps of the impact of the earthquake. Destroyed structures and affected buildings are visible in the Pléiades satellite image acquired before and after the earthquake (Figure 10 a. before b. after).

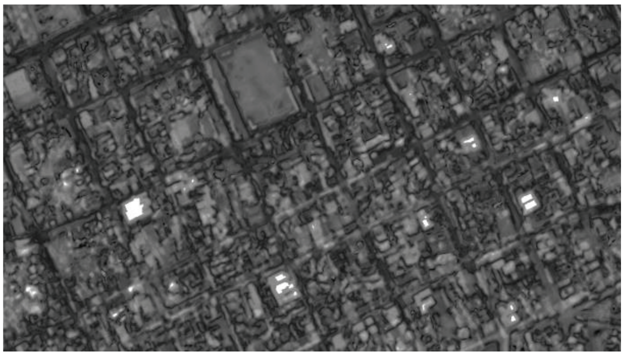
The proposed method (used in case of Pedernale town) uses patches of data features extracted from pre- and post-event satellite images that are mapped into semantic classes and symbolic representations. Another approach to acquire quantitative and qualitative information relative to damages produced by the earthquake involves the use of change detection algorithms.

The scene dynamic is highlighted by means of two similarity measures: KullbackLeibler-KLD (Faur 2008) and conditional information (Alparone) previously used to delineate changes associated to spectral features of the scenes (Vaduva, 2013).

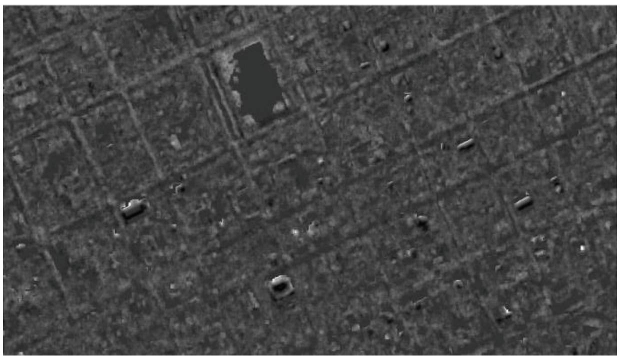
Based on pixel statistics KLD measures is able to detect the divergence between two image's windows described by their probability distribution functions, while CI measure is an adopted version of the Alparone method used for SAR images. It has the advantage of low sensitivity to noise and no constraints of pre-processing data. The results (Figure 10 c. and d.) demonstrate the potential of the considered similarity measures to emphasize the degree of change.

a. Pedernales, September 17$^{th}$ 2015

b. Pedernales, April 17$^{th}$ 2015



c. Alparone algorithm for change detection



d. KullbackLeibler divergence for change detection

Figure 10. Pleiades images before (a) and after (b) Ecuador earthquake Pleiades data
The results of change detection algorithms (c, d), in white the areas subject to major changes

## 4. The GEODIM geoportal

A geospatial portal is a human interface to a collection of online geospatial information resources, including data sets and services. The GEODIM geoportal represent the public face of the GEODIM down-stream service, created to facilitate the sharing of satellite derived hazards information in Romania.
The geoportal consist in several software modules/services, splited into two categories:

- Server-side modules/services (e.g. data processing, transformation, discovery services);
- Client side modules - responsible for interaction with the user (Graphical User Interface).

The geoportal interface was carefully designed, respecting the existing W3C (World Wide Web Consortium) standards and separating the structure from the presentation by using strict HTML5 markup and CSS (Cascade Style Sheets). New web technologies, were also used to increase the interactivity. The goal was to obtain a simple, friendly and accessible environment for emergency situation data management. From the user's perspective, when a button is clicked, an operation is performed, and a result appears on the screen. This summarizes a complex process of communication between the viewer and the server.
The system design was based on project partner's requirements and well-established national and international bodies/initiative. The following relevant European initiatives were taken into account when formulating the requirements INSPIRE, SEIS and Copernicus. A natural step after the design and implementation of the system was to define a series of test cases to verify and validate the system compliance with the initial system requirements and the technical standards (e.g. network services defined by OGC/INSPIRE Directive). The components were developed entirely with standard compliant free and open source software (the most important libraries/applications are listed in Figure 11).

