[***Source***: https://www.icsm.gov.au/sites/default/files/styles/banner_background_image/public/geodesy-banner.jpg?itok=WmiM6Gfh]

GEODESY

CROP MAPPING WITH SENTINEL DATA
CASE STUDY
BEČEJ, SERBIA

**BSc. Bojan Popović[1]; BSc. Stevan Milovanov[2]
Asst. MSc. Dragana Popović[3]; Asst. Prof. Dr. Dušan Jovanović[4] Prof. Dr. Miro Govedarica[5]**

[1,2,3,4,5] Faculty of Technical Sciences, University of Novi Sad, Novi Sad, Serbia
E-mail: bojanpop94@uns.ac.rs; Tel: +381645534766; E-mail: s.milovanov@uns.ac.rs; Tel: +381637817379; E-mail: draganapop@uns.ac.rs; Tel: +381691632640; E-mail: dusanbuk@uns.ac.rs; Tel: +381214852417;
E-mail: miro@uns.ac.rs; Tel: +381214852258


Bojan Popović


Stevan Milovanov


Dragana Popović


Dušan Jovanović


Miro Govedarica

ABSTRACT

Based on the available data about crops in the municipality of Bečej, a model for crops classification was derivate and tested. The classification was based on the machine learning Random Forest algorithm applied on multitemporal Sentinel images. Every step in the procedure was conducted in open source software. Sentinel images from different periods were preprocessed and based on the available crops data, spectral characteristics for each crop type were extracted and used as reference values for modelling classifier that was then applied for crop classification. After accuracy assessment results showed that this model can produce satisfactory results even for a large number of classes.

The aim of this paper was to test and validate the applicability of Sentinel open access data and software in agriculture.

Keywords: crop classification, remote sensing, Sentinel, open access

1. INTRODUCTION

Reliable information on crops is required to improve agricultural management and reduce the environmental impact of this activity. Different methods can be used to gather this information but satellite Earth observation techniques offer a suitable approach based on the coverage and type of data that are provided. A few years ago, the European Union (EU) started an ambitious program, Copernicus, which includes the launch of a new family of Earth observation satellites known as the Sentinels. Amongst other applications, this new generation of remote sensing satellites will improve the observation, identification, mapping, assessment, and monitoring of crop dynamics at a range of spatial and temporal resolutions. The imagery data from Sentinel satellites enables a new approach for agriculture monitoring. The combination of their temporal, spatial, and spectral resolutions together with relevant analysis can lead to improvements in the decision-making process.

2. MATERIALS AND METHODS

2.1. Area of interest

In this paper Sentinel-2 multispectral images were used for the purpose of crop mapping in the area of Bečej municipality, located in the northern part of Serbia, in Vojvodina province. Agriculture is a priority sector in Vojvodina. Traditionally, it has always been a significant part of the local economy and a generator of positive results, due to the abundance of fertile agricultural land which makes up 84% of its territory. The share of agribusiness in the total industrial production is 40% that is 30% of the total exports of Vojvodina.

It should be noted that identification was only conducted for one part of the municipality, in the area where the spatial distribution of certain crop types was known. Those data were split into two equal categories: training data set for modeling the classifier and validation data set for accuracy assessment. Area for which classification was done is shown in figure 1, together with training and validation reference data.

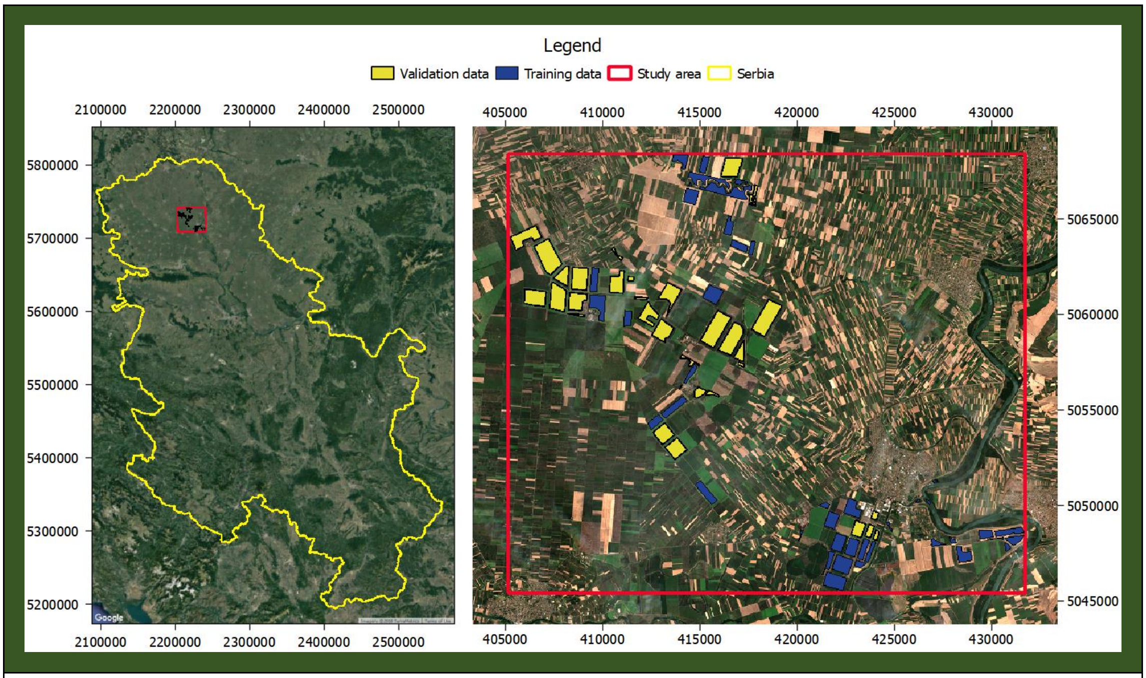


Figure 1 *Area of interest for which crops identification was conducted*

2.2. Sentinel-2 images and preprocessing

European Space Agency (ESA) is an international agency, founded in 1975., which deals with space exploration and coordinates European civil space activities. ESA is an international organization with 22 Member States. By coordinating the financial and intellectual resources of its members, it can undertake programs and activities far beyond the scope of any single European country.

Copernicus is the most ambitious Earth observation program to date. It will provide accurate, timely and easily accessible information to improve the management of the environment, understand and mitigate the effects of climate change and ensure civil security. This initiative is headed by the European Commission (EC) in partnership with the European Space Agency (ESA). Sentinel-2 mission provides multispectral high-resolution images of the Earth's surface. The mission consists of two satellites that are in the same orbit at a height of 786 km and are positioned 180° from each other. Sentinel-2A was launched on June 23, 2015, and Sentinel-2B on March 7, 2017.

Each of the Sentinel-2 mission satellites has a Multispectral Instrument (MSI) capable of recording in 13 spectral bands: 4 bands at 10 m, 6 bands at 20 m and 3 bands at 60 m spatial resolution. The Multispectral Instrument (MSI) works passively by collecting the Sun's rays that are reflected from the Earth's surface. It uses the push-broom concept by collecting rows of image data across the orbital swath and uses the forward motion of the spacecraft along the path of the orbit to provide new rows for acquisition. Temporal resolution of one Sentinel-2 satellite is 10 days, which means that the combined temporal resolution of the whole system is 5 days.

Images from these Copernicus program are open access data and users only need to register at the Copernicus Data Hub in order to download it. Hub offers different filters for the image data acquisition, amount of cloud coverage, area of interest. Beside raw images users can download preprocessed data with different level of corrections. For Sentinel-2 there are processing levels 1C (radiometric and geometric corrected data) and 2A (scene classification and an atmospheric correction applied to Top-Of-Atmosphere (TOA) Level-1C orthoimage product).

For the area of interest shown on the figure 1, five Sentinel-2 level 2A images were downloaded. (Table 1)

Table 1 *Images used for crop identification*

Image name	Acquisition date
S2A_MSIL2A_20170604T094031_N0205_R036_T34TDR_20170604T094032.SAFE	2017-06-04
S2A_MSIL2A_20170624T094031_N0205_R036_T34TDR_20170624T094315.SAFE	2017-06-24
S2A_MSIL2A_20170704T094031_N0205_R036_T34TDR_20170704T094030.SAFE	2017-07-04
S2A_MSIL2A_20170714T094031_N0205_R036_T34TDR_20170714T094230.SAFE	2017-07-14
S2A_MSIL2A_20170803T094031_N0205_R036_T34TDR_20170803T094046.SAFE	2017-08-03

Since the Sentinel-2 images have different pixel sizes depending on the spectral band, it is necessary to resample the product and equalize the different spatial resolutions. This step is generally required for any further processing. All images were first resampled so that each band has the same pixel size of 10 meters. Resampled bands were then clipped on the size of the study area. These two steps were conducted in SNAP (Sentinel Application Platform), software developed by ESA.

2.3. Random Forest classification

The Random Forest algorithm is a machine learning technique that can be used for classification or regression. In opposition to parametric classifiers (e.g. Maximum Likelihood), a machine learning approach does not start with a data model but instead learns the relationship between the training and the response dataset. The Random Forest classifier is an aggregated model, which means it uses the output from different models (trees) to calculate the response variable. (Breiman, 2001).

Decision trees are predictive models that recursively split a dataset into regions by using a set of binary rules to calculate a target value for classification or regression purposes. Given a training set with n number of samples and m number of variables, a random subset of samples n is selected with replacement (bagging approach) and used to construct a tree. At each node of the tree, a random selection of variables m is used and, out of these variables, only the one providing the best split is used to create two sub-nodes. By combining trees, the forest is created. Each pixel of a satellite image is classified by all the trees of the forest, producing as many classifications as number of trees. Each tree votes for a class membership and then, the class with the maximum number of votes is selected as the final class. (Biau and Scornet, 2015). Random Forest supervised classification was conducted in Orfeo Toolbox (OTB). OTB is an open-source project for state-of-the-art remote sensing, including a fast image viewer, applications callable from command-line, Python or QGIS, and a powerful C++ API. Thanks to its modular architecture, OTB allows fast prototyping and covers the full spectrum of algorithms for remote sensing image processing from preprocessing to advanced feature extractions methods allowing one to go from raw data to value added products. (Grizonnet and others, 2017)

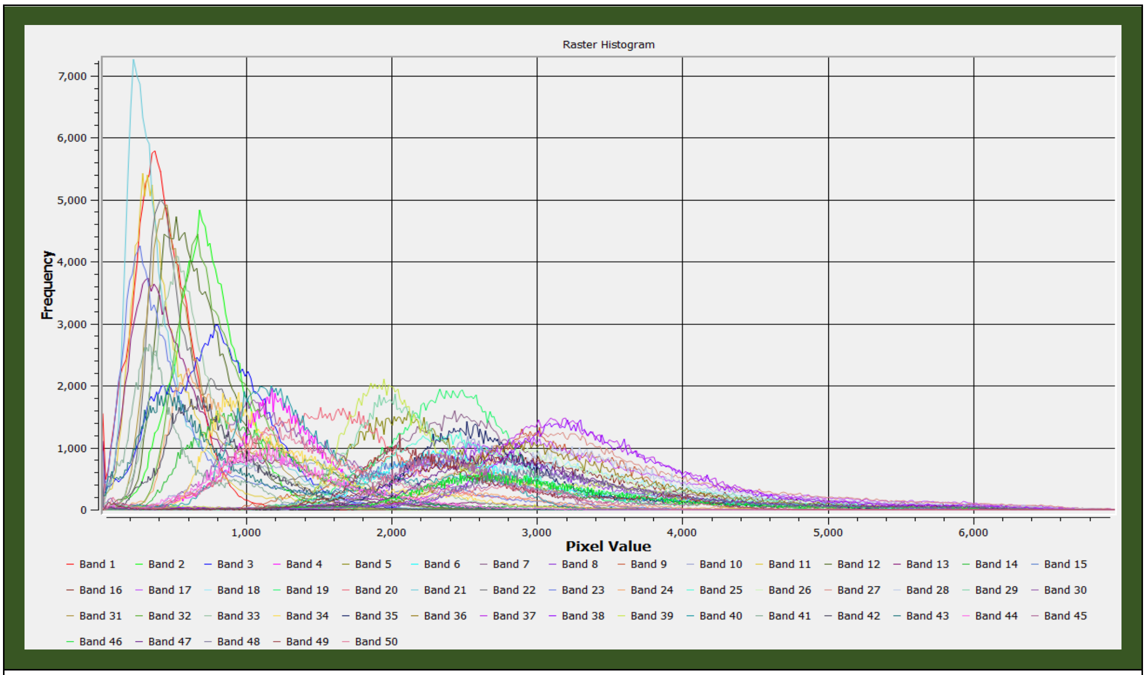


Figure 2 *Histogram of the raster with 50 spectral bands*

Because this identification is based on multi-temporal satellite image classification, two different approaches were conducted. First, all spectral bands from all five images were merged into one raster with 50 spectral bands (bands

B1, B9 and B10 were not used). This was done in QGIS with Stack raster bands from Semi-Automatic classification plugin. Histogram for the resulting raster is shown in figure 2.

Obtained raster was then classified in OTB. The first step for any supervised classification in OTB is to generate a classification model in Train Images Classifier tool. Input data for this tool are raster that's been classified and training data set. Based on the selected algorithm different parameters can be adjusted. In this case, Random Forest was selected and all parameters were left on default values except the Maximum number of trees in the forest which was set to 500. After the model was generated, classification was conducted in Image Classifier tool. This tool classifies the input raster based on the model that was created in the previous step.

The second approach was to merge bands from each image into separate raster, and get five rasters with 10 spectral bands. For each of those raster, a classification model was created and those images were then classified based on those models. Because in this case there are five classified images, they were merged into one file with Fusion of Classification tool in OTB. This tool combines classified raster of the same scene from different periods and creates one classification output that is more accurate than input files.

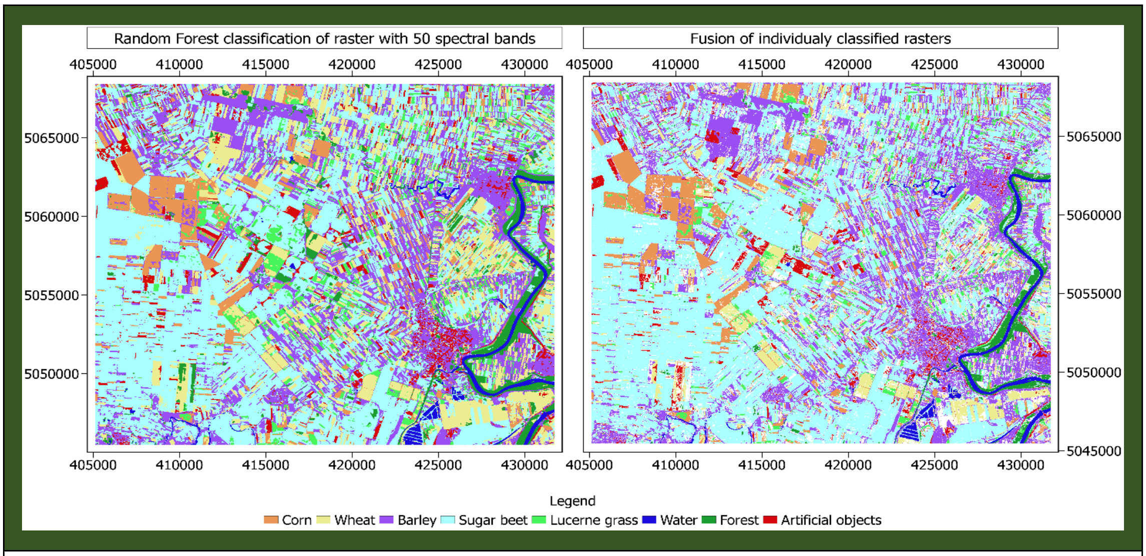


Figure 3 *Results of the both approaches*

After the classification, it often happens that inside certain class few pixels "stray" from a different class. This is known as the "salt-and-pepper" effect and usually occurs at the boundary between two classes that have similar spectral characteristics. This effect is more noticeable on the images with high spatial resolution. In order to eliminate this, classification results were filtered with Classification Map Regulation tool. This tool filters the input labeled image using Majority Voting in a ball-shaped neighborhood. Majority Voting takes the more representative value of all the pixels identified by the circle shaped structuring element and then sets the center pixel to this majority label value. Results from both approaches are shown in figure 3.

3. RESULTS

Accuracy assessment is a necessary step for each type of image classification in remote sensing. It determines the quality of the map obtained by remote detected data. The thematic map obtained from the classification can be considered accurate if it provides an impartial representation of the region that displays. Error matrixes and overall classification accuracy for both approaches are shown in table 2 and table 3.

Table 2 *Error matrix for the fusion of classified rasters*

Class	Corn	Wheat	Barley	Sugar beet	Lucerne grass	Total
Corn	36333	13647	6087	7	1840	**57914**
Wheat	0	14030	462	15	0	**14507**
Barley	212	30	23	3671	3459	**7395**
Sugar beet	0	1841	407	67036	707	**69991**
Lucerne grass	961	2183	3167	24	311	**6646**
Total	**37506**	**31731**	**10146**	**70753**	**6317**	**156453**
Overall accuracy [%] = 74.82332155						

Table 3 *Error matrix for classified raster with 50 bands*

Class	Corn	Wheat	Barley	Sugar beet	Lucerne grass	Total
Corn	38470	12175	5821	220	4572	**61258**
Wheat	304	17065	1274	139	95	**18877**
Barley	703	32	302	6494	2635	**10166**
Sugar beet	0	1909	253	53237	298	**55697**
Lucerne grass	401	5561	2780	9843	133	**18718**
Total	**39878**	**36742**	**10430**	**69933**	**7733**	**164716**
Overall accuracy [%] = 63.9823532513						

From the tables above, it is obvious that fusion of classified rasters yielded better accuracy over classified raster with 50 bands. Both approaches used the same reference data for training and validation, the same algorithm was used for the classification and yet results are not the same. Reason for that is that identified crops are not the only crop types represented in the study area.

The first approach, used raster with 50 bands and all pixel were classified into one of five types, from which some didn't belong to any of them. In the second approach, five classified rasters were fused together into one with Majority Voting algorithm. For each pixel, the class with the highest number of votes is selected and in case of an equal number of votes, the pixel is declared as undecided and his value set to 0. Because of that some of the pixels are white, which can be seen in figure 3. In this way, certain pixels that may belong to some other crop type are eliminated.

4. CONCLUSION

In this paper was presented and tested the applicability of multitemporal Sentinel-2 satellite images for the purpose of crop types identification in the municipality of Bečej, Serbia. Random Forest algorithm was used as a method for the classification of these images.

Two different approaches were used to combine multitemporal images, in one all bands were merged into one file which was then classified and other in which they were first classified and then fused into resulting raster. These two methods yielded an accuracy of 63% and 75% respectively. This has shown that besides choosing the right algorithm, it is very important to determine the appropriate data organization and combination, especially for multitemporal images. Nevertheless, the high usability of Sentinel-2 images together with Random Forest algorithm for this type of application has been proven and that was the goal of this paper.

5. LITERATURE

[1]. **Biau, G. and Scornet, E**. *(2015). A Random Forest Guided Tour. [online] Arxiv.org. Available at: https://arxiv.org/abs/1511.05741 [Accessed 10 Sep. 2018].*

[2]. **Breiman, L**. *(2001). Random Forests. Machine Learning, 45(1), pp.5-32.*

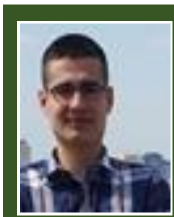
[3]. **Clevers, J. and Gitelson, A.** *(2013). Remote estimation of crop and grass chlorophyll and nitrogen content using red-edge bands on Sentinel-2 and -3. International Journal of Applied Earth Observation and Geoinformation, 23, pp.344-351.*

[4]. **Grizonnet, M., Michel, J., Poughon, V., Inglada, J., Savinaud, M. and Cresson, R**. *(2017). Orfeo Toolbox: open source processing of remote sensing images. Open Geospatial Data, Software and Standards, 2(1).*

[5]. **Laine, J**. *(2018). Crop identification with Sentinel-2 satellite imagery in Finland. [online] Aaltodoc.aalto.fi. Available at: https://aaltodoc.aalto.fi/handle/123456789/33726 [Accessed 10 Sep. 2018].*

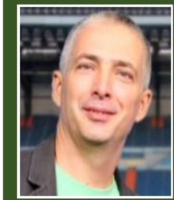
AUTHORS BIO

BSc. Bojan Popović graduated from the Faculty of Technical Sciences in 2017 and currently attends postgraduate studies at the same faculty. From 2017 actively participates in the teaching process at the Faculty of Technical Sciences as a Teaching Associate. Areas of interest include Geoinformation technologies and systems, remote sensing, technologies for the collection and processing of spatial data, laser scanning and GIS.



BSc. Stevan Milovanov graduated from the Faculty of Technical Sciences in 2017 and currently attends postgraduate studies at the same faculty. From 2017 actively participates in the teaching process at the Faculty of Technical Sciences as a Teaching Associate. Areas of interest include geoinformation technologies and systems, geospatial databases, remote sensing, laser scanning, Smart City and GIS.

Asst. MSc. Dragana Popovic is a PhD Candidate at Faculty of Technical Sciences. She also works at the Faculty of Technical Sciences as Teaching Assistant in the field of Geoinformatics. She obtained her Master Degree in Geodetic Science in September of 2015. Topics of Master Thesis were Geospatial databases. Her research areas are 3D models, 3D Cadaster, Smart City and GIS



Asst. Prof. Dr. Dušan Jovanović Born in Novi Sad, Serbia 1976. He successfully defended master thesis titled "System for generating topographic symbols in SVG format" in 2003. He successfully defended his magister thesis titled "Comparison of object-oriented classifications and standard techniques of image analysis in the forest detection" in 2010. The doctoral thesis entitled "Model Object-Oriented Classifications in Geospatial Objects Identification" was successfully defended in 2015. From the 2004 he is engaged in projects and teaching process at the Faculty of Technical Sciences. Areas of interest include Geoinformation technologies and systems, technologies for the collection and processing of spatial data, remote sensing, application of Geoinformation technologies and systems in various fields such as water management, agriculture, forestry.

Prof. Dr. Miro Govedarica graduated from the Faculty of Civil Engineering in Sarajevo in 1987, finished Master degree at the Faculty of Technical Sciences in Novi Sad in 1998. He received his PhD at the Faculty of Technical Sciences, University of Novi Sad, in 2001. Has been permanently employed at the Faculty of Technical Sciences in Novi Sad since February 1994. Areas of interest include object-oriented software engineering, databases, geospatial databases, database management systems, and development of service-oriented information and geoinformation systems, photogrammetry, laser scanning, remote detection, global navigation satellite systems, geoservices and geospatial data infrastructure.

AN OVERVIEW ON THE DEVELOPMENT OF GEODETIC REFERENCE SYSTEMS IN ALBANIA



Gëzim Gjata　Bilbil Nurce　Ethem Bejko

Prof.as. Gëzim Gjata[1]
Dr. Bilbil Nurce[2]**;**
Eng. Ethem Bejko[3]

Department of Geodesy, Civil Engineering Faculty,
Polytechnic University of Tirana, Albania
E-mail: g.gjata2@gmail.com
Tel: 0682069259; E-mail: billnurce@gmail.com
E-mail: bejko_ethem@hotmail.com

ABSTRACT

Evidence and analysis on the construction of geodetic coordinating reference networks and systems in Albania, which started from the foreign geodetic institutions in 1860 till in our days, are an important knowledge and information not only for the community of specialists and engineers who work with geospatial data but also as an value evidence in the framework of economic and scientific developments in Albania.

This article describes and provides detailed information on all geodetic reference coordinate systems built in Albania to support topographic mapping in national level initially for small scale topographic charts up to the top scales of topographic plans in the framework of development in geologic studies, cadastral activities, in urban planning of cities, in the support and realization of high geometrical quality of engineering works such as roads, hydropower plants, etc. Currently in the framework of rapid technological developments in the field of geodesy, specifically of modern geodetic positioning equipment and the need for the establishing the National Spatial Data Infrastructure (NSDI) under the European Directive INSPIRE 2007, the recent construction of the ALBPOS is an basic element of this infrastructure.

These modern systems provide high quality geospatial data to support all geodetic activities as registration and cadastre of property, design and implementation of roads and highways, urban planning and support for studies related to shelf and coastline.

Keywords: Coordinate refereeing systems, geo-information, geospatial data, satellite positioning and rephrasing, GNSS.

1. INTRODUCTION

This article tends to make evident the unique importance of the geodetic reference coordinative systems by achieving that through the knowledge on building and developing consistently them in more than 150 years [1] [2], their basic role in supporting the topographic mapping of Albania in various large scale and all engineering works as well for building of SDI based in the principle of EC directive of Inspire.

In this article are given all the coordinative systems built in Albania from the year 1860 till now, as well as the data and information for all the geodetic systems in Albania, main parameters of them which relatively serve as the datum to support all technical and mapping activities. Article gives the possibilities to understand the developing of such systems from decade to decade, using and need of building of the geoid as vertical geodetic reference which should be seen in unity with horizontal datum.

Actually building of National Spatial Data Infrastructure has as the main and basic layer or theme just the coordinative systems, their transformations from one to another reference to support the principle of "capture spatial data only once" [13] in the function of building and completion of themes in the structure of NSDI, it doesn't matter where and when those data are produced. Understanding of the reality and the development of such systems enable the building of NSDI, supporting the process of cadastral works, the ownership process as well as the realisation of engineering and urban works with high quality and efficiency.

2. Developing the reference coordinative systems, data and information during 1860 -1994

Concerning of the request of foreigners (European regional institutions) in the territory of Albania, it should be underlined since the second half of the XIX century were constructed several coordinate reference systems, mainly to support the territory mapping at different scales.

The stages of these activities briefly are as follow: During **1860 ÷ 1873** period, MGIV (Military Geographical Institute of Vienna), Austria carried out the geodetic basis for mapping, mainly in the north part at 1:75 000 scale and during 1913 ÷ 1918 for mapping at 1:50 000 in area between Korça and Vlora with density 1-point/40 km^2 (Figure 1).

The geodetic datum can be formulated as follow:

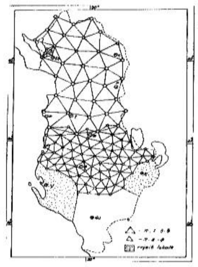
Ellipsoid North ellipsoidal reference origin East ellipsoidal reference origin The projection False Northing origin (FN) False Easting origin (FE)	Bessel 1841 $\varphi = 0°$ $\lambda_{Ferro} = 17° 30' 46.5"$ Gauss- Krüger 0.0	

Figure 1 *The Albanian triangulation network by MGIV*

During **1927 ÷ 1934** MGIF (Military Geographical Institute of Florence), Italy carried out the geodetic basis in four orders (Figure 2) for mapping at 1:50 000. The ellipsoid was oriented at the astronomical point of Lapraka, Tirana [3]. **The geodetic datum** can be formulated as follow:

Ellipsoid	Bessel 1841
The North ellipsoidal reference origin	φ = 0°
The East ellipsoidal reference origin	$λ_0$ = 20°
The projection	Gauss- Boaga
False Northing origin (FN)	0.000 m
False Easting origin (FE)	

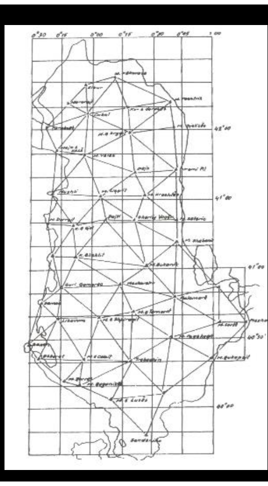


Figure 2
The 1st MGIF triangulation

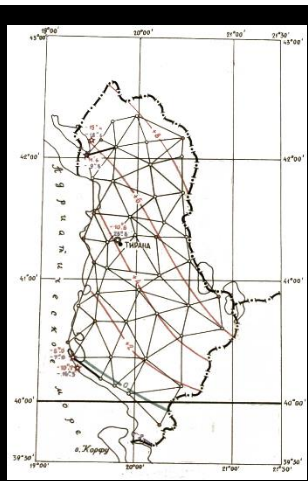


Figure 3
The 1st network and geoid-ellipsoid heights

In **1955**, in order to fulfill the request for territory mapping at 1:25 000 scale, the horizontal coordinative base (Figure 3) were transformed from Moscow's CNIGA-IK Institute into Krassowsky ellipsoid with central meridian (CM) $λ_0$ = 21˚.

During **1970 ÷ 1987** period, MTIA (Military Topographical Institute of Albania) designed, constructed and conducted the new state coordinative network (Figure 4), which includes two main parts: *the horizontal coordinative base* and *the state levelling network.*

The "origin" is 8814-Kamza's hill, Tirana, where were performed astronomical observations (latitude, longitude and astronomical azimuth) with relevant accuracy: $m_φ$= ±0.22", $m_λ$= ±0.285", $m_α$= ±0.19". There are 7-initial sides at the ends of 7- rhombus systems of network, with relevant accuracy: $m_φ$=±(0.11"÷0.24"), $m_λ$= ±(0.19"÷0.21"), $m_α$=±(0.15"÷0.34"). There are not performed gravimetric measurements. The absolute elevations (by leveling) are used to reduce initial sides on the Mean Sea Level, but not to the ellipsoid. It was possible and has performed the reduction of initial sides on *Gauss-Krüger* projection. The new state geodetic network it is not oriented by astronomical azimuth although it was observed. The starting point has assumed the coordinates of the old existing network (1955), which that is essentially the same, built in the period 1927÷1934 from IGJUF.

3. GNSS CAMPAIGNS IN ALBANIA

For different purposes, as well as to establish a satellite reference system were performed several GPS campaigns in Albania, were carry out. The first campaign during 6 ÷ 21 **October 1994** period between ex-MTIA in collaboration with DMAAC (Defense Mapping Agency Aerospace Center), USA [5]. The aim was transformation of the state geodetic network into global WGS84. There were measured in total 35-points, 24-points selected from triangulation and 11-points from state levelling network (Figure 5). There are 5-absolute determinations with standard deviation ±1m per station and the relative determinations with standard deviation until 10cm for (N,E,h). The transformation parameters were [6]: T_X = + 24m ± 4m, T_Y = - 130m ± 4m, T_Z = - 92m ± 4m.

The geodetic datum can be formulated as follow:

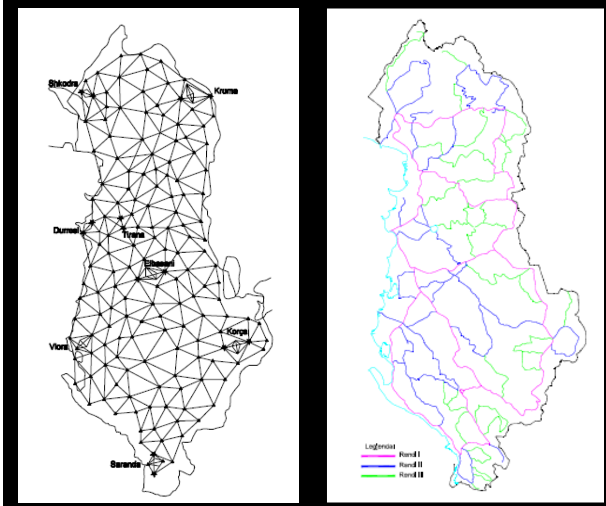


Figure 4
The 1st MTIA triangulation network (left) and the leveling network (right), 1970 ÷ 1987

Ellipsoid	Krassowsky 1945
The North ellipsoidal reference origin	φ_0 = 0°
The East ellipsoidal reference origin	λ_0 = 21°
The projection	Gauss-Krüger (TM), 6° zone
False Northing origin (FN)	0.000 m
False Easting origin (FE)	4 500 000 m
The deformation in Central Meridian	$s_0 = 1$

In the framework of an agreement with World Bank, a project to the Albanian Cadaster, PMU (Project Management Unit) in collaboration with Wisconsin University, USA performed GPS campaign at **February 1998** [7]. The main goal was connection of the State Geodetic Network to ITRF. The observations were performed at 3-stations, 8814 (Kamza's hill), 6339 (Shkoder) and 12602 (Korça) for more than 14-hours per each day. The standard deviation for the calculated coordinates (X,Y,Z) and (φ,λ,h) on WGS84, **ITRF96, Epoch1998** were 1÷2 cm, while for re-calculated DMA points until 10 cm.

In the framework of "CRODYN" project under the account of EUREF98, was performed a GPS campaign during 4 ÷ 9 September 1998, in collaboration with BKG (Bundesamt für Kartographie und Geodäsie), Germany [8]. The goal was to realize the connection of Albanian State Geodetic Network (ALB86) to European Reference System (ETRS89). The observations at 5-sections 24-hours were performed at 9- stations, 5-triangulation and 4-geodynamic stations (Figure 5). The standard deviations of coordinates at *ITRF96, Epoka1998.7* were: ± 2 *mm* for (*N, E*) and ± 6.5 *mm* for (*h*).

Military Geographical Institute of Florence, Italy in collaboration with Military Geographical Institute of Albania performed a GPS campaign during ***autumn 2007 ÷ spring 2008*** [9]**.** The main goal was finding a best possible mathematical relationship between the European Reference ETRF2000, Epoch 2008.0 and Albanian Reference (ALB86). For this purpose, the geodetic network has been organized in two different levels, dynamic (RDN) and static (RSN) network (Figure 6). The projected RDN consisted from 14-permanent stations on average distance 100 km, including *6*-existing stations of ex-seismological service and 8-new stations. For the realization of dynamic network, the observations were performed for more than 15-days with at least 5-hours per observation. While RSN consisted from 150 points selected from triangulation and state levelling network, on average distance between points 35 ÷ 40 km. GNSS surveys for each area have extended about 20-days with 2 ÷ 3 hours per observation.

The final coordinates of 129-points (90-triangulation and 39-levelling points) in *ITRF2005, Epoch 2008.0* were transformed into *ETRF2000, Epoch 2008.0*. The geoid-ellipsoid heights of EGM-2008 model were downloaded from the internet by a grid 2' 30" *x* 2' 30" and adapted locally using the 7-parameters from Helmert transformation of 125-points (Table 1). The calculation errors of geoid heights from ellipsoid heights with *ALBGEO-3* software by *MGIF* are: 20 cm (the confidence level 68%), 40 cm (the confidence level 95%).

Table 1 *7-parameters from Helmert transformation*

a = 6378137; f = 0.003352811	
The target Ellipsoid	**Krassovsky 1940**
a = 6378245; f = 0.00335233	
Tx (m)	44.183
Ty (m)	0.58
Tz (m)	38.489
Rx	2.3867''
Ry	2.7072''
Rz	-3.5196''
S(ppm)	8.2703

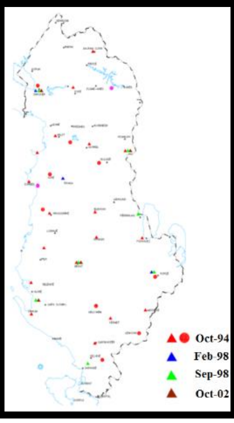


Figure 5
GPS campaign, Oct 1994 ÷ 2002

Figure 6
The Albanian RDN and RSN network

4. NETWORK OF PERMANENT REFERENCE STATIONS OF ALBANIA-ALBPOS (2009 ÷ 2014)

The Albanian network of permanent reference stations (ALBPOS) was established in 2009 under the responsibility of a consortium (Albanian Military Geographical Institute, Immovable Property Registration Office, Polytechnic University of Tirana and ex-Seismology Institute) and fully operational in 2010. It comprises of 16 permanent GNSS stations and the Control Centre (Figure 7) to provide real time corrections for the users in the field. ALBPOS primarily supports the land and property registration work of IPRO (Immovable Property Registration Office), for surveying new data (particularly property boundaries), ALUIZNI (Agency for Legalization, Urbanization and Integration of Informal Areas and Buildings) and AKKP (Agency for Restitution and Compensation). The RINEX observation data (3÷5 December 2009) at an interval of 30 sec had been processed. In order to derive coordinates in ETRF2000, Epoch 1989.0, the data of three EPN/ IGS stations had been used in the processing (MATE (Matera), DUBR (Dubrovnik) and SOFI (Sofia). The final coordinates in ITRF2005, Epoch 2009.926 are transformed into ETRF2000, Epoch 1989.0. During February 2010, it was performed a new processing of RINEX data with the Bernese GNSS

Software version 5.0. The final coordinates in IGS05, Epoch 2009.926 were transformed into ETRF2000, Epoch 2008.0 and ETRF2000, Epoch 1989.0. To check the usability of ALBPOS in the field, were performed the field tests (GNSS campaign ALB-2007/8) in the RTK (Real Time Kinematic) mode (17 ÷ 18 February 2010) [11]. The differences between the campaign values and the field tests were 2 ÷ 3 cm latitude/longitude, 3 ÷ 5 cm height. After being shut down for more than a year, ALBPOS restarted during 2013 under new management, the civil Immovable Property Registration Office (Figure 8).

Figure 7 *ALBPOS-2009 stations*

Figure 8 *ALBPOS-2014 stations*

The data of 15 ALBPOS stations observed in seven 24-hour sessions during March 3÷9, 2014 had been processed with the Bernese GNSS Software version 5.2. The final coordinates in ITRF2008 (IGb2008), Epoch 2014.177 *were transformed into* ETRS89 (ETRF2000), Epoch 2014.177 *and compared to early realization (*ETRF2000, Epoch 2008.0*).*

5. GEWEI'S GNSS CONTINUOUS OPERATION REFERENCE STATIONS

Currently, another the continuous permanent GNSS network is administrated by the Geosciences, Energy, Water and Environment Institute of Tirana (GEWEI). It comprises 8-stations (Figure 9, left), with specific purpose to monitor the tectonic deformations [12]. These stations are equipped with dual-frequency GPS receivers, where antennas are mounted on concrete pillars, as well as founded on the bedrock (Figure 10, center/right). Their remote control and data transfer is made via radio-links or mobile *3G*. Sampling binary file 30-*sec* extracted and archived in compact Rinex format, the data are stored in website (*ftp*: geo.edu.al), which are freely available. These stations have been suggested to monitoring the Albanian Permanent Reference Stations.

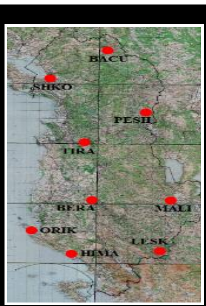


Figure 9 *The GEWEI's GNSS CORS*

Figure 10 *Shkodra pillar (center) and Himara (right)*

6. GEOID

The lack of a precise gravimetrical geoid deprives us currently to use the satellite heights, the determination of which is rapid and quite low cost compared to other traditional methods. So, as soon as possible Albania should realize the precise gravimetric geoid.

As the first step of the project, during Sept. 21st to Oct. 14th 2015 were performed absolute gravimetrical measurements in Shkodra, Tirana and Saranda. Gravimetric network of 1^{-st} order consists of 30 points, with dense *1 point/ 1 000 km*^{2}, 2^{-nd} order consists of 140 points, with dense *1 point/ 200 km*^{2} and 3^{-st} order consists of 14 000 points, with dense *1 point/ 2 km*^{2}, designed to be free materialized on the ground. The gravimetric reference system will be realized by *reference gravimetric frame*, which is seen to be materialized by 5 ÷ 10 points, with dense *1 point/ 4 000 km*^{2}), as well as the Earth gravity values at a given time epoch. The positions of points will be determined by GNSS technology. In lowland areas or hilly (where possible), the differences of point heights will be determined via geometric levelling, while in the mountainous terrain via trigonometric levelling.

7. TRANSFORMATION BETWEEN THE GEODETIC REFERENCE SYSTEMS

In the context of building of NSDI in Albania, the coordinative geodetic systems are the first and basic layers of themes to support the transformation of geospatial data between different geodetic systems as well the connection to the various systems of European countries as Inspire Directive suggest [14]. For that in the geoportal of NSDI is foreseen to put the parameters of all the geodetic systems built in Albania as well the main geodetic coordinative systems in Europe. In order to realize that is foreseen to use as main tool the transformation of such systems. In this case the transformations from one to another geodetic system will be realized by using the well known the transformation routine as Molodensky-Badeka, Burša-Wolf, Helmert, E. Grafarend-R. Syffus, etc.

8. CONCLUSIONS

- Building and consistency of geodetic reference systems in Albania is a good index which show the efforts for application of geodesy for mapping and supporting cadastral and engineering works.
- Those geodetic systems have been basic factor for the realizing of main enlarge engineering works in Albania with high quality and efficiency.
- Building of ALBPOS and the new geodetic reference frame is seen as important key for building of NSDI in Albania.
- Increasing of knowledge and practices on context of geodetic transformations systems still remain a task which should be under the attention of University and other institutions responsible for NSDI data.