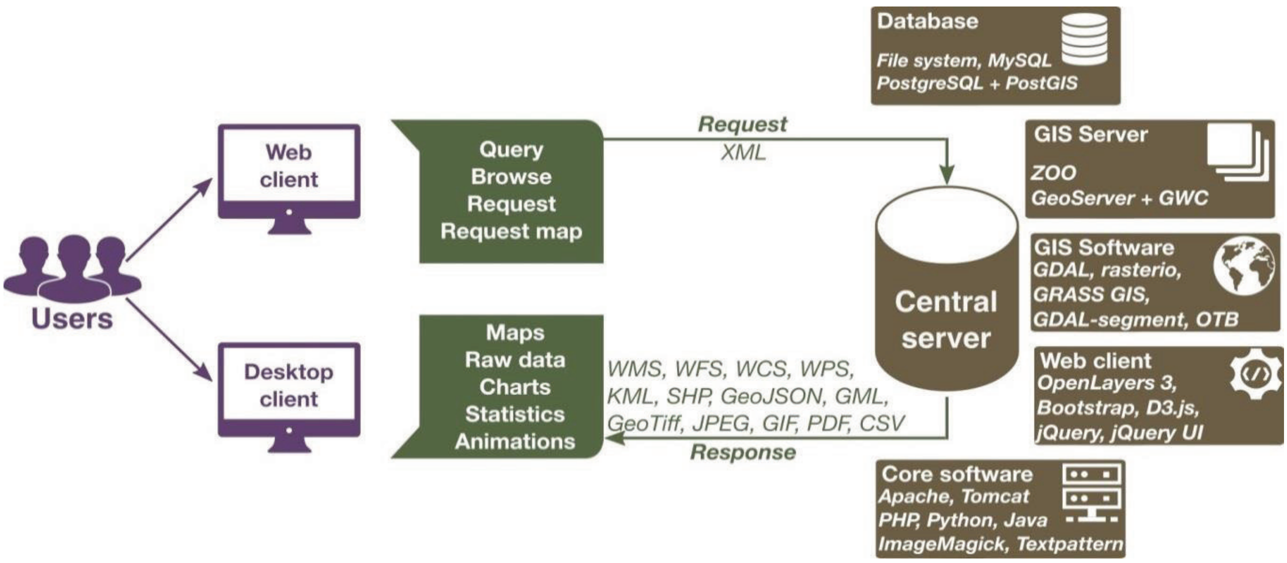



Figure 11. GEODIM geoportal architecture

*4.1 Catalogue service*
The GEODIM geoportal integrates data from several sources. When the volume and diversity of data increase, the rapid and intuitive retrieve of specific information from the system (by a user or a client application) becomes a challenge. In order to comply with this challenge a geospatial catalogue service was implemented. Catalogue services are the key technology for locating, managing and maintaining distributed geo-resources. With a catalogue service the client applications are capable of searching for geo-resources in a standardized way (i.e. through standardized interfaces and operations) and retrieve back relevant information's. GEODIM catalogue service is powered by an application called GeoNetworkOpensource (http://geonetwork-opensource.org). GeoNetwork is a standards based, catalog application to manage spatially

referenced resources through the web. It provides powerful metadata editing and search functions as well as an embedded interactive web map viewer. GeoNetwork was developed in Java and provides support for an important number of catalogue protocols (e.g. OGC-CSW 2.0.2 ISO Profile, OAI-PMH, Z39.50) and map services interfaces (e.g. WMS, WFS, WCS, KML). Also, has out-of-the-box support for a large range of metadata standards (e.g. ISO19115, ISO19119, ISO19110, ISO19139, FGDC, Dublin Core).