REFERENCES

[1]. **Dragovoja M., Shehu A**. *(1984) Shqipëria në hartat e para-çlirimit*
[2]. **Shehu A**. *(1995) Buletini i Informacionit dhe Mjedisit*
[3]. **Marussi A**. *Sul colegamento fra le rete geodetico Albanese e Greca. L'UNIVERSO (Nr 4/1943), Milano, Itali*
[4]. **Isufi E**. *(1993) The First-Order Triangulation Network of Albania, p. 326-340*

[5]. **GPS Geodetic** *Control Network Survey in Albania (1994) Publication GGB-94-038, p. 1-8*

[6]. **Skuka Q, Kuka N** *(1997) The conversion from Albanian Coordinate System to WGS84 and vice versa, Revista Gjeodezike 4/2003.*

[7]. **Measurement Science**, *Inc.&The University of Florida (1998) Establishment of a Geodetic Infrastructure and Property Surveying and Mapping Methodology for Albania, April p.1-15*

[8]. **IAG, EUREF** *Publication No. 8, ISSN 0340-7691, ISBN 3769696220, p.106-113*

[9]. **Renzo Maseroli**, *Janar 2010: Relazione sui lavori geodetici eseguiti sul territorio albanese per la realizzazione della rete geodetica satellitare*

[10]. ***Stangl, G****, 2010; ALBPOS ETRF2000 Coordinates Technical Report- Federal Office of Metrology and Surveying, Graz, Austria*

[11]. **Valsson G**, *2014, April 22, 2014; Landmælingar Islands E-mail correspondence*

[12]. **Kuka N, 2015**; *GNSS Continuous operation reference stations of Albania*

[13]. **INSPIRE** – *EC Directive 2007/2/EC.*

AUTHORS BIO

Gëzim Gjata: Studied Geodesy at Faculty of Civil Engineering (FCE), Tirana and graduated as “Engineer in Geodesy” in 1981. In 1992, one year, he carried out the Post graduate studies in ITC/Netherlands. He doctorate his PhD Thesis at doctorate his PhD thesis in department of Geodesy, Faculty of Civil Engineering, PUT, Tirana at 1997. In 2012 he appointed as Professor Associated. He is elected and later appointed as the Head of Department of Geodesy. He is active lecturer at FCE, teaching General Cartography, Digital cartography as well as Satellite Images (Remote Sensing). He is author of some published scientific papers and various presentation in geodesy, Geoinformation, etc. He has participated in various international and local scientific conferences and workshops where he has presented his work. Also he have been Local Coordinator and collaborator in two EU projects.

Bilbil Nurçe; studied Geodesy at Faculty of Civil Engineering (FIN), Tirana and graduated as “Engineer in Geodesy” in 1992. He finished his PhD Thesis at Department of Geodesy, Faculty of Civil Engineering in Tirana. Mr. Nurçe is an active lecturer at FCE, teaching Satellite geodesy, reference coordinative systems and High Accuracy Leveling. He is author of some published scientific papers in geodesy and he has participated in various international and local scientific conferences and workshops where he has presented his work. Actually he is local coordinator of two Erasmus plus.

Ethem Bejko; Studied Geodesy at Faculty of Civil Engineering (FIN), Tirana and graduated as “Engineer in Geodesy” in 1994. He is in the process of his PhD Thesis at “Geosciences, Natural Resources and Environment School of Doctorate”, Faculty of Geology and Mining, Tirana. Dr. Karriqi is an active lecturer at FGM, teaching General geodesy as well as Topography and State networks. He is author of some published scientific papers on in geodesy and he has participated in various international and local scientific conferences and workshops where he has presented his work. He has more than 5 years of successful experience monitoring and studies of crustial and albanian coastal movements.

EDUCATION IN GEODESY AT THE UNIVERSITY OF PRISTINA AND THE BOLOGNA PROCESS

Cand.Dr.Sc. Fitore Bajrami Lubishtani[1]
Cand.Dr.Sc. Milot Lubishtani[2]

[1]Department of Geodesy, Faculty of Civil Engineering and Architecture. University of Prishtina"Hasan Prishtina" St. "Bregu i Diellit", n.n., 10 000 Prishtinë, Republic of Kosovo.
E-mail: fitore.bajrami@uni-pr.edu; Tel: 0038344710371
[2]Department of Geodesy, Faculty of Civil Engineering, Polytechnic University of Tirana, St."Muhamet Gjollesha", 54, Tirana, Albania.
E-mail: milot.lubishtani1@hotmail.com; Tel: 0038344720210

ABSTRACT

University of Prishtina with 17 faculties is the most important educational, scientific and cultural institution in Kosova of which 14 are academic faculties, and 3 are faculty of applied sciences, with 45 years' experience in higher education system.Kosovo started to apply the Bologna process since 2001/2002, in cooperation with the Ministry of Education, Science and Technology.

Beginning of surveying education in Kosovo on year 2003 is the opening of surveying department within the faculty of civil engineering and architecture, as a three-year Bachelor studies. In the shorter periods, the Faculty of Geodesy has made more significant changes of the curricula. Through the Tempus project, for the first time in the akademic year 2015/2016 its opened the Master deggre of Geodesy in Kosovo in the framework of the faculty of civil engineering and architecture, as a two-year Master studies.

Key words: Geodesy, students, education, Bologna Process, curricula, MPG, Prishtina.

1. INTRODUCTION

University of Prishtina with 17 faculties is the most important educational, scientific and cultural institution in Kosova of which 14 are academic faculties, and 3 are faculty of applied sciences, with 45 years' experience in higher education system.Kosovo started to apply the Bologna process since 2001/2002, in cooperation with the Ministry of Education, Science and Technology. Beginning of surveying education in Kosovo on year 2003 is the opening of surveying department within the faculty of civil engineering and architecture, as a three-year Bachelor studies. In the shorter periods, the Faculty of Geodesy has made more significant changes of the curricula. Through the Tempus project, for the first time in the akademic year 2015/2016 its opened the Master deggre of

Geodesy in Kosovo in the framework of the faculty of civil engineering and architecture, as a two-year Master studies.

2. UNIVERSITY OF PRISHTINA

The University of Prishtina is the most important educational, scientific and cultural institution in Kosova. The University of Prishtina was founded by the SAP Kosova Assembly, which approved the Law on the Foundation of the University of Prishtina on 18 November 1969, with faculties of philosophy, of law and economics, of engineering and the medical faculty. The Foundation Assembly of the University of Prishtina was held on 13 February 1970. Today University of Prishtina has 17 faculties, which 14 are academic faculties, and 3 are faculty of applied sciences. In Academic year 2007/2008 University of Prishtina has enroll 28.318 students. Academic units that are part of University of Prishtina: Faculty of Philosophy; Faculty of Mathematical-Natural Sciences; The Faculty of Philology; Faculty of Law; Faculty of Economics; Faculty of Civil Engineering and Architecture; Faculty of Electrical and Computer Engineering; Faculty of Mechanical Engineering; Faculty of Medicine; Faculty of Arts; Faculty of Agriculture; Faculty of Mining and Metallurgy; Faculty of Physical Culture and Sport; Faculty of Education; Faculty of Applied Business Sciences in Peja; Faculty of Applied Technical Sciences in Mitrovica and Gjakova; Faculty of Applied Technical Sciences in Ferizaj.

2.1. FACULTY OF CIVIL ENGINEERING AND ARCHITECTURE

The Faculty was erected on the foundations of the Higher Engineering School in Prishtina, on 20/10/1961, with sections of Civil Engineering, Electrical Engineering and Mechanical Engineering. In year 1965, the Executive Council of Kosova adopted the Law on the Establishment of the Faculty of Engineering with the Section of Civil Engineering. The Faculty of Engineering was transformed on year 1988 on which occasion it was divided into three faculties: the Faculty of Civil Engineering and Architecture, Faculty of Electrical Engineering and Faculty of Mechanical Engineering. Today, faculty of civil engineering and architecture consists two sections, civil engineering and archtiecture, where the civil engineering section consist construction, hydro-technique, geodesy, environmental engineer and road infrastructure courses.

2.2. Bologna Process in Koosvo

The term Bologna Process implies higher education reform in which 47 European countries are currently involved. The main goal of this process is to increase the competitiveness and quality of European higher education in relation to other developed countries. Bologna Process started with the signing of the Bologna Declaration in September 1999, in Bologna, by ministers of education from 29 European countries. The main goals of the Bologna Process: Adoption of a system of easily readable and comparable degrees; Adoption of an education system based on cycles; Introducing the European Credit Transfer and Accumulation System - ECTS; Support for student and teacher mobility; Improvement in the quality of higher education; Promotion of the European dimension in higher education.

After the ministerial meeting where the Declaration was adopted, ministerial conferences were held in Prague (2001), Berlin (2003), Bergen (2005), London (2007) and Leuven (2009) where new goals were added: Introducing the concept of lifelong learning in higher education; Introducing the third cycle of postgraduate programmes; Establishing the European Research

Area - ERA; Introducing a national framework for qualifications comparable to the Framework for Qualifications in the EHEA; Defining learning outcomes for all three cycles according to the Dublin Descriptors; Ensure quality in accordance with the Standards and Guidelines for Quality Assurance in European Higher Education – ESG; Recognition of diplomas and other higher education qualifications in accordance with the Convention on the Recognition of Qualifications concerning Higher Education in the European Region by the European Commission/UNESCO. Kosovo started to apply the Bologna process since 2001/2002, in cooperation with the Ministry of Education, Science and Technology.

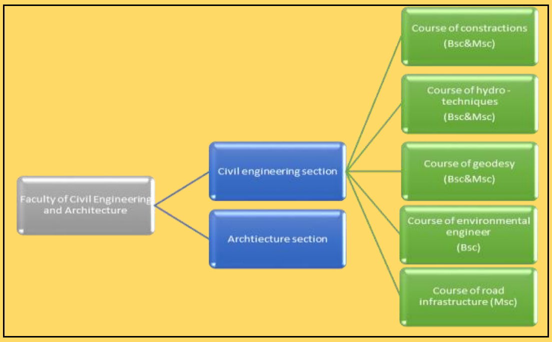


Figure 1
Sections and courses within the Faculty of Civil Engineering and Architecture in Prishtina

Figure 2
View of Declaration of Bologna

3. STUDY PROGRAMS OF GEODESY

3.1. BACHELOR STUDY

Bachelor study program for Geodesy, for the first time has started in the academic year 2003/04, within 30 students registered in first generation under the faculty of civil engineering and architecture. Bachelor studies are with duration three years in six semesters. Students obtains 60 ECTS credits for each academic year.In the end of their studies thay have Diploma thesis. By finishing Bachelor study, thay acquires 180 credits and the title: "Bachelor of Geodesy". After finishing bachelor studies for Geodesy, the students will be an expert with university qualification and technical experience to:

- Be familiar with concepts of geodetic technical sciences
- To know how to apply theoretical knowledge in the practical part and the construction's experimental part.
- To know how to use surveying instruments of the newest technology and apply them in problem solutions, cadastral services in Kosovo and even in construction-related jobs.
- To know through his/her knowledge to help updating the data with international application systems, to create state and local coordinates to be used in property issues etc.
- To have basic knowledge in updating and maintaining land cadastre.
- To know how to use geoinformation and their usages in different fields land-related.
- To have knowledge on how to use electronical systems and GIS.

3.2. MASTER STUDY

Master study program for Geodesy, for the first time has started in the academic year 2015/16 through the Tempus project MPG (Development of a new master program in geodesy).In the first year in this programe are enroll 31 students. The Master study at the Faculty of Geodesy lasts two years, i.e. four semesters, and a student obtains 60 ECTS for each academic year. The Master study ends by producing a diploma thesis. By finishing the Master study, one acquires 120 credits and the title "Master of science in Geodesy".

As a result of the lack of internal staff in the academic year 2017/2018 the master study programe for geodesy is not accredited from Kosovo Accrediatition Agency and in that year we doesn't had competition to enroll new students. In this academic year 2018/2019 we are accredited from Kosovo Accreditation Agency and we will have competition to enroll new students in master study program for geodesy.

4. NUMBER OF STUDENTS ADMITTED TO THE TWO LEVELS OF HIGHER EDUCATION FOR GEODESY

According to the Bachelor and Master study curricula, the optimal number of new students able to enrol each year with respect to space, equipment and staff number at the faculty of geodesy of the University of Prishtina is 90.

Table1 *Number of students enrolled in the first year of the geodesy studies at the Faculty of Geodesy of the University of Prishtina*

Academic year	Bachelor students enrolled in the 1st year	Master students enrolled in the first year
2003/04	30	-
2004/05	30	-
2005/06	45	-
2006/07	45	-
2007/08	60	-
2008/09	60	-
2009/10	60	-
2010/11	56	-
2011/12	60	-
2012/13	57	-
2013/14	82	-
2014/15	54	-
2015/16	62	31
2016/17	64	28
2017/18	34	-
2018/19	48	20

5. QUALITY ASSURANCE IN HIGHER EDUCATION IN THE REPUBLIC OF KOSOVO

The purpose of the Law on Higher Education is to establish a legal base for regulating, functioning, financing, providing the quality in higher education in compliance with European standards as well as the role of state and society in development of higher education in the Republic of Kosovo. In Kosovo quality assurance system in Higher Education is framed by: National legislation and normative acts on higher education institutions and programs; University of Prishtina Statute and accompanying regulations

Some of the most important subject of the law on higher education of Kosovo are: Accreditation; Data protection; European Area of Higher Education; Internal quality assurance; Learning results; Life-long learning; Public-private partnership etc.In evaluation of academic education institutions, general documents/programs required for arrangement of scientific and educational work at the institution are taken into consideration, as well as quantitative and qualitative elements characterizing the institute-on's work. Having the purpose of controlling the quality of academic and administrative activities, the Senate of UP has approved three types of instruments for quality evaluation: questionnaires for academic staff, questionnaires for administrative staff, and question-naires for students.

Besides these questionnaires for quality, in accordance with the statute of UP, students evaluate teaching and learning in specific subjects each semester through anonymous questionnaires for lectures. This is coordinated by Faculty Deans (or Vice-Deans for Teaching) in cooperation with Department Heads with the initiation of the Vice-Rector for Quality Development. There are a number of mechanisms for quality improvement in the University. The quality of research activities of the academic staff of UP is measured through publications in scientific journals with international review and participation in scientific conferences in the country and abroad. Also, the promotion of academic staff is done based on the number of publications in journals with international review. The data is collected from the faculties for students' performance such as: the percentage of passing in exams, organization of continuous assessment, duration of studies etc.

Also, a traditional mechanism is the accreditation of study programs by the Senate of UP, where every new study program should pass through the faculty structures, and then be approved by the Senate. In order to control the quality of academic and administrative activities, UP's Senate has approved three types of quality evaluation instruments: questionnaires for academic staff; questionnaires for administrative staff; questionnaires for students.

5.1. QUALITY ASSURANCE AT THE FACULTY OF GEODESY

Quality assurance in higher education is a comprehensive expression which usually includes all policies, processes, activities and mechanisms acknowledging, maintaining and developing higher education quality. Quality assurance begins with the quality of an individual study program and the responsibility individual higher education institution has for that quality. By signing the Bologna Declaration, we became responsible for implementing standards and following guidelines for higher education quality assurance.

The higher education quality assurance policy is based on the statues of universities and individual higher education institutions and rules and recommendations made by the Ministry of Science Education and Sport. In addition, some activities were also done at the Geodesy Program Study to improve study organization and education quality.

Faculty of Civil Engineering and Architecture monitors activities in the faculty through: an internal evaluation process (administered at the University level) with questionnaires twice a year (each semester); Course evaluation are digitalized by the university (electronic evaluation platform); Faculty own evaluation of courses through feedback from students

Department of Geodesy monitors the quality of courses through: Survey questionnaire distributed to students at each end of semester.

6. CONCLUSIONS

The Bologna process has started to apply in Kosovo since 2001/2002.
Throughout this period of time, the University of Prishtina is able to bring a new spirit of higher education by applying the rules and standards of the Bologna decelerate.

To achieve this, the sector for quality assurance in education was established at the University of Prishtina. The same course has also been attended by the Faculty of Architecture and Architecture for the highest quality assurance at the Faculty.

Along with this in the Faculty of Architecture and Architecture, surveys were conducted after the completion of each semester regarding the teaching process, the organization of lectures and exercises, passing exams and so on. Based on the survey's responses, it's possible to make changes to their requirements every year.

In the academic year 2015/2016 it was made possible to open the geodesy master program and through the Tempus project. With the help of foreign lecturers, the operation of this program is made possible. In the academic year 2017/2018, this master program was not accredited due to the lack of professors. This academic year is again made possible accreditation of this master program.

Beside upper mentioned positive results, geodetic education needs further development within the surveying department in Prishtina, by increasing the number of academic staff in geodesy field, publishing new university books, change curriculum and involvement in national and international professional geodetic projects.

7. REFERENCES

[1]. **Idrizi B., Kabashi I.**, *(2010) CARTOGRAPHIC EDUCATION OF SURVEYORS WITHIN THE UNIVERSITY OF PRISHTINA*
[2]. **Monografia** – *Monograph. (2005) University of Prishtina. Prishtina. Kosova.*
[3]. **Pasqyra e planeve mesimore** *dhe personelit akademik 2007-2008 (2007) University of Pristina. Prishtina. Kosovo.*
[4]. **http**://*www.uni-pr.edu/*
[5]. **http**://*fna.uni-pr.edu/*
[6]. **http**://*fna.uni-pr.edu/Files/Dokumente/Relevante/pasqyra_up_2008.aspx*
[7]. **http**://*fna.uni-pr.edu/Files/Dokumente/Relevante/Monografia_opt.aspx*
[8]. **https**://*gzk.rks-gov.net/ActDocumentDetail.aspx?ActID=2761*
[9]. **http**://*www.akreditimi-ks.org/new/index.php/en/*

8. AUTHORS BIO

Ms. Fitore Bajrami, was born on 10.11.1986 in Gjilan-Kosova. She graduated in geodesy department of the University of Prishtina – Faculty for Civil engineering and Architecture-Prishtina, on November 2008. In July of 2012 graduated for master degree in Faculty of Civil Engineering in Polytechnic University of Tirana. Actually she is in PHD studies for geodesy in Polytechnic University of Tirana. Actually she is working as teaching assistant at geodesy department of the University of Prishtina "Hasan Prishtina" in Prishtina.

Mr. Milot Lubishtani, was born on 10.05.1987 in Gjilan-Kosova. He graduated in geodesy department of the University of Prishtina – Faculty for Civil engineering and Architecture-Prishtina, on November 2008. In July of 2012 graduated for master degree in department of geodesy in Faculty of Civil Engineering in Polytechnic University of Tirana. Actually he is in PHD studies for geodesy in department of geodesy in Faculty of Civil Engineering in Polytechnic University of Tirana. Actually he has private company for geodesy and cadaster.

DEFORMATION ANALYSES OF GEODETIC NETWORK IN "JABLANICA" DAM THROUGH HANNOVER METHOD

Ass.Prof.Dr Ismail KABASHI[1]; Prof. Dr. Pal NIKOLLI[2]
Assoc.Prof.Dr. Bashkim IDRIZI[3]; Ass.MSc. Veton HAMZA[4]

[1,3,4] Faculty of Civil Engineering and Architecture, University of Prishtina
Faculty of Architecture and Civil Engineering, Mother Teresa University – Skopje
Email :ismail.kabashi@uni-pr.edu;Tel: +377 44 325 819
[2]Tirana University, Faculty of History and Philology, Tirana, ALBANIA,
E-mail: pal.nikolli@unitir.edu.al, Tel: 00355 692472451
Email: bashkim.idrizi@uni-pr.edu; Tel: +389 75 712 998
Email: veton.hamza@unt.edu.mk; Tel: + 389 72 755 215


Ismail KABASHI


Pal NIKOLLI


Bashkim IDRIZI


Veton HAMZA

ABSTRACT

Engineering buildings are exposed to natural forces and factors that cause deformations and movements over the time. These displacements are calculated by using geodetic methods and measurements that are crucial for the longevity of the buildings and for the prevention of natural disasters. The Hannover method has found great practical application for calculating deformations of engineering buildings and determining the stability of points from the geodetic control network. In this paper results and conclusions from the implementation of Hannover method in "Jablanica", "Grabovica" and "Salakovac" dams in Bosnia and Herzegovina are presented, where two epochs of measurements are conducted. This method is used because it is among the safest methods for calculating deformations and represents the basis for the development of other classical methods. In conventional methods such as Hannover method and others, the deformations can be calculated as displacements of points between two epochs, so the exact time when deformation occurs cannot be estimated.
The deformation of the building is calculated from the displacements of discrete points while with the modern technology of scanning deformations can be estimated in every points of objects.

***Key words**:* geodetic control network, stable points, displacements, deformation analyses.

1. DEFORMATION ANALYSES THROUGH HANNOVER METHOD

The Pelzer method that can also be called as Hannover method was developed by Pelzer and it was adopted for practical usage by Niemer. This method is based on the compatibility of the coordinates obtained from the equalization of the network were two epochs are used. Each epoch is treated independently, assuming that the measurements are free from the systematic errors and may contain random errors that have normal dispersion. The theory of smaller squares is used during the equalization of the network while the next conditions need to be fulfilled:

$$v^T P v = \min \qquad (1)$$

$$x^T x = \min \qquad (2)$$

where: $trag Q\hat{x} = \min$ (3)

These two conditions of the minimum can be fulfilled during the equalization of the network, or in case that the $v^T Pv$ = min is fullfilled during the equalization than the $x^T x$ = min will be fulfilled during the transformation of the coordinates.The Pelzer method is based on the transformation of the network from the final epoch to the first epoch. In cases that the measurments may contain rough errors they can be detected by using of the Baarda method (Data snooping), Popeo Method (Data screening), Danish method and others (Caspary, 1988).

1.1. DEFORMATION ANALYSES FOR TWO EPOCHS

Geodetic measurements need to be done in two epochs while the configuration of the network is the same. In case that the differences between two epochs are minimal than there is no displacement of the points. The displacements of the points occur when the coordinates changes so much that in comparison with the nominal value and the accuracy achieved cannot be tolerated. In the beginning the issue was orientated in the determination of the deformations for one point (Pelzer 1971, Niemeier 1976, 1979, Heck et al. 1977, Koch 1980), than the authors orientated their research to determine the movements for group of points (Bruner, 1979, Caspary 1981, Pelzer 1982, Welsch 1982, Schneider 1982), the research is still continuing nowadays (Jäger, 1997; Jäger, 2011). In deformation analyses the congruence of the networks is crucial, two networks are congruent if one network with the help of the isometric representation is integrated into the other network.During the examination of the congruence,the stohastic information should be considered.These test are called congruence test (Niemeier, 1979).

1.2. HOMOGENEOUS ACCUARACY OF MEASURMENTS IN TWO EPOCHS

From the equalization of the epochs the empiric dispersion S_1^2 and S_2^2 are obtained, so it is neccesarry to prove their equalization with the respective probability and to reach the conclusion if the measurrments have homogene accuarcy in two epochs. For this purpose the zero *(H_0)* alternative hypothesis *(H_a)* is set (Pelzer, 1971, Dupraz, 1979, Niemeier, 1978; Niemeier, 1985)

$$H_0 : E(S_1^2) = E(S_2^2) = \sigma^2 \quad (4)$$

$$H_a : E(S_1^2) \neq E(S_2^2) = \sigma^2 \quad (5)$$

Acceptance of the zero hypothesis *(H_0)* means that the accuracy of observations of two epochs is homogeneous, whereas accepting the alternative hypothesis *(H_a)* means that the precision of the observations at two epochs is not homogeneous.Statical test are as follows:

$$F = \frac{S_1^2}{S_2^2}\ ;\ S_1^2 = m_x^2\ ;\ S_2^2 = m_y^2 \quad (6)$$

In case of zero hypothesis the Fisher central dispersion will be conducted

$$F \sim F_{f_1, f_2} \quad (7)$$

While in the case of the alternative hypothesis the non-central dispersion of the Fisher will be followed

$$F \sim F_{f_1, f_2, \delta} \quad (8)$$

where:

f_1 – *number of surplus measurments in the equalization of the first epoch*

f_2 - *number of surplus measurments in the equalization of the second epoch*

δ – *non central parametar*

When the value of the statical test is smaller than the critical value, i.e:

$$F \leq F_{1-a, f_1, f_2} \quad (9)$$

then the zero hypothesis is accepted. In this case the unique value of empiric standard deviation is determined, which represent the homogeneous accuracy of the measurments in two epochs.

$$S^2 = \frac{f_1 S_1^2 + f_2 S_2^2}{f_1 + f_2} \quad (10)$$

When the value of the statical test is greater than the critical value, the alternative hypothesis is accepted which means that the accuracy of the measurments between two epochs is not homogeneous.In this case the unique epmiric value of the standard deviation is not determined.

1.3. TESTING THE COMPATIBILITY OF THE REFERENCE POINTS

The hypothesis for compatibility of network reference points is established when with the statistical tests it is verified that there are unstable points. In this case the network is divided into the group of base points and group of points in the object. Hypotheses are (Dupraz, et al 1979, Niemeier, 1979; Niemeier, 1985):

$$H_0 : E(\hat{x}_{S_1}) = E(\hat{x}_{S_2}) \quad (11)$$

$$H_a : E(\hat{x}_{S_1}) \neq E(\hat{x}_{S_2}) \quad (12)$$

where:

$\hat{x}_{S_1}$ - *The coordinate vector of points from reference network in the first epoch*

$\hat{x}_{S2}$ - *The coordinate vector of points from reference network in the second epoch*

H_0 : *Acceptance of H_0 means that the coordinates of the reference points match in both epochs.*

H_a : *Acceptance of H_a means that the coordinates of the reference points don't match in both epochs.*

The vector of differences of the coordinates is divided in subvectors:

$$\hat{d} = \begin{vmatrix} \hat{d}_S \\ \hat{d}_O \end{vmatrix} \quad (13)$$

in the vector $\hat{d}_S$ are represented the difference of the coordinates from the reference points, while in the vector $\hat{d}_O$ are represented the differences of the coordinates from points of dam. According to this, the matrix $Q^+_{\hat{d}}$ is diveded into submatrixes.

$$Q^+_{\hat{d}} = P_{\hat{d}} = \begin{vmatrix} P_{SS} & P_{SO} \\ P_{OS} & P_{OO} \end{vmatrix} \quad (14)$$

$$F = \frac{\theta_S^2}{S^2} ; \quad \theta^2 = m_x^2 ; \; S^2 = m_y^2 \quad (15)$$

When the value of the statistical test is smaller than the critical value:

$$F \leq F_{1-a,h_s,f} \quad (16)$$

the zero hypothesis is accepted. While when the value of statistical test is greater than critical value, then the alternative hypothesis is accepted which means that some of the reference points are not stable.

1.4. DETERMINATION OF THE UNSTABLE POINTS

The process of separating the unstable points is accomplished by their locali-zation. For this purpose, the $\hat{d}_S$ vector is divided into two subvectors (Niemeier, 1979, Niemeier, 1985):

$$\hat{d}_S = \begin{vmatrix} \hat{d}_F \\ \hat{d}_B \end{vmatrix} \quad (17)$$

In the $\hat{d}_F$ vector are represented the differences of coordinates of the points that are conditionally stable, while in the $\hat{d}_B$ vector are represented the differences of the coordinates of the others points that are conditionally unstable.According to this classification the cofactor matrix of the diferences of the coordinates is divided into submatrixes.

$$P_{SS} = \begin{vmatrix} P_{FF} & P_{FB} \\ P_{BF} & P_{BB} \end{vmatrix} \quad (18)$$

For every base point of the network the θ_j^2 value is determined.

$$\theta_j^2 = \frac{\overline{d}_B^T P_{BB} \overline{d}_B}{h_B} \qquad (j = 1, 2, ..., k) \quad (19)$$

where: $h_B = rangP_{BB}$.

For one dimensional network the $h_B = 1$, while for two dimensional network the $h_B = 2$. When the network has k referent points then k values of standard incompability need to be estimated.

$$\theta_{\max}^2 = \max \theta_j^2 \quad (20)$$

The points that will have the maximum value of the θ will be declared as unstable point, so it will be excluded from the group of the conditionally stable points. The same procedure will be applied in the group of the points *k*, which will be (*k-1*). In this way the next unstable point will be detected or it will be concluded that there are no unstable points which means that all others points are stable.For this reason the value of the standard incompabilty will be determined as follows:

$$\theta_{REST}^2 = \frac{\hat{d}_F^T \overline{P}_{FF} \hat{d}_F}{h_F} \quad (21)$$

Then the statistical test will be conducted:

$$F = \frac{\theta_{REST}^2}{S^2} \quad (22)$$

where $h_F = rangP_{FF}$.

When the value of the statistical test is smaller than the critical value:

$$F \le F_{1-a, h_F, f} \quad (23)$$

the zero hypothesis will be accepted, which means that all referent points *(k-1)* can be declared as stable points. When the value of the statistical test is greater than the critical value, then the alternative hypothesis will be accepted. This means that in the group of *(k-1)* points, there are more unstable points. The same procedure needs to be repeated until all of the unstable points will be detected.When the unstable point is detected, than it needs to be excluded from the following calculations, also the row and the column from the Q_d^+ matrix that are related with that point will be excluded.

2. DEFORMATION ANALYSES OF THE GEODETIC NETWORK IN "JABLANICA " DAM

The data that was used for deformation analysis is taken from the report (Spohn, et al. 2012). The monitoring was done for three dams „Jablanica", „Grabovica" and „Salakovac", in Bosnia and Hercegovina, within the project „Rehabilitation and Modernization of the Dam Monitoring System at the HPP Jablanica, HPP Grabovica and HPP Salakovac". The project was financed from the World Bank and it was conducted (2011-2014) by company Vermessung Angst, ZT GmbH, Vienna. The dam was built in 1953, while the monitoring began from 1954. The local network in the framework of the project was expanded with new points (Figure 2.). The monitoration has shifted from the classic method of measurments to the automatic mode, for this purpose additional work was done. In the points that are located in the object were mounted metal sings in which prisms for automatic measurments were set. The first epoch was conducted from 22 to 23.06.2012 while the measurments in the second epoch were done from 06 to 09.10.2012. The measurments were done in three series with the TC Sokkia NET05AX (Kabashi, et.al, 2013).

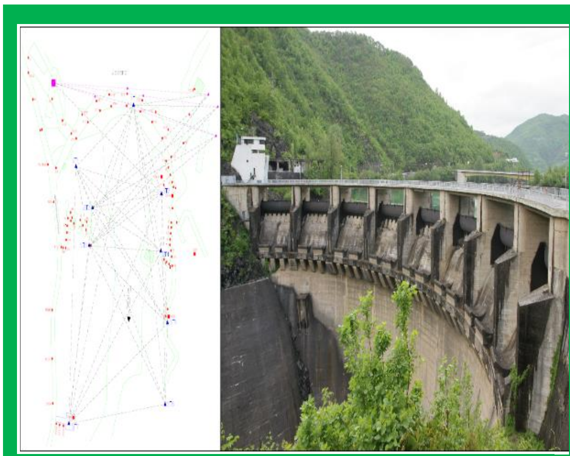


Figure 1
View on the "Jablanica" Dam

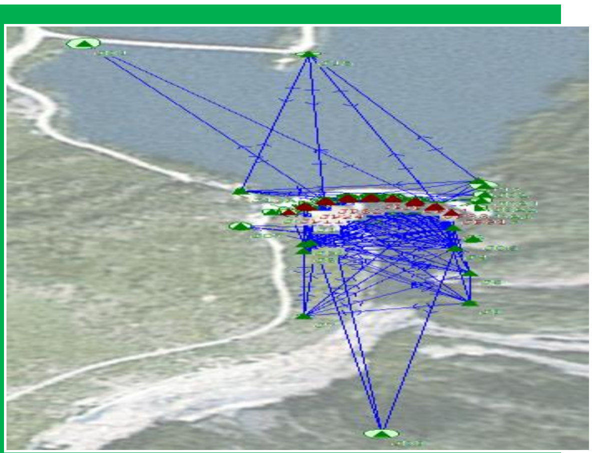


Figure 2
The local network, "Jablanica" Dam

Further data are given in Spohn, et. al., 2012. To detect the rough errors the values obtained from the equalization of the epochs will be used. For approved values: α_0=0,1% β_0=20% from the monogram are obtained λ_0=17,0743 and $u_{\alpha 0}$=3,29.

Table1 *Local test of epochs in „Jablanica" dam*

	v^TPv	f	T	α	χ^2	T<or>χ^2	Local test
Epoch 1	379.528	98	168.679	0.39	101.281	>	Yes
Epoch 2	320.423	98	142.410	0.39	101.281	>	Yes

Because T > $\chi2(_{\alpha,f})$ in the first and second epoch, there are rough erros so the local test needs to be conducted.

Table 2 *Local test of epochs in "Jablanica" dam after elemination of the rough*

	v^TPv	f	T	α	χ^2	T<or>χ^2	Local test
Epoch 1	191.188	95	84.972	0.39	98.2207	<	No
Epoch 2	206.789	96	91.906	0.39	99.2410	<	No

Because the T <$\chi2(_{\alpha,f})$ in the first and second epoch, then the zero hypothesis is accepted so there is no need for another local test. From the equalization of the epochs the empiric variance are obtained, which can be used to determined the homogeneous accuracy of the measurments. In the first epoch, as result of the equlization the following values are gained: *pvv=191.188*, $f_1=95$, $\sigma_1=1.42''$ In the second epoch, as result of the equlization the following values are gained: *pvv=206.789*, $f_2=96$, $\sigma_2=1.47''$.
Because the statical test *F=1.070* is smaller then the critical value $F_{f2,f1,1-\alpha}=1.403$, it can be concluded that measurements are with homogeneous accuracy, while the common variance is σ^2=2.084. The standard incompability θ^2 in the first and second epoch is 134.019, while the value F of the statistical test is *3.573*. Since the statical test is greater than $F_{1-\alpha,h,f} = 2.84$ with $\alpha=0.05$ $h=18$ and $f=191$, the alternative hypothesis is accepted, then it can be concluded that the two epochs do not match. After testing it can be concluded that points J2 and J9 are unstable, these points need to be removed from the following calculations because they can cause additional/false deformations at the points that are located in the dam.

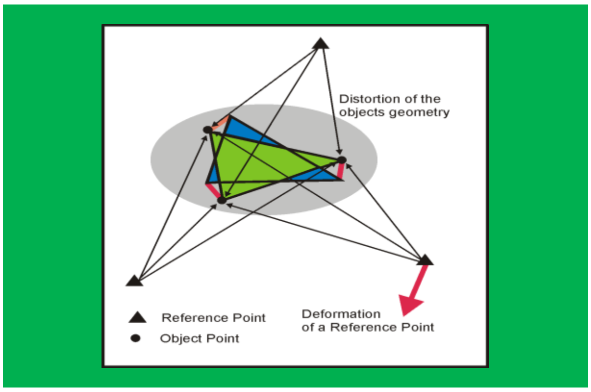


Figure 3 *False deformation of points located in object as a result of unstability of reference points (Jäger, 2011).*

The stability test of the referent points shows that the network is not stable, so it is necessary to detect the unstable points. For every point the standard incompability θ^2_i is calculated. In the first iteration the point J2 (Table. 3) is declared as unstable while in the second iteration as unstable point is J9 (Table. 4). The third iteration is not necessary because the remaining points are declared as stable points, so they don't have deformation between the two epochs.

Table 3 *Results from the first iteration*

Point	Θ_i^2	θ_{REST}	84.414
J1	1.35	hF	16
J2	**24.80**	F (ose T)	2.53
J3	2.22	$F_{1-\alpha,hF,f}$	1.6967
J4	5.24	**New**	**Yes**

Table 4 *Results from the second iteration*

Point	Θ_i^2	θ_{REST}	50.769
J1	0.28	h_F	14
J3	4.10	F (ose T)	1.7404
J4	0.01	$F_{1-\alpha,h,F,f}$	1.7439
J5	8.17	**New**	**NO**

		iteration	
J5	11.37	α_F	0.05
J6	12.37		
J7	2.01		
J8	1.51		
J9	20.18		

		iteration	
J6	7.19	α_F	0.05
J7	0.77		
J8	2.46		
J9	**16.82**		

Table 5 *Definitive coordinates of points from the referent network in two epochs*

	Epoch 1		Epoch 2		Deformation mm	
Point	Y[m]	X[m]	Y[m]	X[m]	Δy[mm]	Δx[mm]
J1	946.5785	1025.1769	946.5782	1025.1768	-	-
J2	1069.3507	1008.6301	1069.3504	1008.6318	-0.93	1.77
J3	950.5091	973.8243	950.5085	973.8247	-	-
J4	1070.6931	960.3525	1070.6937	960.3523	-	-
J5	945.8432	953.6016	945.8426	953.6019	-	-
J6	1082.4218	901.2160	1082.4227	901.2145	-	-
J7	944.9845	800.5334	944.9839	800.5325	-	-
J8	1082.7207	832.4687	1082.7216	832.4681	-	-
J9	945.4761	969.7456	945.4761	969.7465	0.51	0.37

3. CONCLUSIONS

Determining the displacements and deformations of the physical surface of the Earth and the objects in it, is a very demanding and complex task in geodesy, particularly in engineering geodesy. In practice, especially in recent times, the stability of points in geodetic networks needs to be determined. The causes for the deformation of the points are different. For this reason it is very difficult to answer the question: "Is this a stable point," "Is this or that part of the network stable?"

The paper describes the process of deformation analysis with the Hannover method, where the network is equalized as a free network. Each epoch of measurments is tested for rough errors, also the variances of the measurments in each epoch were tested with the matter of determining/testing the homogeneous accuracy of the measurments in two epochs which was concluded from the tests that were conducted. In the next phase, the global congruence of the individual measurement series is tested. After conducting the compliance tests of the reference network the point J2 and J9 were verified as unstable points. In the next iteration the test verified that all other points are stable.

Frequent measurments of the geodetic network in epochs is one of the most accurate and reliable method for monitoring, the Hannover method enables to locate and remove unstable points from calculations.

4. LITERATURE

[1]. **BRUNNER, F.K**. (1979): *On the analysis of geodetic networks for the determination of the incremental strain tensor*. Survey Review 25, 192, p. 56-67.

[2]. **CASPARY, W., SCHWINTZER, P**. (1981): *Bestimmung von Einzelpunktbewegungen und von Relativbewegungen zweier Netzteile in geodätischen Deformationsnetzen.* ZfV, vol 106, S. 277 – 288.

[3]. **CASPARY, W. F**. (1988): *Concepts of Network and Deformation Analysis. Kensington, The University of New South Wales, School of Surveying, 1988, str. 68-84.*

[4]. **HECK, B., KUNTZ, E., MEIER-HIRMER, B**. (1977): *Deformationsanalyse mittels relativer Fehlerellipsen.* AVN, vol. 84, S. 78 – 87.

[5]. **DUPRAZ, H., NIEMEIER, W., PELZER, H.,** (1979): *Analyse von Deformationsmessungen durch Klaffungszerlegung, angewandt auf die Netze "Montsalvens" und "Huaytapallana".* V: Seminar über Deformationsanalysen (ed. W. Caspary, W. Welsch). Schriftenreihe, Wissenschaftlicher Studiengang Vermessungswesen. München [Hochschule der Bundeswehr München], 1979. Heft 4, S. 45-66.

[6]. **JÄGER, R.** (2011)*: GNSS/LPS based Online Control and Alarm System (GOCA)-Mathematical Models and Technical Realization of a Scaleable System for Natural and Geotechnical Monitoring Analysis.* Vortrag Reiner Jäger auf der Veranstaltung 'Monitoring bei Bauarbeiten zur Sicherung bestehender Gebäude' Veranstalter: VMT GMBH; 26. Mai - 28. Mai 2011, Sankt Petersburg, Russland.

[7]. **JÄGER, R.** (1997): *Ein ISO 9000 Handbuch für Überwachungsmessungen*. DVW-Schriftenreihe, Heft Nr. 27, Wichmann Verlag, Karlsruhe.

[8]. **KABASHI, I., ANGST, J., RAGOSSNIG-ANGST, M., JÄGER, R. UND SPOHN, P.** (2013): *Automatisiertes geodätisches Monitoring an den Staudämmen Jablanica, Grabovica und Salakovac*. 17. internationale Geodätische Woche, 17-23. 02.2013, Obergurgl -Ötztal/Tirol-Austria,S. 95-106.

[9]. **KOCH, K.R.** (1980): *Ein automatisches Testverfahren zur Aufdeckung von Punktverschiebungen bei der Deformationsanalyse.*VIII. Int. Kurs für Ingenieurvermessung, Zürich

[10]. **NIEMEIER, W**. (1976): *Grundprinzip und Rechenformeln einer strengen Analyse geodätischer Deformationsmessungen.* VII. Int. Kurs für Ingenieur- messungen, Darmstadt.

[11]. **NIEMEIER, W**. (1979): *Zur Kongruenz mehrfach beobachteter geodätischer Netze.* Wiss. Arb. Fachrichtung Vermessungswesen Uni Hannover, Nr. 88.

[12]. **NIEMEIER, W**. (1980): *Hypothesentests in Geodätischen Netzen.* In: Pelzer, H. (Hrsg.): Geodätische Netze in Landes- und Ingenieurvermessung. Wittwer Verlag, Stuttgart

[13]. **NIEMEIER, W**. (1985): *Geodätische Netze in Landes- und Ingenieurvermessung II*, Konrad Wittwer, Stuttgart, Kap. Deformationsanalyse, S. 559-623.

[14]. **NIEMEIER, W**. (2002): *Ausgleichungsrechnung*. Walter de Gruyter, Berlin.

[15]. **PELZER, H.** (1971): *Zur Analyse geodätischer Deformationsmessungen.* DGK, Reihe C, Nr. 164, München.

[16]. **PELZER, H.** (1976): *Über die statischen Eigenschaften der Ergebnisse von Deformationsmessungen.* VII. Int. Kurs für Ingenieurmessungen, Darmstadt.

[17]. **PELZER, H.** (1982): *Geodätische Modelle zur Erfassung von Deformationen, insbesondere von Rutschungserscheinungen.* V. Int. Symp. für Marktscheidewesen 1982.