*4.2 Data delivery and portrayal service*

Represent one of the main services of the system and is bringing GIS functionality into the web environment. The geospatial server application helps the users to access and display the GIS datasets and to perform layer selection, different queries and spatial analysis. Geospatial server works with the web server application. The web server receives requests for maps and passes them to geospatial server to create. Geospatial server generates the requested map image/vector/grid and hands it to the web server, which transmits it back to the user (Figure 12).


Figure 12. Geospatial service generic architecture

The map server functionality within GEODIM geoportal is provided by GeoServer. GeoServer is a Java (J2EE) implementation of the OGC's Web Feature Server specification (Ramsey 2007). It is free software, available under the GPL 2.0 license. GeoServer supports efficient publishing of geospatial data to a numerous types of formats, including: WMS (Web Maping Service), WMS-C/WMTS/TMS (tiled web map services - dddd), WCS (Web Coverage Service), WFS (Web Feature Service), KML (Keyhole Markup Language), GML (Geographic Markup Language), Shapefile, GeoRSS, PDF (Portable Document Format), GeoJSON, JPEG, GIF, SVG (Scalable Vector Graphics), PNG, GeoTiff. Through gazetteer service, the geospatial server is able to retrieve the known geometries for one or more features, given their associated well-known feature identifiers (text strings), which are specified at run-time through a query (filter) request. An access control service provides a solid base for user authentication management. From the services supported by GeoServer, GEODIM makes extensive us of:

- WMS: a standard protocol for serving georeferenced map images over the Internet that are generated by a map server using data from a GIS database. The specification was developed and first published by the Open Geospatial Consortium in 1999. GEODIM end-users can access the datasets published through WMS service using the web or desktop clients;
- WFS: provides an interface allowing requests for geographical features across the web using platform-independent calls. The XML-based GML furnishes the default payload-encoding for transporting the geographic features, but other formats like shapefiles can also serve for transport.

*4.3 Web GIS client*

The users are able access the geoportal GIS client with a web browser (like Internet Explorer or Mozilla Firefox. The system compatibility was tested on Windows, Mac OS X and Linux (Ubuntu and Fedora) platforms, with the following browsers: Internet Explorer, Mozilla Firefox, Safari, Google Chrome, Opera.

The GEODIM web mapping application allows the users to analyse the reference database and the thematic products (e.g. flood extent maps) in a geospatial context. The application has a simple user interface, with several functional areas (Figure 13):

- Map. The map is the main component of this module;
- Layer list. The layers list is used to determine the way the map is composed and displayed;
- Pan-zoom control. This is a navigation tool to zoom and pan around the map;
- Map toolbar. This contains all the instruments needed for the map navigation (zoom, pan, etc.);
- Transparency slider. The slider allows changing the transparency percentage of the active layer.