[18]. **SCHNEIDER, D**. (1982): *Complex Crustal Strain Approximation. Mitt. Inst. für Geodäsie, ETH Zürich.*

[19]. **SPOHN, P.; KABASHI, I., HAMULA, E., JÄGER, R., RAGOSSNIG-ANGST, M.,** (2012):

[20]. **WELSCH, W**. (1982): *Einige Erweiterungen der Deformationsermittlung in geodätischen Netzen durch Methoden der Strainanalyse.* III. Int. Symp. Deformationsmessungen, Budapest 1982.

5. AUTHORS BIO

Ass. Prof. Dr. Ismail KABASHI graduated in geodesy department of the University of Saraevo-Bosnia and Hercegovina. In 2003 year, he held the degree of Doctor of sciences (PhD) in Geodesy engineering department of TU Vienna. Currently he is employee in Vermessung ANGST ZT GmbH Vienna as project manager for Planning and execution of Cadastre and Geomonitoring Projects. From year 2004, he works as a geodesy engineering Professor at the University of Prishtina-Kosova. He is the author of many papers published and presented in national and international scientific conferences related to engineering geodesy.

Prof. Dr. Eng. Pal NIKOLLI (Cartographer). Professor of subjects: "Elements of Cartography", "Thematic Cartography", "The interpretation of aerial photographs and satellite images" and "Geographic Information Systems (GIS)" in the branch of geography at the University of Tirana. His research interest is mainly oriented in cartography, GIS/Remote Sensing and analysis of the dynamics of the shoreline. "Doctor of Science" in cartography in 1994, "Associate Professor" in 1999 and "Professor" in 2016. Author and coauthor of more than 100 articles and studies published in scientific journals at inside and abroad, more than 80 papers and reports kept in seminars and conferences at inside and abroad, 11 textbooks, 3 monographs, some books, geographical atlases, several national and international research projects and about 20 items journalism scientific character. Member of several scientific organizations and associations

Assoc. Prof. Dr. Bashkim IDRIZI is full time university lecturer at the geodesy and geoinformatics department of the University "Mother Teresa" in Skopje, part time lecturer at geodesy department of the University of Prishtina "Hasan Prishtina" in Prishtina, and president of the Geo-SEE Institute in Skopje. He is author of 3 books, 7 handouts and more than 100 scientific research papers. His research interests are cartography, map projections, coordinate reference systems, SDI and GIS.

Mr. sc. Veton HAMZA graduated in geodesy department of the Ss.Cyril and Methodius University-Skopje in 2013. He got the degree of master of sciences (MSc) in Ss.Cyril and Methodius University-Skopje in 2015. During 2015 year he worked as research assistant in department for geodesy and geoinformation at University of Tetova. Since 2016 is research assistant at the geodesy and geoinformation of the "Mother Theresa" University in Skopje. He is the author of some papers related with engineering geodesy.

THE ROLE AND CONTRIBUTION OF GEODETIC REFERENCE FRAME TO THE NSDI IN ALBANIA

Best Paper Award

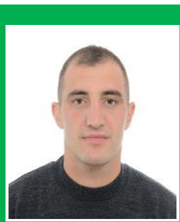
BEST YOUNG SCIENTIST PAPER

Arian LASKU[1]; Eduart BLLOSHMI[2]; Oltjon BALLIU[3]

[1,2,3] National Authority for Geospatial Information (ASIG) Tirana, ALBANIA
E-mail: arian.lasku@yahoo.com; Tel: +355 69 42 72 918
E-mail: eduartblloshmi@yahoo.com; Tel: +355 693925144
E-mail: oltjon.balliu@gmail.com; Tel: +355 699424199


Arian LASKU


Eduart BLLOSHMI


Oltjon BALLIU

ABSTRACT

In the context of the EU integration, Albania has undertaken concrete steps to enable the implementation of EU INSPIRE Directive 2007/02/CE, first by establishing the necessary legal basis, with the adoption of law no. 72/2012, "On the organization and functioning of the National Geospatial Information Infrastructure", and advancing with the establishment of the National Authority for Geospatial Information (ASIG) as a decision-making, executive and coordinating organization, who leads the implementation of this law and regulations in relation to it, in order to create a modern NSDI as an important basis on which the country's sustainable development will be based and thus fulfilling an important prerequisite for the country's EU integration. Pursuant to the law no. 72/2012, the Decision of the Council of Ministers no.669, dated 7.8.2013, "On the adoption of the rules for defining, creating and realization of the Albanian Geodetic Reference Frame (KRGJSH) as metadata" (amended), which reflects all the INSPIRE Directive requirements, related to the "Coordinate Reference Systems (CRS)". By designing and constructing the Albanian Geodetic Reference Frame we will realize an essential element of the National Spatial Data Infrastructure (NSDI), and will ultimately avoid duplications, inaccuracies and uncertainties that exists in Albania over this important technical process.

KEY WORDS: *ASIG, NSDI, INSPIRE Geodetic Reference Frame, GNSS, CORS-ALBCORS, Gravity, Geoid.*

1. INTRODUCTION (BACKGROUND)

The National Authority for Geospatial Information in Albania (hereinafter ASIG), is a relatively new organization created in 2013, with the main mission to establish NSDI in Albania. The activities are based on law no. 72/2012, which specifies ASIG as the responsible organisation for creating and maintaining the geodetic reference frame (hereinafter GRF) in Albania including the following networks:

1. National GPS Network (Active (CORS) + Passive Network);
2. National Levelling Network;
3. National Gravimetric Network;
4. National Tide Gauge stations Network;
5. National Magnetometric Stations Network.

Implementation of GRF will provide a common, accurate and reliable reference for positioning throughout our country, and it will provide the following effects:

- *Improve the quality of the existing Geo-information (support creation of cadastral maps which will prevent property conflicts; have smooth transactions etc.).*
- *Monitoring horizontal and vertical crustal motion and plate tectonics for natural disaster mitigation and prediction (high demand from the Albanian Institute of Geosciences).*
- *Provide accurate and reliable information for urban planning and decision making to territory management.*
- *Support development of geographic information systems for planning and service management functions. These include boundary determination for site planning, land use regulation, hydrology, soil conservation etc.*
- *Provide a reliable and accurate geodetic base to Surveying and Mapping companies for implementation of all engineering projects throughout our country (cost and time effective).*

2. BRIEF HISTORY AND CURRENT SITUATION OF GEODETIC WORKS IN ALBANIA

From 1970s to 1986 the Albanian Military Geographical Institute (hereinafter AMGI) established the triangulation and levelling networks which were both developed in three orders covering all Albania. This horizontal and vertical datum has been in use for a long time and has supported all the surveying works throughout our country. Nowadays most of those points are unfortunately damaged or no longer exist due to the big infrastructure changes and some other significant problems during the last decade.

During 2007 and 2008, the AMGI with the support of Florence Geographical institute performed a GNSS campaign on around 150 points from the existing datum in order to establish a mathematical connection between the old existing Datum to the new European one. This campaign was also the first realization of ETRS89 in Albania.

During 2008, a new active GNSS network (ALBPOS system) was established for the first time through EU donation, consisting of 16 roof type antennas with 75km average distance between stations, with control centre initially installed at the AMGI. But, mainly due to the lack of experience, after around 1 year the system stopped operating until 2013. During 2009 the system was moved to IPRO until a civil organization responsible for the geodetic reference frame will be established.

During this transition some stations were also moved so recalculation of the network stations coordinates was necessary. After 2014, with the support of Lantmäteriet (Swedish Mapping, Cadastral and Land registration Authority), the operation of ALBPOS system was restarted, but still the system have had a lot of problems so far in relation with reliability, sustainability, equipment seniority, antenna stability etc.

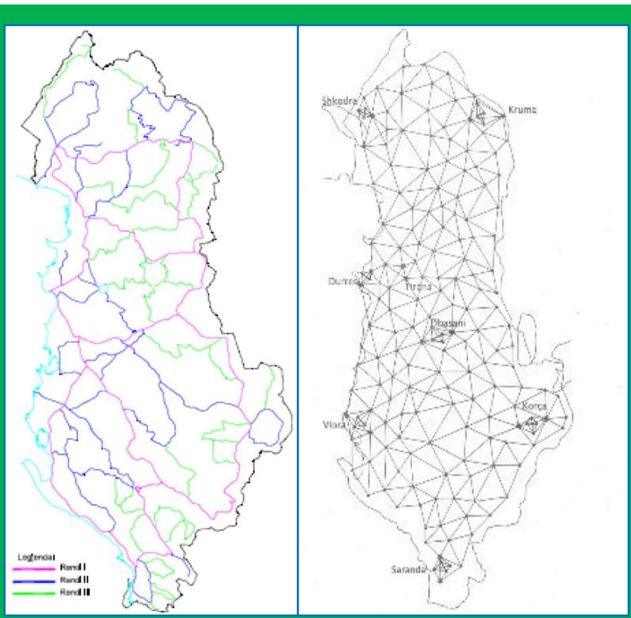


Fig. 2.1 *The existing levelling and triangulation networks*

Fig. 2.2 *The ALBPOS network*

During 2015, the working group consisting of representatives from ASIG, Immovable Property Registration Office (IPRO), Albanian Military Geographical Institute (AMGI) and Faculty of Civil Engineering (FIN), after the detailed inspection came to the final decision that ALBPOS system doesn’t meet the minimum requirements and standards to be certified as a National CORS (referring to the Guideline number 3, date 06.09.2013).

Due to the above reasons, and pursuing the law 72/2012, we are now engaged to establish a new modern geodetic reference frame, based on latest technology, which will support the nationwide accurate positioning throughout Albania.

3. PROGRESS OF IMPLEMENTATION OF THE NEW GEODETIC REFERENCE FRAME

In terms of executing the regulations of Law no. 72/2012 and having regard the EU requirements for Coordinate Reference Systems, we are engaged to establish a modern geodetic reference frame, focusing on GNSS technology solutions to support the accurate and efficient 3D positioning throughout Albania

3.1 Horizontal Datum

In support of horizontal datum we have designed a new National GNSS network consisting of passive and active points. The new designed active network, ALBCORS system, will provide an accurate and reliable positioning infrastructure and facilitate the access, sharing, and utilization of GNSS data in an efficient and effective way in order to meet the needs of the public and private sectors to support economic growth and sustainable development in Albania. The new ALBCORS network, which will replace the existing ALBPOS system, will be the base to improve the existing geospatial information and to provide accurate and reliable Fundamental Geospatial Data to a wide range of users. ALBCORS at the same time will support land and crustal deformation monitoring as well as creation of large scale national base maps, which are the basis for planning and decision making by central and local governments in the territory management which has a direct impact on our society's life.

The configuration of the ALBCORS stations is designed in a way to meet the needs and requirements of all governmental, scientific and private users. The stations density is increased from 16 to 21 stations, with an average distance of 40-50km, in order to guarantee the network sustainability and coverage with the required quality all over Albania (Fig. 3.1).

The technical specifications of the ALBCORS system will be in accordance with the EU recommendations and guidelines, and will meet the Albanian regulations to be certified as a National CORS network.

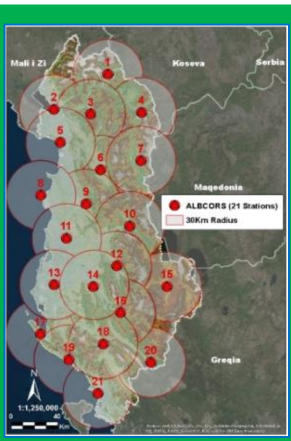
Implementation of the new active GNSS network will have the following effects:

- Create a time-based dynamic Geodetic Reference frame.
- Implement and maintain ETRS/ITRS in Albania.
- Provide a common and reliable reference for accurate gathering and creation of geo-information.
- Land movement and crustal deformations monitoring of the Albanian territory (in cooperation with Albanian Institute of Geosciences).
- Improve the countermeasures to floods by monitoring the distribution of precipitable water vapour in the atmosphere for weather prediction.
- Improve counter-measures to floods and other natural disasters.
- Provide and infrastructure for productive and efficient use of GNSS for engineering surveying works, which means time and cost effective.
- Support navigation and augmentation.
- Support research activities.

Within 2018, the site selection and construction of all 1st order GNSS active (CORS) pillars and passive points will be finished. The configuration of those points is shown in the figure 3.2.

The final site selection process is done by performing the necessary investigations and measures to assess the factors that directly or indirectly influence the performance of base stations and their physical position (satellites visibility, land stability, multipath and interferences etc.).

After finding the most suitable location, the construction of points is done in accordance with the specifications of the project designed by ASIG. An example for each type of point is shown in the following figures.



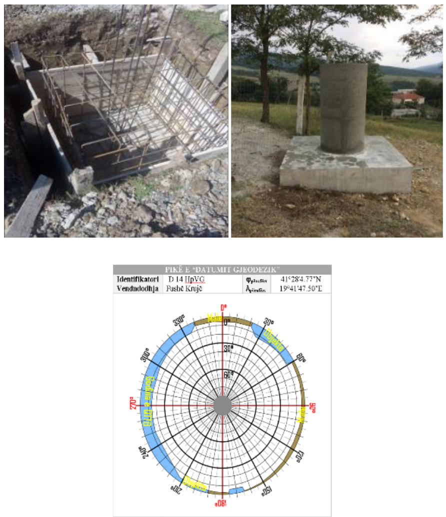


Fig. 3.1 *The new "ALBCORS" network*	**Fig. 3.2** *CORS and GNSS passive points configuration*

Fig. 3.3 *CORS pillar*

3.1 Vertical Datum

In order to realize a more sustainable, reliable, convenient and up to date vertical reference frame for Albania, we are working on to shift from the levelling-based to the new Geoid-based vertical datum. The national Gravimetric network will be the source for the terrestrial gravimetric data needed for determination of the high accuracy gravimetric geoid model. The new gravimetric network is designed in four orders as below:

1. Zero Order (three absolute points with a density of 1 point per 7000 km^2, with accuracy 2-3 μGal);
2. First Order (42 points with a density of 1 point per 650 km^2, and with 33 km min. distance and 55 km max. distance between points; required accuracy 10 μGal);
3. Second Order (common with the second order passive GNSS network; required accuracy 20 μGal);
4. Third Order (the GRID network with a density of 1 point per 2km^2 in lowland and hilly areas and 1 point per 5km^2 in mountainous areas; required accuracy 30 μGal);

The gravimetric network schema is shown in the following figure:

The base between Absolute points in Tirana and Shkodra will serve as the calibration base where the relative gravimeters will be calibrated by calculating and applying the calibration coefficient (K) based on the calculated and measured gravity difference:

$$K = \frac{\Delta g_{ABS}}{\Delta g_{meas}}$$

To obtain the highest precision in the measured gravity difference, a number of mathematical corrections will be applied to the measurements in order to minimize the effect of different factors in the accuracy of the final gravity values for each point. Those include corrections for external factors (earth and ocean tides etc.) and internal factors (drift, temperature, magnetic field etc.).

The measurements and calculation of the gravity value on the Absolute gravimetric points are finished during 2015, where FG5 is used (at least over 2 nights and one day on each station) and the measurements uncertainty varies between ± 2.4 and ± 2.7 μGal. Concerning other parts of the Gravimetric network, the implementation of the first order gravimetric network covering all Albania, and the second + third order covering Tirana-Durres area is in progress and will be finished within 2018 (fig. 3.6).

It is worth noting that during the field measurements in the first order gravity network the real vertical gradient is measured and at least two relative gravimeters (Scintrex CG-5) are being used.

Fig. 3.4
Passive GNSS point

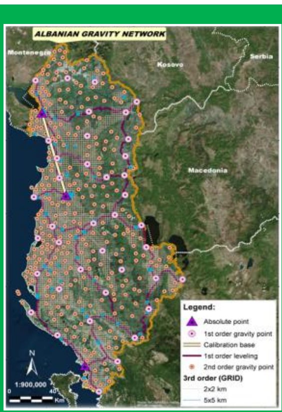


Fig. 3.5
The National Gravimetric Network

Fig. 3.6

Besides the Gravity network, we have designed the National Levelling network as an alternative for the geoid model validation, fitting and evaluation of the accuracy of orthometric heights through GNSS Levelling. In addition, four new dual sensors Tide Gauge stations will be constructed within 2019, which will complete the National Tide Gauge stations network and will serve as the source to define the mean sea level, ensure safe sea navigation, record and predict sea-level trends and support other oceanographic studies across the Albanian coastline. Furthermore, the National Magnetometric stations network is designed, consisting of 11 "Repeat Stations", which will serve to define the Magnetic declination (D) and inclination (I) necessary for mapping and navigation purposes. The 2018th measurements campaign is in progress and will be finished by the end of the year.

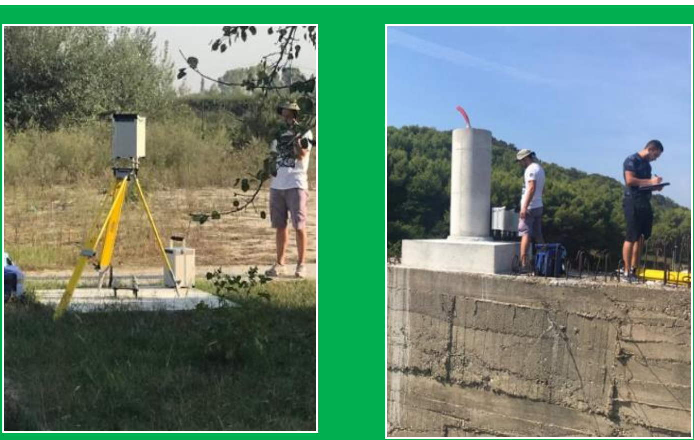


Fig. 3.7 *Photos during the field gravity measurements*

Fig. 3.8

4. NEXT PHASE OF IMPLEMENTATION OF GEODETIC REFERENCE FRAME

Our aim for the near future is to establish the necessary infrastructure and develop efficient methods for surveying by taking advantage of the evolving GNSS and communication technologies. In order to realize this goal, realization of the ALBCORS network and determination of the Albanian precise Geoid model based on the National Gravimetric network is necessary. In consequence, the next implementation steps for GRF are as follows:

a) Regarding CORS:

- Complete the installation and run the new CORS system; Testing and system validation;
- Organize promotion activities for utilization of new CORS by all users;
- Development of guidelines and manuals on utilization of CORS services and data;
- Provide and maintain services with the required accuracy/precision;

b) Regarding Geoid model:

- Cover all Albania with gravity data by through terrestrial and/or airborne gravity survey;
- Determine the precise Geoid model of Albanian territory by utilizing our national gravity data (terrestrial and marine data) and the data from neighbouring countries;
- Introduce the new height determination system and develop new “Smart” surveying technique based on CORS and precise Geoid model.

The number of physical benchmarks will be kept minimum enough to maintain the height system, for accuracy check and validation purposes only. Shifting from the levelling-based to the new geoid-based vertical datum is an important step towards modernizing our geodetic infrastructure.

This new modern geodetic reference frame in Albania will play a fundamental role in creation and development of all geospatial information’s and assure the integration of those data into the National GIS.

5. REFERENCES

[1]. **Project** for integration of Albanian Geodetic Reference Frame networks, ASIG, 2018.
[2]. **Project** for the Albanian National GNSS network, ASIG, 2018.
[3]. **Project** for the Albanian National Gravity network, ASIG, 2018.
[4]. **Project** for the Albanian Levelling network, ASIG, 2018.

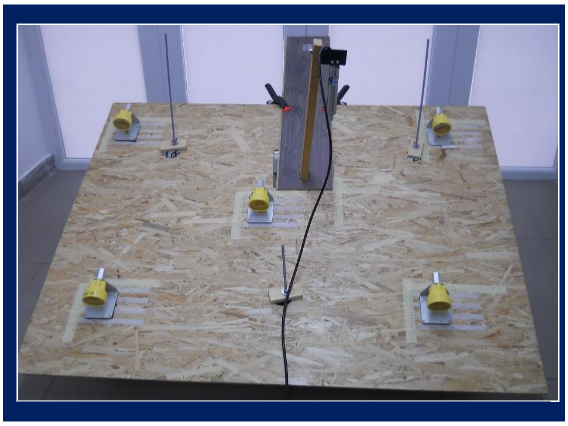
-

6. AUTHORS BIO

M.Sc. Arian Lasku. Finished the Master of Science studies for Geodesy Engineering at the Faculty of Civil Engineering, Polytechnic University of Tirana, in 2013. Head of CORS Systems Infrastructure sector at the National Authority for Geospatial Information (ASIG), and part-time lecturer on *"Satellite Geodesy", "Precise Levelling"* and *"Engineering Surveying"* at the Faculty of Civil Engineering in Tirana. Chief of the topographic works at the private construction-design company AM-RES, as well as part-time consultant in several other private construction and geospatial companies. High technical expertise in surveying and mapping technology gained through several long and short-term trainings in Japan, Norway, Italy and also by getting involved and playing an important role as project coordinator of JICA high scale digital-mapping project, Norwegian Hydrographic project (ALNO-HIP) and leading the working groups to design the technical specifications for implementation of Albanian Geodetic Reference Frame (CORS, Leveling and Gravity network).

M.Sc. Eduart BLLOSHMI. Has finished Geodesy at Faculty of Construction Engineering (FIN), Tirana, in 2013. Specialist of the Geodetic Reference Frame (KRGJSH) at State Authority for Geospatial Information (ASIG). Part-time university lecturer on subjects "Road and Railway design and Engineering Geodesy" at Geodesy Department. Part-time expert for topographical works at several private construction companies. Advanced skills in Surveying (field and office processing with the latest surveying technology (Total Station, GNSS, Digital Levels) and software (AutoCAD Civil 3D), Mapping (by utilizing ArcGIS, AutoCAD Map 3D & Global Mapper).

M.Pr. Oltjon Balliu. Has finished Geodesy at Faculty of Construction Engineering (FIN), Tirana, in 2013. Specialist of the Geodetic Reference Frame (KRGJSH) at the State Authority for Geospatial Information (ASIG).
Good skills in Geospatial Information related to "Planning and Management of National Mapping and Surveying" (training in Japan from JICA).
Advanced user of geodetic instruments (Total Station, GNSS, Digital Levels) and software as (Microsoft Office; AutoCAD Civil 3D, ArcGIS, QGIS, Global Map).



GENERALIZED MODEL OF REAL-TIME DEFORMATION MEASUREMENTS

Milan VRTUNSKI[1]; Miro GOVEDARICA[2]
Aleksandar RISTIĆ[3]; Željko BUGARINOVIĆ[4]

[1,2,3,4] Department of automation, geomatics and control systems. Faculty of technical sciences, University of Novi Sad. *Trg Dositeja Obradovića 6, 21000 Novi Sad, Serbia*
e-mail: milanv@uns.ac.rs; Phone: +381 21 485 2250
e-mail: miro@uns.ac.rs; Phone: +381 21 485 2258
e-mail: aristic@uns.ac.rs; Phone: +381 21 485 2417
e-mail: zeljkob@uns.ac.rs; Phone: +381 21 485 2250


Milan VRTUNSKI


Miro GOVEDARICA


Aleksandar RISTIĆ


Željko BUGARINOVIĆ

ABSTRACT

Deformation monitoring is very important task that surveyors are faced with. Many man-made structures like bridges, dams, high buildings, as well as parts of terrain such as landslides and rockfalls have to be monitored since they present a hazard that can cause material damage, environmental degradation and even human casualties. Many technologies were used for deformation monitoring. Measurements were done periodically and the results were compared in order to detect deformations. Due to limitations of applied technologies periods between measurements were long and the time provided for measures to be taken was reduced. Nowadays modern technologies allow the possibility of real-time monitoring and thus timely response and appropriate measures.

Systems for real-time deformation monitoring have wide range of applications and can be designed specifically for the object that will be monitored. In this paper a generalized model of real-time deformation measurements is presented. The aim of the paper is to propose general procedure which, with minor modifications, can be applied in designing various systems for deformation monitoring. Model is implemented as a system that includes geodetic and geotechnical sensors, which are two most commonly used groups of sensors, and later applied in an experiment carried out in laboratory environment.

***Keywords*:** deformation measurements, real-time monitoring, geodetic sensors, geotechnical sensors

1. INTRODUCTION

With the development of modern technology and real-time monitoring, natural disasters and severe structure damage can be predicted, and their impact on the loss of life and destruction of property can be reduced. The information gathered in real time allow to obtain quick and accurate reports on the behaviour of the object being monitored and more effective planning and engineering works on prevention and mitigation. Real-time monitoring systems utilize many advantages of modern technologies and therefore have a wide range of applications. They are used to monitor man-made structures like bridges [1-3], dams [4-6], high buildings [7-9], tunnels [10-12], wind turbines [13], but also to monitor unstable terrain such as landslides and other types of slope processes [14-16].

Systems for real-time deformation monitoring consist of sensors, communication devices and computers. Sensors can be geodetic (robotic total stations, GNSS receivers, digital levels), geotechnical (tiltmeters, piezometers, extensometers, accelerometers, strain gauges etc.) and meteorological sensors (thermometers, wind speed sensors, rain gauges…). Often some auxiliary sensors are used as well. Sensors are connected to a computers by lines or by wireless communication. Communication devices enable connection of sensors using different standards. Software installed on computers is used to configure and manage the measurements and to alarm if a triggering event occurs [17].

Although each system for real-time deformation measurements is designed for a specific case certain steps that can be considered general [18]. Sequence of these steps makes a procedure which can be considered a generalized model of real-time deformation measurements.

The main purpose of real-time monitoring system is to obtain measurements that are done in automated manner. Also, certain requirements in terms of functionality, reliability, accuracy, flexibility and robustness have to be met. Steps in designing and functioning of the systems can roughly be divided into three groups:

1. Planning and designing steps;
2. System installation;
3. Exploitation of the system, i.e. conducting real-time measurements.

Planning and designing steps are based on the knowledge of the object being monitored and the capabilities and properties of technology. These steps are not automated and involve the definition of measured values, selection of sensors, locations of sensors, definition of tolerances, measuring intervals and limit values. Actions triggered by limits and alarms are defined, and error checking procedures as well. System installation involves activities such as placing sensors, connecting them, software installation and configuration and system testing. As it was mentioned before, measurements are done automatically, but some activities, such as zero-series measurements and the maintenance are exceptions.

Generalized model of real-time deformation measurements is represented in a flowchart with blocks representing mentioned activities (Fig. 1). When designing such system, some activities not strictly related to measurements have to be taken into consideration, like burglary or damage protection, but this generalized model is oriented to measurements therefore these activities are not included.

Proposed generalized model is very simple in describing performed measurements, in case when no alarm occurs. That is because no other actions than measuring is necessary, except to check if the interval between two series is elapsed or not. Also, maintenance interval has to be checked as well, but usually it is done manually, or the firmware in instruments offers that functionality, therefore this is not included in this model.

The most diverse part of the model is description of occurrence of the alarm. Alarm can occur due to various reasons: measured value is above the limit, measurement out of range, prism cannot be found by the total station, no signal from sensor, burglary sensor activated etc. Many scenarios can be present and including the detailed model for each one into general model is not possible.

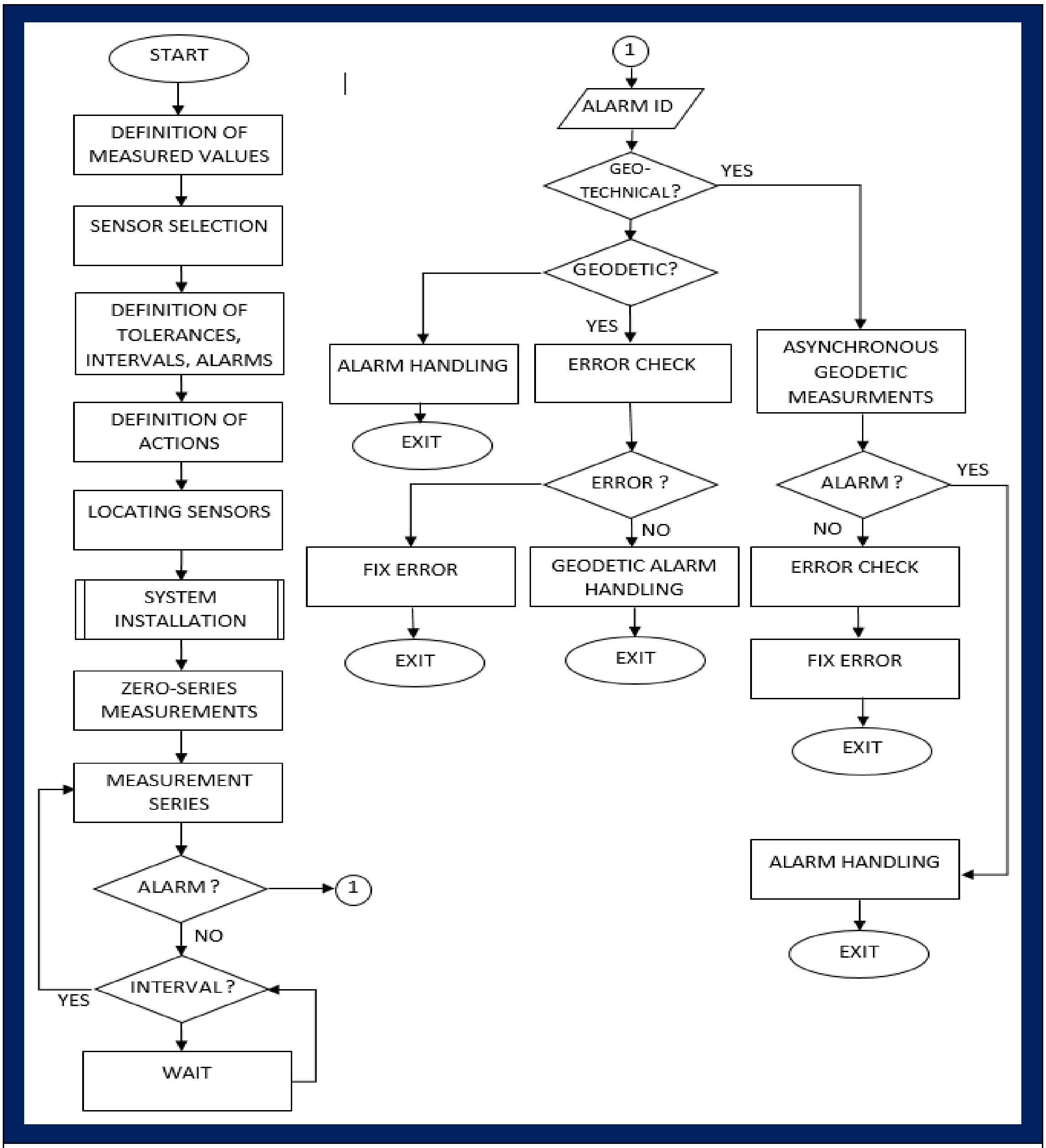


Figure 1 *Flowchart of generalized model of real-time deformation measurements.*

2. EXPERIMENTAL SETUP

An implementation of the generalized model of deformation measurements was done through the experiment conducted in laboratory environment. A system which included geodetic and geotechnical sensors, as well as software for deformation measurement was designed.

Measurements were done on a physical model that was designed in a way to simulate movements on the slope, such as on landslide, for instance (Fig. 2). Physical model is comprised of a panel on which five monitoring prisms were mounted. Sixth prism was not placed on the panel but aside of it, representing fixed point outside of the zone of expected deformations. This prism was used to detect errors in measurements. Measurements were done with Leica TCRP1201+ robotic total station, which was connected to the computer via MOXA Nport COMServer.

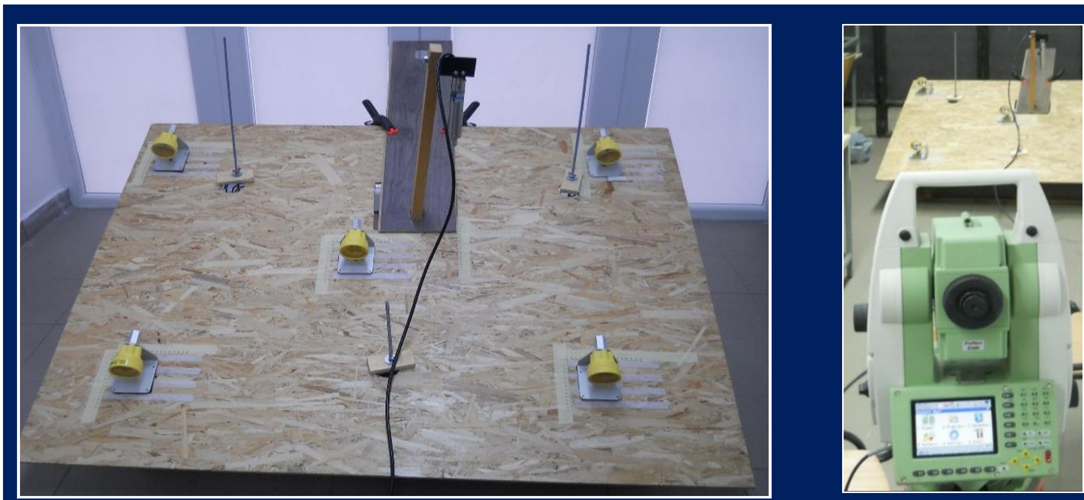


Figure 2
Physical model of slope movements (left) and Leica TCRP 1201+ robotic total station (right)

Also, a biaxial tiltmeter Geokon 6160 was mounted so that changes in inclination could be measured. Similar to prisms, it was mounted so that displacements along and across the panel could be given. Tiltmeter was connected to Campbell Scientific CR1000 DataLogger which was programmed to make readings of sensors in both A and B planes every second and to write the average value in its table every 20 seconds.

All measurements were done in Leica GeoMos Monitor software. A project was created in local coordinate system which was defined by giving coordinates of station and orientation point so that the axes (Easting, Northing) are approximately parallel to the axes of local coordinate systems of prisms (LX, LY) (Fig. 3). Also measurement intervals, tolerances and alarms were defined. Virtual sensor was designed in GeoMos so in the experiment measurements using geodetic, geotechnical and virtual sensors were done.

Experiment was designed as application of general model described above to a landslide monitoring. It was done in laboratory environment, with limited set of sensors, therefore some steps, e.g. sensor selection or locating sensors, were very simple, and definition of measured values and sensor selection were also determined by available sensors and physical model. Virtual sensor or soft sensor is a software module that enables the reliable real-time estimation of the value that cannot be measured directly, by calculating it from directly measured values.

In this experiment it was used to check the occurrence of alarm indicated by geodetic sensor measurement.

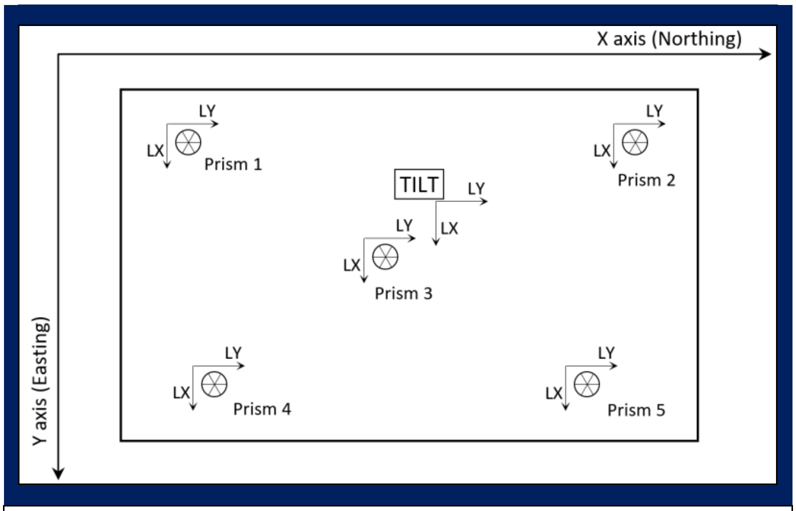


Figure 3 *Coordinate systems of project, prisms and tiltmeter*

3. RESULTS AND DISCUSSION

Six series of measurements were done, with displacement for each prism and tiltmeter were given for every series separately. Displacements were given in order to simulate the movement of the landslide body. Obtained measurements are presented in following figures.

Horizontal lines on figure 4 represent values of three levels of limit. It can be noticed that in some series measured values were above the limits which triggered the alarm. In this experiment the only action related to this alarm was displaying a warning in Message tab of GeoMos Monitoring.

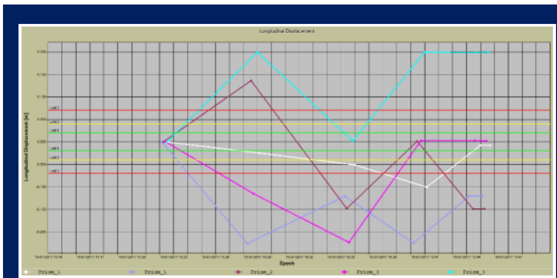


Figure 4
Longitudinal displacements of the prisms

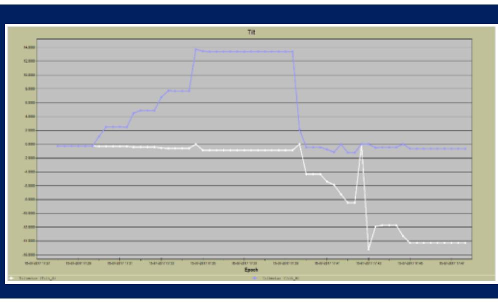


Figure 5 *Angular displacements measured with tiltmeter*

Angular displacements measured by using tiltmeter were recorded as well (Fig. 5). Even though limit values were defined, due to software limitations it was not possible to show them on the graph (as limits for prism displacements on figure 4). Obtained results were compared in order to assess the accuracy. Both given and obtained displacement are presented graphically (Fig. 6). Differences between given and obtained values are within 10mm, which is sufficient level of accuracy for landslide monitoring. Used instrument provides even higher accuracy, but non parallel axes and slight inaccuracy in positioning of prisms yield these values.

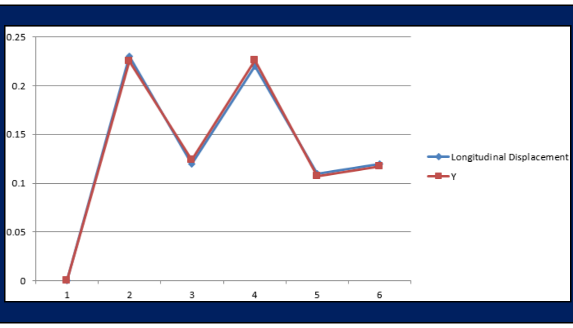


Figure 6 *Longitudinal and transverse displacement of prism1 (blue). Given displacement along Y axis of prism in local coordinate system (brown).*

Error detection using virtual sensor was also tested. If displacement greater than the limit value was measured on prism 4 and on fixed prism it meant that false reading occured on prism4 and virtual sensor Prism4_EC got value 10 (Table 1).

Limit on this virtual sensor was set to be lower than 10 so the warning message appeared, alerting that false alarm was detected.

Table 1. *Value of virtual sensor Prism4_EC used to detect error in geodetic measurements. When alarm occurred on both prisms, value became 10 indicating that themeasurement of prism4 contains an error.*

Prism4_T > 0.05	PrismF_T > 0.001	Prism4_EC	Meaning
T	T	10	False alarm
T	F	0	Alarm Prism4
F	T	0	Alarm PrismF
F	F	0	No alarm
Prism4_EC limit: 0.1			

Even though the experiment was done on a smaller scale and in controlled, laboratory environment, monitoring system implemented all important functions and properties that, according to generalized model, such system should have. Software does not provide functions for error detection, but that function was implemented as well using virtual sensor. Desingning a system based on the generalized model and some spesific demands for landslide monitoring can be a good starting point do design a real-time deformation system which would be implemented in the field.

4. CONCLUSIONS

Various applications of systems for real-time deformation measurements demand different properties, but the main goal is the same: to timely provide information of any alert. Proposed model of real-time deformation measurements involves steps that are common for almost all types of applications and presents a basis for more detailed planning and design.

Real-time monitoring system established in the experiment is based on proposed model, and includes geodetic and geotechnical sensors, communication devices and software. Several functions included in generalized model were implemented in the experiment: measurement series, alarming and error detection. Proposed general procedure can be applied in designing various deformation monitoring systems with respect to specific requirements of the application.

ACKNOWLEDGMENTS

Results presented in this paper are part of the research conducted within the Grant No. 37017, Ministry of Education and Science of the Republic of Serbia.