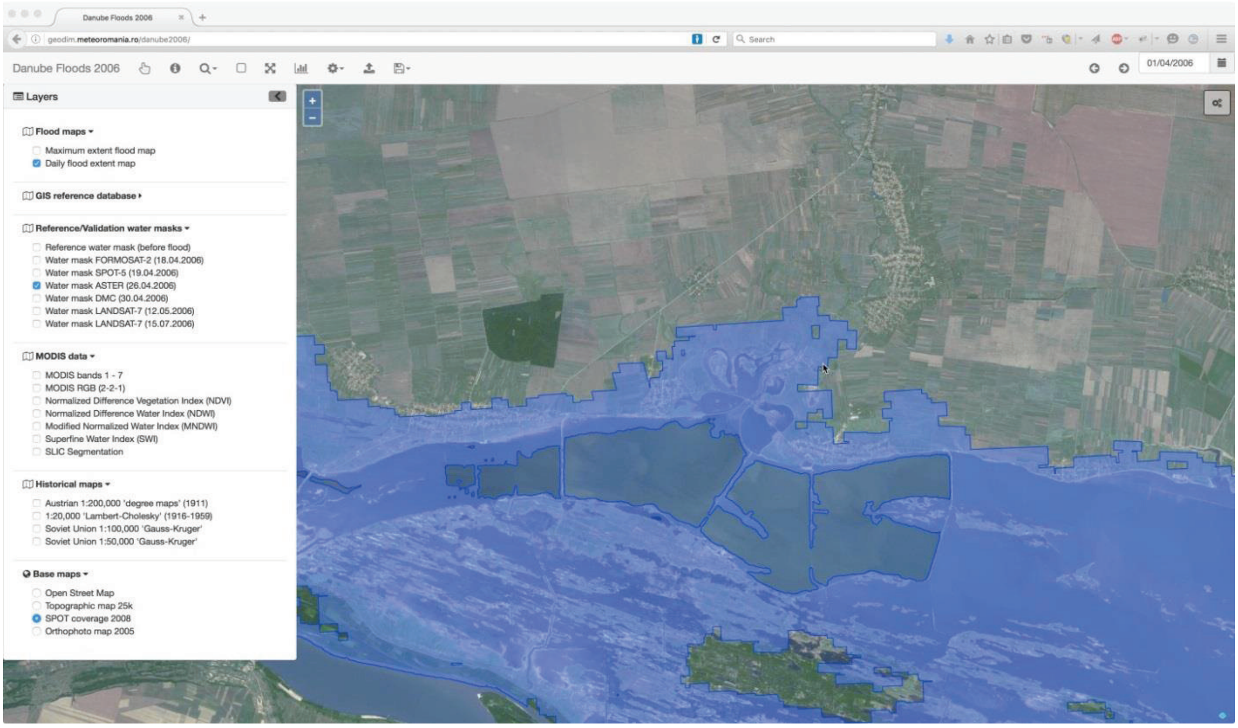



Figure 13. GEODIM Web GIS client interface

## CONCLUSIONS

Satellite observations can supply regular, detailed updates on the status of flood hazards on a regional or national basis. The new Sentinel Constellation with continuous spatial and temporal (every 6 days) coverage of the whole Earth is able to provide data available directly and free of charge. This is a great opportunity to define a robust service based on this mission.

Furthermore, the possibility of using this monitoring method can improve the capabilities of hazard surveying at a large scale, by being able to identify areas where the landslides are not observed yet or by monitoring large areas with well-known problems.

The GEODIM downstream emergency servicewas designed and developed following the principles of the Copernicus downstream services and the end-users requirements. This service will strength the collaborative approaches between the existing expert institutions/groups in the domain of geo-information applications for disaster management and will contribute to the availability of critical information for the decision-makers and other end-users in near-real time. The results can be disseminated in near-real time to the decision makers by using the service.

The service allows the storage, management and exchange of raster and vector information and also related ancillary data for flood monitoring activities. The service contributes to regional quantitative risk assessment.

The main aim of the national downstream service for emergency response is to reinforce the Romanian capacity to support disaster management based on geoinformation, covering all the phases of a disaster cycle: prevention, preparedness, response and recovery. The emphasis is put on value-added, validated products and services for each phase of the disaster management.

## ACKNOWLEDGEMENTS

This work was supported by a grant of the Romanian National Authority for Scientific Research, CNDI - UEFISCDI, project number 202/2012.

The series of TerraSAR-X High Resolution SpotLight images are courtesy of DLR and the German Commission for UNESCO. The TerraSAR-X images were received within the LAN 1988 proposal "Monitoring of Sighisoara UNESCO World Heritage Site Using Space Technologies".

## REFERENCES


Alparone L., Aiazzi B., Baronti S., Garzelli A. and Nencini F., 2007. Robust change analysis of SAR data through information-theoretic multitemporal features," 2007. IEEE International Geoscience and Remote Sensing Symposium, Barcelona, p. 3883-3886.