REFERENCES

[1] **Chae, M.J., Yoo, H.S., Kim, J.Y. and Cho, M.Y.** *(2012) Development of a wireless sensor network system for suspension bridge health monitoring. Automation in Construction, vol. 21, pp. 237-252.*

[2] **Kopáčik, A., Lipták, I., Erdélyi, J. and Kyrinovič, P**. *(2017) Deformation monitoring of Danube bridges in Slovakia by integrated measurement system. FIG Working Week 2017, Helsinki, Finland.*

[3] **Wong, K.Y.** *(2004) Instrumentation and health monitoring of cable-supported bridges. Structural control and health monitoring, vol. 11, pp. 91-124.*

[4] **Wilkins, R., Bastin, G. and Chrzanowski A**. *(2003) ALERT: a fully automated real time monitoring system. FIG Working Week 2003, Santorini, Greece.*

[5] **Scaioni, M. and Wang, J.** *(2016) Technologies for Dam Deformation Measurement: Recent Trends and Future Challenges. 3rd Joint International Symposium on Deformation Monitoring, Vienna, Austria.*

[6] **Sunantyo, T.A., Suryolelolo, K.B., Djawahir, F., Swastana, A., Darmawan, A. and Adityo, S**. *(2012) Design and installation for dam monitoring using multi sensors: A case study at Sermo Dam, Yogyakarta Province, Indonesia. FIG Working Week 2012, Rome, Italy.*

[7] **Van Cranenbroeck, J., Hayes, D.M. and Sparks, I.R.** *(2006) Driving Burj Dubai core walls with and advanced data fusion system. 3rd IAG/12th FIG Symposium, Baden, Germany.*

[8] **Kurata, N., Spencer, B.F.J. and Ruiz-Sandoval, M.** *(2005) Risk monitoring of building with wireless sensor networks. Structural control and health monitoring, vol. 12, pp. 315-327.*

[9] **Erol, B.** *(2010) Evaluation of High-Precision Sensors in Structural Monitoring. Sensors, vol. 10, pp. 10803-10827.*

[10] **Kontogianni, V.A. and Stiros, S.C.** *(2005) Induced deformation during tunnel excavation: Evidence from geodetic monitoring. Engineering Geology, vol. (79), pp. 115-126.*

[11] **Zhang, C., Ni, Y., Zhou, L. and Wang, C**. *(2017) A New Railway Tunnel Deformation Monitoring System using FBG Bending Gauges. The 2017 World Congress on Advances in Structural Engineering and Mechanics (ASEM17), Seoul, Korea.*

[12] **Tse, C. and Luk, J.** *(2011) Design and implementation of automatic deformation monitoring system for the construction of railway tunnel: a case study in west island line. FIG Joint International Symposium on Deformation Monitoring, Hong Kong, China.*

[13] **Hesse, C., Heer, R., Horst, S. and Neuner, H.** *(2006) A concept for monitoring wind energy turbines with geodetic techniques. 3rd IAG/12th FIG Symposium, Baden, Germany.*

[14] **Puglisi, G., Bonaccorso, A., Mattia, M., Aloisi, M., Bonforte, A., Campisi, O., Cantarero, M., Falzone, G., Puglisi, B. and Rossi, M.** *(2005) New integrated geodetic monitoring system at Stromboli volcano (Italy). Engineering Geology, vol. 79, pp. 13-31.*

[15] **Tu, R., Zhang, P., Zhang, R. and Liu, J.** *(2016) The study of key issues about integration of GNSS and strong-motion records for real-time earthquake monitoring. Advances in Space Research, vol. 58, pp. 304-309.*

[16] **Pingue, F., Troise, C., De Luca, G., Grassi, V. and Scarpa, R.** *(1998) Geodetic monitoring of Mt. Vesuvius Volcano, Italy, based on EDM and GPS surveys. Journal of Volcanology and Geothermal Research, vol. 82, pp. 151-160.*

[17] **Sladić, D., Vrtunski, M., Alargić, I., Radulović, A., Petrovački, D**. *(2012) Development of geoportal for landslide monitoring. Bulletin of the Serbian Geographical Society, vol. 92(4), pp. 51-62.*

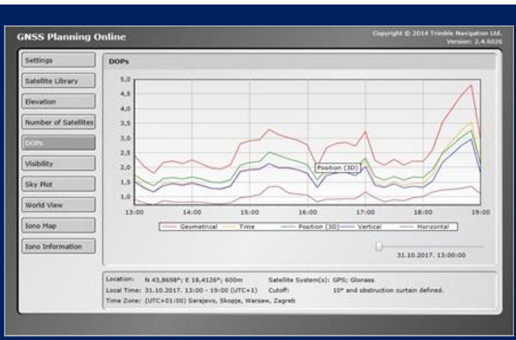
[18] **Thuro, K., Singer, J. and Festl, J.** *(2013) A Geosensor Network Based Monitoring and Early Warning System for Landslides. in Landslides Science and Practice, vol. 2 (Margottini, C. et al., eds.), Springer-Verlag Berlin Heidelberg, pp. 79-86.*

Milan Vrtunski received the M.Sc. degree in Electrical engineering and computer science at Faculty of technical sciences, University of Novi Sad. Currently he is a PhD candidate. He works as assistant at Department of automation, geomatics and control systems and teaches exercises in subjects related to sensor systems, GPR, GNSS and other geoinformation technologies. His current research interests include real-time measurement systems, development of advanced methods for joint data acquisition by GPR and other ND technologies and spatial data processing. Mr. Vrtunski published a number of papers in journals and scientific conferences proceedings and participated in many projects.

Miro Govedarica received the PhD degree in Geoinformatics and information systems at Faculty of technical sciences, University of Novi Sad. He is currently a Full Professor in the Department of automation, geomatics and control systems and lecturer in geoinformatics, remote sensing and geospatial services. Dr. Govedarica is Head of the studying program Geodesy and geomatics at Faculty of technical sciences. His research interests include geoinformation technologies and systems, remote sensing and GPR technology. He published and reviewed a number of papers in journals and scientific conferences proceedings and participated in many projects.

Aleksandar Ristic received the PhD degree in Electrical engineering and geo-informatics at Faculty of technical sciences, University of Novi Sad. He is currently an Associate Professor in the Department of automation, geomatics and control systems and lecturer in utility detection by GPR and EML, geosensor networks and control systems in geomatics. His research interests include development of inspection procedures for GPR surveying, quantitative estimation of EM and physical properties from GPR data with development of advanced GPR data processing techniques. He published a number of papers in journals and scientific conferences proceedings and was a reviewer in several journals.

Željko Bugarinović received his M.Sc. degree from the Faculty of technical sciences, Novi Sad, study program Geodesy and Geomatics. Currently he is a PhD. student of the Faculty of Technical Sciences in Novi Sad. He works as assistant at Department of automation, geomatics and control systems and teaches exercises in subjects related to application of GPR, GNSS and other geoinformation technologies. His area of research are non-destructive technologies (GPR and other) for underground utility detection, algorithms for automatic data extraction, pattern recognition and remote sensing.



HYBRID GEODETIC MEASUREMENTS IN THE URBAN ENVIRONMENT

BEST STUDENT PAPER

Jasmin ĆATIĆ

Faculty of Civil Engineering, University of Sarajevo, Sarajevo,
BOSNIA AND HERZEGOVINA
E-mail: jasmin.catic16@gmail.com; Tel: +38761708654

ABSTRACT

Hybrid adjustment is a modern approach to improve accuracy and efficiancy in geodetic networks. Combining different positioning techniques gives good results in the urban areas. Specifically, in this project the locality of Koševo in Sarajevo was designed, observed and analyzed in the network using methods such as the GNSS, total stations and leveling. Equipment used: Trimble R8 receivers, Trimble S7 total station, and for leveling network Trimble DiNi, Trimble Business Center software (TBC version 4.0), all provided by the GEOWEB project. Observation data were processed in Bosnian National coordinate system. Data were adjusted separately and also together, i.e. as hybrid network. Accuracy of the all solutions were analyzed. Results show the accuracy improvement of the coordinates in the combined network since applying new technologies and instruments.

Keywords: *Hybrid adjustment, accuracy, GNSS, Traversing, Leveling.*

1. INTRODUCTION

Hybrid geodetic measurement is modern approach that nowdays is worldwide used in design and processing of measurement in geodetic networks in Bosnia and Herzegovina. Available literature indicates that combination of GNSS and terrestrial measurements gives very good results. (Caspary, 2000). In order to use efficiently satellite observations in a combination with classical terrestrial methods (common name: hybrid measurements), many new methods around the world have been continuously developed. Using the advantages of these methods, one can increase efficiency, reliability and accuracy of the results. (Vrce and Bilajbegović, 2016, p.201). This paper describes procedure of measuring and analysing data as well as presents main results of the project that students accomplished during regular project base learning process. The modern instruments, i.e. GNSS receivers, total stations, and precise digital levels, as well as the software package Trimble Bussines Center 4.0 used in this project were provided by Erasmus+ CBHE GEOWEB.

The important thing is to choose the appropriate place to set GNSS points. Another important task for geodetic network designer is to find the optimal ratio of GNSS and traverse points. This paper presents the improved accuracy of traverse points by inserting an additional GNSS points. (Krdžalić and Vrce, 2011, p.22)

2. METHODOLOGY AND DATA

Students' work here presents advantages and disadvantages of both GNSS and terrestrial measurements methods, and also how one method complements the other. There was task to learn by doing, i.e. to carry out GNSS observations by a static method and terrestrial geodetic measurements, at the location of the field laboratory of the Faculty of Civil Engineering in Sarajevo. After determing the network, selecting and stabilizing points, observation plan is made and next were the GNSS observations. After completing it, the network was measured by terrestrial method and afterwards the leveling measurements. It was necessary to select 14 evenly spaced points, taking into account that there was no disturbance to observations at selected points. Seven Trimble GNSS receivers were available (Trimble R8 and Trimble 4000SSI with suitable antennas). Two sessions were done at every point. The design of the network was arbitrary. The length of session was calculated according to the equation (Ghilani and Wolf, 2011, p.370):

$$T = 30\,\mathrm{min} + 3\ min/km \qquad (1)$$

Before going on the field, observation plan and other parameters were determined: elevation mask 15^0, PDOP (Positioning Dilution of Precission) had to be lower than 7, each point must close the figure with other two points, vectors which close the figure must be independent. Report, with number of satellites, satellite geometry etc., is also obtained, prior to observation, using Trimble GNSS planning software (Fig.2). The measurements lasted for 2 days and this was 31.10. and 2.11.2017.

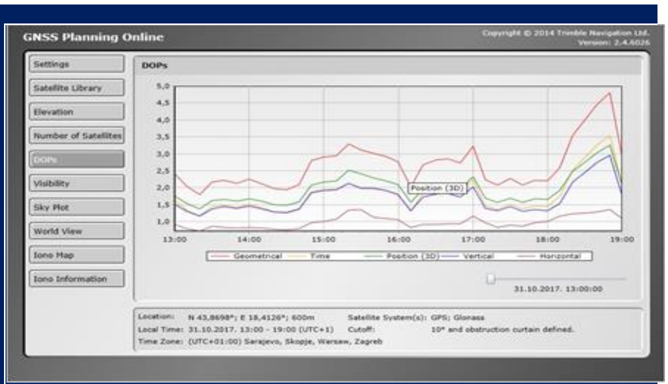


Figure 1 *Student on a field during measurement (Left),*

Figure 2 *Trimble GNSS planning software report (Right)*

Data of measurements stored in receivers were transferred to the computer to be processed, and coordinate differences of points resulted. The traverse network was measured by Trimble S7 (1") total station (Fig.3) and following equipment: Three stands, two reflectors. Horizontal angles were measured by the gyrus method, in three gyrus. Vertical angles were also measured in three gyrus in two positions of durbin. The distances were measured six-fold and two-way so that the distance between two points was measured 12 times. There were 13 new points that were connected with GNSS points, all together measured in traverse network. Atmospheric parameters, temperature and pressure, were measured and the distances were corrected by instrument itself. Obtained data were angles (horizontal and vertical) and slope distances between points. Data were recorded in instrument TS, and transfered to PC to be processed. Leveling was performed among the GNSS and traverse points to get more precise point heights. Using GNSS measurements ellipsoidal heights related to mathematicaly defined ellipsoid were obtained. However ellipsoidal heights are useless, because orthometric heights related to geoid are of geodetic interest. The geoid was defined by Gauss as the equipotential surface of the earth's gravity field coinciding with the mean sea level of the oceans. (Torge, 2001, p.76). Method performed was leveling using precise digital level (0,7 mm per km) such as Trimble DiNi 03 (Fig.4). Level network was adjusted using least squares method, conditional adjustment. Adjusted height differences were obtained and related to known height points (benchmarks). Heights of four node points were calculated and afterwards used in hybrid adjustment as fixed values.

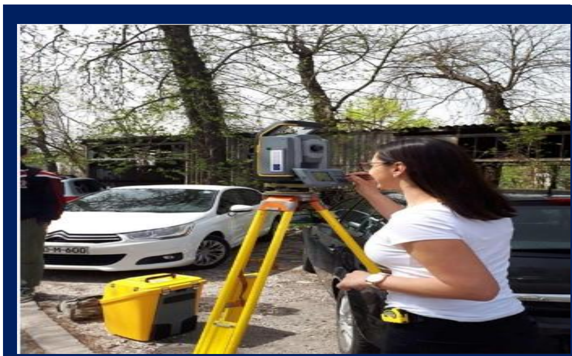


Figure 3 *TS Trimble S7 on field*

Figure 4 *Trimble DiNi 03 level*

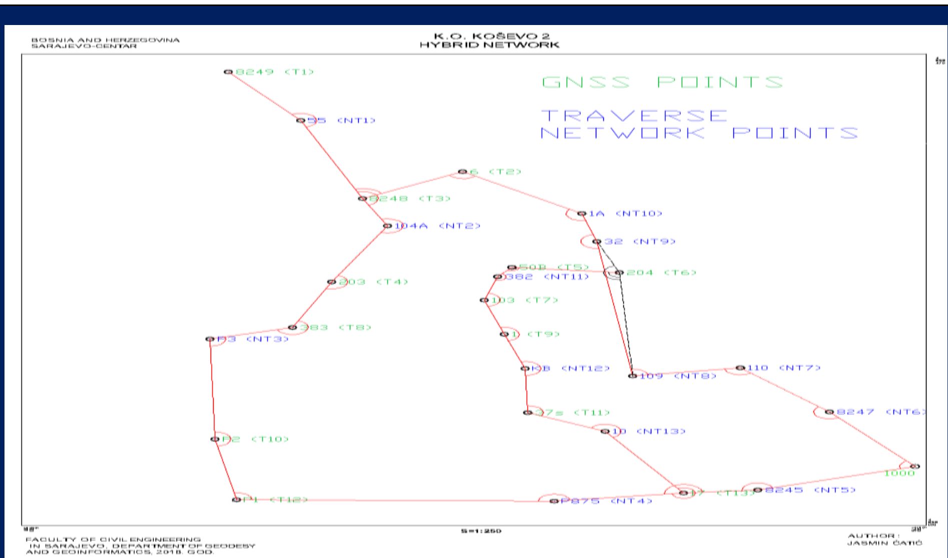


Figure 5 *The hybrid network*

2.1. DATA PROCESSING

First, data were checked in detail to correct the blunders (point names, types of antennas and receivers, and similar). Baseline processing and network adjustment were done using by the commercial software Trimble Bussines Center 4.0. The least squares method applied in the adjustment, and the entire procedure for obtaining the final positions and the heights of the points was carried out with the following steps:

1. Setting project parameters (coordinate system, projection,..) (Table 1);
2. Enter GNSS observations into software and process baselines;
3. Entering terrestrial measurements into software;
4. Minimaly constrained adjustment (one point fixed);
5. Analysing results of performed adjustment and removing data with errors;
6. Constrained adjustment (two or more fixed points);
7. Analysing results of performed adjustment and removing data with errors, obtaining final coordinates

Table 1: *Project settings*

Coordinate system	National coordinate system of Bosnia and Herzegovina (DKS BiH)
Projection	Gauss-Krueger Zone 6
Geoid model	Global geoid model EGM96

Table 2: *Apriori standard errors and weighting*

Apriori standard errors		Weigthing	
GNSS		GNSS	
Error in height of anntena	0.001m	Error horizontal	0.010m+1.0ppm
Instrument centering error	0.001m	Error vertical	0.015m+2.0ppm
Terrestrial measurements		Terrestrial measurements	
Instrument centering error	0.001m	Horizontal angle	1.000 sec
Backsight centering error	0.001m	Vertical angle	5.000 sec
Error in height of instrument	0.001m	Slope distance	0.001m+3.0ppm
Error in height of target	0.001m		

In order to make hybrid adjustment of GPS and terrestrial measurements, it was necessary to process baselines, in order to obtain coordinate differences. The selection of baselines that were processed was such that the triangular figure is closed using independent vectors. Loop closure test follows a series of procedures that check the data for internal consistency and eliminate possible blunders. (Ghilani and Wolf, 2011, p.36). Minimaly constrained and constrained adjustments were next. Performing these adjustments, the quality of the performed measurements was tested by appropriate statistical tests. The most commonly used is Chi square test. And in this example, this statistical test, as well as the Tau test.

The adjustments were repeated in a few steps, until the statistical test was passed, and until the Network Reference Factor was 1. If the measurements did not pass the statistical test, the network adjustment report was opened and the measurements were analysed. During the adjustments, GNSS network was adjusted without terrestrial measurements and afterwards including terrestrial measurements. Minimaly constrained adjustment is used to test the internal network accuracy (one point fixed). A constrained adjustment is performed to compute coordinates for the measured marks relative to the existing known control marks (Remaining points fixed). (Trimble Bussines Centre 3.7 Manual, 2016, p.38 and 51). Two points with GRID coordinates in National coordinate system of BIH were fixed and 4 node points for vertical adjustment with heights calculated by previous conditional adjustment, according to precise level network.

3. RESULTS AND DISCUSSION

Baseline processing were done without any major problems and GNSS loop closure test was performed. In loop closure test report all the figures passed the test except two figures (Fig. 6). Conducting further research it was analyzed that the error was caused by vertical parameter so this was accepted because there weren't better results with those baselines.

GNSS Loop Closure Results

Summary

Legs in loop:	3
Number of Loops:	22
Number Passed:	20
Number Failed:	2

	Length (Meter)	Δ3D (Meter)	ΔHoriz (Meter)	ΔVert (Meter)	PPM
Pass/Fail Criteria			0,030	0,050	
Best		0,000	0,000	0,000	0,258
Worst		0,069	0,028	0,063	78,773
Average Loop	1005,063	0,017	0,009	0,014	18,582
Standard Error	291,252	0,025	0,012	0,022	18,768

Figure 6 *GNSS Loop closure results*

As said, GNSS network alone was adjusted first and the coordinates were obtained. This was compared with the coordinates of the common points, which were determined five years ago (Precise terrestrial measurement network i.e. PTM) and which are considered correct. Also the coordinates obtained by hybrid adjustment were compared, and the analysis was done. Hybrid adjustment was done afterwards, minimaly constrained first. What can be concluded is that traverse points which are not between the inserted GNSS points have greater errors than points connected to the neighboring GNSS points. By fixing the remaining points constrained adjustment was performed. After the first offset, the Chi test failed, after which was found that errors were again in the measurements at the traverse points that were not connected to the GNSS points, but after the inability to correct the errors, which are still minor, weight parameters for measurements were changed and thus Chi test passed as well as Tau test for all measurements (Fig. 7).