Crosetto M., Crippa B., Biescas E., Monserrat O., Agudo M., Fernandez P., 2005. State-of-the-art of land deformation monitoring using SAR interferometry, Photogrammetrie Fernerkundung Geoinformation, 6, p. 497-510.

Faur D., Vaduva C., Gavat I. and Datcu M., 2008. An information theory based image processing chain for change detection in Earth Observation. 15th International Conference on Systems, Signals and Image Processing, Bratislava, 2008, p. 129-132.

Faur D., Espinoza Molina D., Gavat I., Datcu M., 2013. Multitemporal Analysis of Floods and Tsunami Effects: Annotations and Quantitative Analysis. IEEE Proceedings of MultiTemp 2013 Conference, DLR.

Faur D., Datcu M., 2015. A Rapid Mapping Approach to Quantify Damages Caused by the 2003 Bam Earthquake Using High Resolution Multitemporal Optical Images. IEEE Proceedings of the 2015 8th International Workshop on the Analysis of Multi-temporal Remote Sensing Images, 22-24 July 2015, Annecy, DOI: 10.1109/Multi-Temp. 2015.7245752.

Poncos V., 2008. In SAR Processing: Processing Methodology, Analysis Procedures and Results. The Permanent Scatterers Techniques Applied to Corner Reflectors. In SAR Monitoring of Active Geohazards Sites in Canada GRIP Annual Report, Canadian Centre for Remote Sensing.

Poncos V., Teleaga D., 2010. Monitoring Water Dams Related Geomorphologic Changes and Increased Ground Instability Using SAR Interferometric Techniques. Geophysical Research Abstracts, Vol. 12, EGU 2010-12252, EGU General Assembly 2010, Vienna, Austria.

Přidal P. and Žabička P., 2008. Tiles as an approach to on-line publishing of scanned old maps, vedute and other historical documents. e-Perimetron, Vol. 3, No. 1, ISSN 1790-3769, p. 10-21.

Ramsey P., 2007. The State of Open Source GIS. Refractions Research Inc report, viewed April 2014.

Rus I., Balint C., Crăciunescu V., Constantinescu S., Ovejanu I., Bartos-Elekes Zs., 2011. Auto-mated georeference of the 1: 20,000 Romanian maps under Lambert-Cholesky (1916-1959) projection system. Acta Geodaetica et Geophysica Hungarica, p. 105-111.

Teleaga D., Radu M., Mihai S., 2012. Risk Assessment of Mine Tailing Ponds using Satellite Imagery. International Forum on Satellite EO for Geohazard Risk Management, Santorini Convention Centre, Greece.

Vaduva C., Costachioiu T., Patrascu C., Gavat I., Lazarescu V. and Datcu M., 2013. A Latent Analysis of Earth Surface Dynamic Evolution Using Change Map Time Series. In IEEE Transactions on Geoscience and Remote Sensing, Vol. 51, No. 4, p. 2105-2118.

Van der Maaten L.P.J., Postma E.O. and van den Herik H.J., 2009. Dimensionality Reduction: A Comparative Review. Tilburg University Technical Report, TiCC-TR 2009-005.

Yu J., Hay-Man A., Jung S., Ge L., Rizos C., 2008. Urban Monitoring Using Persistent Scatterers. In SAR and Photogrammetry, Proceedings of the XXI ISPRS Congress, Commission IV, Vol. XXXVII, Beijing, China.

http://docs.geoserver.org (GeoServer Documentation).

http://www.emdat.be/.

http://www.geo-airbusds.com/en/7104-earthquake-in-ecuador-the-collapsed-buildings-in-pedernales-seen-by-pleiades.

http://www.geowebcache.org/docs/current (GeoWebCache Documentation).

http://www.un-spider.org/.