Adjustment Statistics

Number of Iterations for Successful Adjustment:	4
Network Reference Factor:	0,99
Chi Square Test (95%):	Passed
Precision Confidence Level:	95%
Degrees of Freedom:	151

Post Processed Vector Statistics

Reference Factor:	0,96
Redundancy Number:	82,72
A Priori Scalar:	0,83

Total Station Observation Statistics

Horizontal Circle Reading:	**Reference Factor:**	1,19	**Redundancy Number:**	10,30	**A Priori Scalar:**	2,89
Vertical Angle:	**Reference Factor:**	1,03	**Redundancy Number:**	32,07	**A Priori Scalar:**	3,01
Slope Distance:	**Reference Factor:**	0,96	**Redundancy Number:**	25,90	**A Priori Scalar:**	0,92

Figura 7 *Hybrid network adjustment statistics*

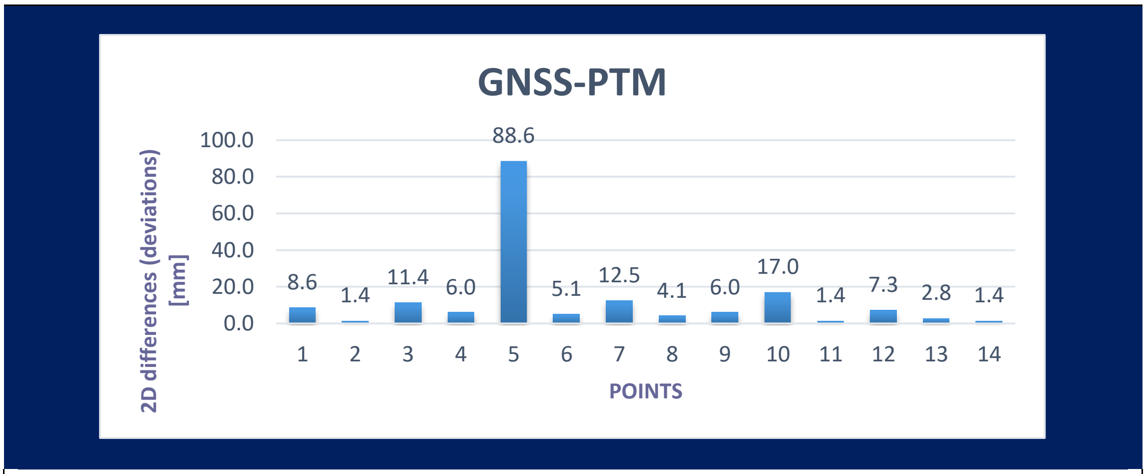


Figure 8 *2D difference of coordinates (y,x) for common points in the GNSS network and PTM network*

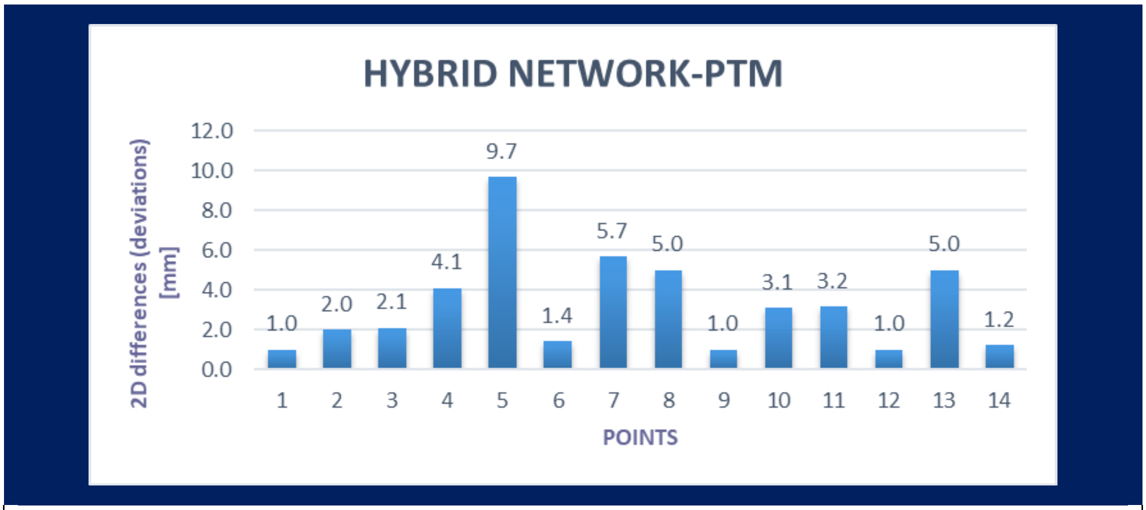


Figure 9
2D difference of coordinates (y,x) for common points in the hybrid network and PTM network

According to figures 8 and 9, coordinates of hybrid network are closer to the Precise terrestrial measurements network. Also it can be seen a blunder in the GNSS network at one point (point no. 5). The deviation of 2D coordinates was 88,6 mm, which is caused probably by poor DOP, multypath effect, etc. However, in hybrid network accuracy of coordinates of this point was improved to the 9,7 mm. Standard deviation in figure 8 is 22,4 mm and in figure 9 is 2,5 mm. When point no. 5 is excluded, standard deviation in figure 8 becomes 4,6 mm.

In 1D comparison it is obvious that heights gained by GNSS are unreliable. There are big amplitudes of differences among points which leads to bad results. On the other hand, heights obtained by hybrid network in which was included precise leveling, are more reliable and common to PTM heights. The biggest difference is 6mm which isn't big for this type of network (Figures 10 and 11). Standard deviation in figure 10 is 12,8 mm and in figure 11 is 2,0 mm.

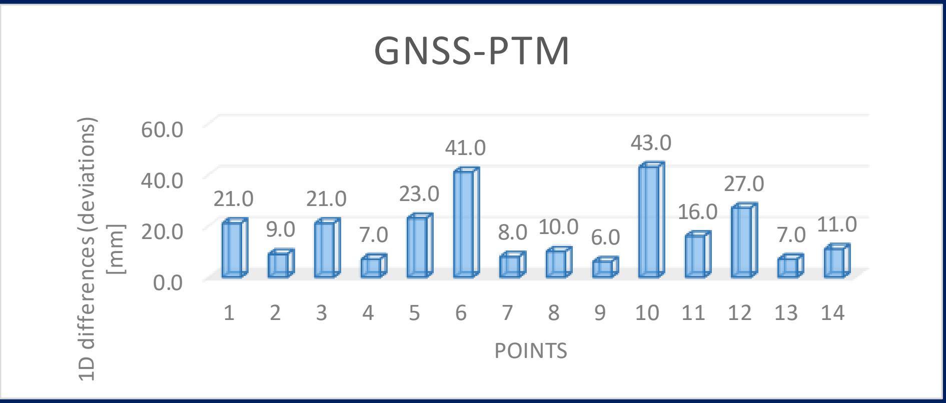


Figure 10 *1D (Height) differences (deviations) for common points in the GNSS network and PTM network*

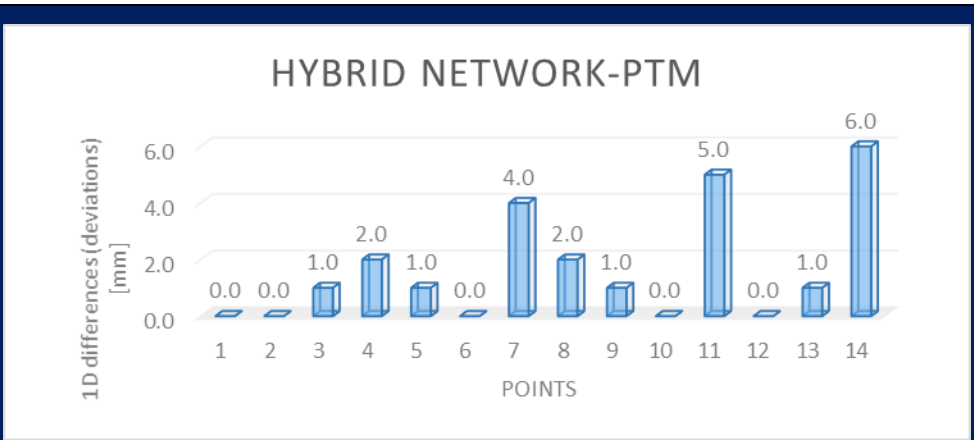


Figure 11 *1D (Height) differences (deviations) for common points in the hybrid network and PTM network*

4. CONCLUSSIONS

In this work, the adjustment model of a hybrid geodetic network was presented, it's establishment, measurement method and adjustment, along with results and comparison to the prior determined network which is found correct.

GNSS network in the urban area resulted with blunders in coordinates of point no. 5. This point was not excluded as blunder, because it was used as an experiment. Hybrid network adjustment showed improvement in accuracy for all points including this one, when the deviation of 88,6 mm was reduced to 9,7 mm. Standard deviations in two figures (8 and 9) indicates better accuracy of hybrid network approach.

Accuracy of GNSS heights were lower than hybrid network heights. Standard deviations also show improved accuracy in hybrid network heights than in only GNSS heights.

Hybrid network turned up to be more precise in both horizontal and vertical parts. Safe to say is that accuracy of the hybrid network was resulted below 1 cm. This accuracy is satisfactory by majority of projects like this one and it can be said that this project was a success.

Lately in Bosnia and Herzegovina, a similar approach has been applied to the establishment of geodetic networks for the one described in this paper. By adopting adequate rules that would regulate use of the GNSS method, as well as use of new technologies in terrestrial measurements, and combining these two in hybrid network, the quality of the performed geodetic works would be increased.

5. REFERENCES

[1]. **Vrce, E., Bilajbegović, A**. *(2016). Optimal Adjustments of 3D-Models of Hybrid Networks and Deformation Analysis. SIG 2016 – International Symposium on Engineering Geodesy, 20–22 May 2016, Varaždin, Croatia. Available online:* http://www.geof.unizg.hr/pluginfile.php/7437/mod_book/chapter/173/TS2_2.pdf *(August, 15, 2018)*

[2]. **Krdžalić, Dž, Vrce, E**. *(2011). Hybrid adjustment of GPS and classical terrestrial measurements. Geodetc Currier No. UDK 528.14, page 22-31, Sarajevo. Available online:* http://www.suggsbih.ba/GEODETSKI%20GLASNIK/GEODETSKI%20GLASNIK%2041/Krdzalic_Vrce_GG41.pdf *(August, 20, 2018)*

[3]. **TBC manual**, *(2016). Trimble Business Centre v3.7 – Planning, Processing and Adjusting GNSS Networks.*

[4]. **Ghilani, C.D., Wolf, P.R**. *(2011). Elementary surveying - An introduction to geomatics, Thirteenth edition, Pearson Education,Inc., New Jersey.*

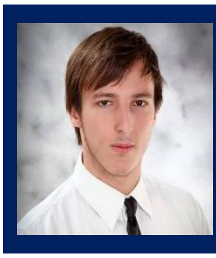
[5]. **Caspary, W.F**., *(2000). Concepts of Network and Deformation Analysis, School of Surveying, The University of New South Wales, Kensington, Australia.*

[6]. **Torge, W.** *(2001). Geodesy, Third edition, Walter de Gruyter, Berlin, New York.*

6. ACKNOWLEDGMENT

The author expresses gratitude to all students of the Bachelor program of Geodesy (Academic year 2017/2018), for their important contribution during the development of this project.

7. AUTHOR'S BIO



BSc (student**) Jasmin ĆATIĆ:** Born in 1996. Currently bachelor student at the Department of Geodesy and Geoinformatics on the Faculty of Civil Engineering, University of Sarajevo. GPA 9.0. Interested in Satellite Geodesy, Adjustment Theory, Engineering Geodesy, Cartography, Geodetic Reference Systems, and Physical Geodesy.

SOLAR FLARE EFFECT ON THE IONOSPHERE AND GNSS POSITIONING ACCURACY IN WESTERN BALKAN REGION

BEST YOUNG SCIENTIST PAPER

PhD Cand.MSc.Eng. Džana HOROZOVIĆ[1]
MSc.Eng. Randa NATRAŠ[2]; MSc.Eng. Alma TABAKOVIĆ[3]

[1]Department of Geodesy and Geoinformation, Vienna University of Technology, Austria
E-mail: dzana.horozovic@geo.tuwien.ac.at; Tel: +43 677 623 374 35
[2]Department of Geodesy and Geoinformation, Vienna University of Technology, Austria
E-mail: randa.natras@hotmail.com; Tel: +387 66 968 609; [3]BNpro d.o.o. Sarajevo
E-mail: tabakovicalma@gmail.com; Tel: +38762370511

Džana HOROZOVIĆ **Randa NATRAŠ** **Alma TABAKOVIĆ**

ABSTRACT

The solar cycle (SC) maximum and minimum are characterized by the amount of sunspot numbers on Sun's surface. The maximum of the current SC 24 was reached in 2014, when the highest amount of solar flares occurred. Despite moving towards the solar minimum, some of the strongest solar flares appeared in September 2017, which is unusual to happen during SC decline phase. Activities on the Sun can cause disturbances in the ionosphere and near-Earth environment, which further can affect the propagation of GNSS (Global Navigation Satellite System) signals from satellites through the atmosphere to a receiver on the Earth. In this work, the impact of solar events on GNSS coordinate estimates, the conditions in the ionosphere and the geomagnetic field have been investigated. The second half of October 2014 within the solar maximum and the first half of September 2017 within transition to solar minimum, when the strongest solar flares during the current SC 24 occurred, were selected as study periods. GNSS observations of Western Balkan ground-based EPN (EUREF Permanent Network) stations were used to derive TEC (Total Electron Content) in the ionospheric regions to F layer, and to estimate static positioning coordinates, using Bernese v.5.2. Data from corresponding SuperSID (Sudden Ionospheric Disturbances) space weather monitors were used to analyze the ionospheric D layer.

Keywords: *Solar flare, Total Electron Content, Ionosphere, GNSS, Positioning accuracy, Western Balkan*

1. INTRODUCTION

In the last few decades geodesy has rapidly evolved following development of new technologies. New technologies such as Global Navigation Satellite Systems (GNSS) opened new questions, which geodesy can help addressing and solving. One of these areas is remote sensing of atmospheric properties, such as the ionized part of the Earth's upper atmosphere – the ionosphere, which has a major effect on the accuracy of GNSS applications. Today's geodesists can play an important role in observing the conditions in the ionosphere by providing information to mitigate its effect on GNSS signals. To do so, additional tools and data are needed to monitor activities happening on the Sun, the near-Earth environment and geomagnetic field. Without those aspects, it is impossible to properly model the ionosphere and develop accurate forecasting models, which are crucial for providing reliable and precise solutions in GNSS positioning and navigation.

Sudden explosions, which appear on the Sun's surface, are known as solar flares. They release a huge amount of radiation from its inner region into space, which can trigger phenomenon known as space weather. If strong enough, it can produce the interference of the released radiation with radio communications on Earth, affect GNSS signal propagation and even harm satellites [1]. Approximately every 11 years, the Sun's magnetic field experiences a reorientation of its magnetic poles, which is known as the solar cycle (SC). It is defined by the amount of sunspots, dark regions on the Sun's surface where the magnetic fields are pronouncedly strong. Therefore, the SC has periods of solar minimum, when the Sun has the least amount of sunspots and solar maximum with the highest amount of sunspots. With the number of sunspots, the occurrence of solar flares is increasing as well, hence the frequency of solar flare occurrences coincides with the 11-year solar cycle [2].

The current SC 24, which began at the end of 2008, reached its peak in 2014, after which it started heading towards its solar minimum. During 2014 a total of 16 solar flares of class X occurred (the strongest solar flare class), where 6 of them happened only in October. The amount of solar flares decreased extremely in the following years as expected, which can be seen in Table 1. However, the strongest solar flare within the SC 24 occurred in September 2017. More information on solar cycle progression, current and earlier solar flare statistics, can be found on: https://www.spaceweatherlive.com/.

Tabela 1 *Yearly amount of solar flares from 2014 up to 2017 within SC 24. (https://www.spaceweatherlive.com/)*

SC 24	Solar flares	Strongest solar flare	Occurrence
2014	1999	X4.9	25.02.2014
2015	1495	X2.7	05.05.2015
2016	335	M7.6	23.07.2016
2017	280	X9.3	06.09.2017

Solar radiation produces free electrons and ions contained in the Earth's upper atmosphere, the ionosphere. Those free electrons have an impact on the propagation of GNSS signals on their way from satellite to receiver, causing signal's phase advance and group delay. Depending on the SC phase, solar activity can have a stronger or weaker impact on the variability of the electron content in the ionosphere and further on GNSS applications. Using dual-frequency GNSS observations, the amount of free electrons, the total electron content

(TEC), can be mitigated from GNSS observations. However, single-frequency receivers, available for the mass market, do not have such a possibility and require additional information from ionospheric broadcast models (e.g., Klobuchar, NeQuick-G) to minimize effects of the ionospheric refraction [3]. Recent studies in Bosnia and Herzegovina have covered the investigation of the ionospheric D layer [4], the ionospheric TEC variability [5] w.r.t. pronounced space weather and moderate seismic activity [6], as well as the impact of the ionospheric variability on precise point positioning during the strongest geomagnetic storm activities within the SC 24 [7]. A first ionosphere TEC model based on GNSS national infrastructure existing in Bosnia and Herzegovina is currently under development [8].

The aim of this study was to broaden the research to the region of the Western Balkan in order to analyze the impact of solar activity on the ionosphere and on GNSS positioning estimates during two opposing periods of SC 24. The study periods were selected to be the second half of October 2014 (12.10.2014-01.11.2014), during pronounced solar activity in the solar maximum, and the first half of September 2017 (27.08.2017-16.09.2017), during higher solar activity and occurrence of the strongest solar flare in SC 24, despite approaching the solar minimum.

2. METHODOLOGY

For this study, different datasets have been used. GNSS observations of Western Balkan ground-based EUREF Permanent Network (EPN) and International GNSS Service (IGS) stations were used to derive the ionospheric TEC, and to derive static precise point positioning (PPP) coordinate estimates, using Bernese GNSS Software v.5.2 (Fig.1). The geomagnetic activity was presented by the disturbance storm time index (Dst) (http://swdcwww.kugi.kyoto-u.ac.jp/dstae/index.html) and the Kp index (ftp://ftp.gfz-potsdam.de/pub/home/obs/kp-ap/wdc/). The solar activity was analyzed utilizing the sunspot number index (SN) (https://omniweb.gsfc.nasa.gov/), as well as data from the Geostationary Operational Environmental Satellites (GOES) and Sudden Ionospheric Disturbances (SuperSID) space weather monitors located in Western Balkan (Fig.1).

Figure 1
Selected GNSS permanent stations in region of Western Balkan: 8 EPN stations (in yellow), 1 EPN/IGS station (in green) included in PPP and TEC estimation and 4 SuperSID monitors included in solar flare detection (in blue).
Source:
http://epncb.eu/_networkdata/stationmaps.php

Space weather monitors are permanently collecting data of chosen very low frequency (VLF) transmitters located all over the world. The SuperSID software was developed at the University in Stanford and is being used to track sudden ionization in the ionospheric D layer due to the occurrence of solar flares (http://solar-center.stanford.edu/SID/DOC/SuperSID-Manual.pdf/). Graphical representations of the collected SuperSID data were used to verify whether the chosen monitors were able to detect the occurrence of stronger solar flares (M and X class) during the study periods. The validation included the comparison to the x-ray flux plots provided by GOES (ftp://ftp.swpc.noaa.gov/pub/warehouse/2014/2014_plots/xray/), as well as to the catalogue of solar events (ftp://ftp.swpc.noaa.gov/pub/warehouse/2014/). In order to perform the estimation of TEC from GNSS observations, the ionosphere was approximated by a single-layer model (SLM) [3]. This model assumes that all free electrons are concentrated within an infinitely thin layer at a fixed height of 400 km above the Earth's surface. The TEC calibration was performed by the Ciraolo methodology [9] with a sampling time rate of 300 seconds. Further, slant TEC values were mapped into vertical TEC values (VTEC). Position estimates (reference frame IGb08) were derived by processing static PPP solutions utilizing the Bernese v.5.2. By applying the L3 ionosphere-free linear combination, the first order ionospheric effects were removed from the observations (http://www.bernese.unibe.ch/docs/_DOCU52.pdf). The results were compared to the EPN weekly combined solution (ftp://epncb.eu/pub/product/combin/). For both, the TEC and static PPP, GPS and GLONASS satellite systems were applied.

3. RESULTS

3.1. Space Weather indices

During October 2014, high solar activity was recorded in the second half of the month, with the peak from 20th to 27th October. Geomagnetic activity was mostly quiet and moderate. At 31st August, temporary disturbances of the Earth´s magnetosphere, known as geomagnetic storms, are observed, but were minor. However, the severe geomagnetic storm occurred on 08th September. The amount of sunspots has doubled within the day of 04th September and remained high until the 10th September, which is connected with higher solar radiations and strong solar flares detected in the following days (Fig.2).

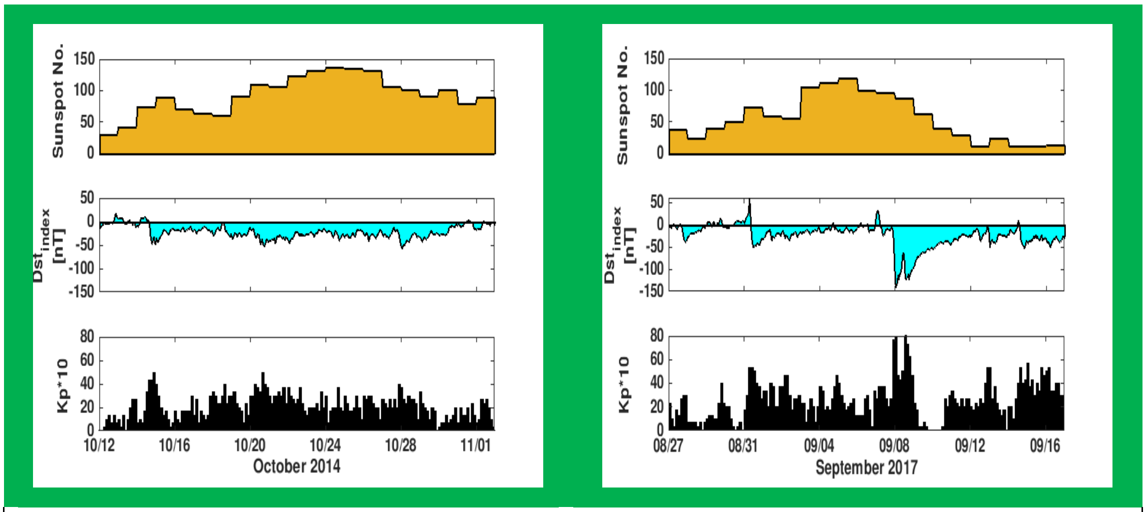


Figure 2 *Space weather indices left: October 2014, right: September 2017. From up to bottom: Sunspot number, indices of geomagnetic activity: Dst (disturbance storm time) and Kp index (Quiet K<3, Moderate 3≤K<4, Active 4≤K<5, Storm 5≤K).*

3.2. Solar flares detection

The frequency of occurred M and X class solar flares was observed. According to this, only flares that occurred during local daytime of the monitors were taken into account, hence, the time when the monitors on the Earth were directed to the Sun. A statistics with the amount of M and X class solar flares that occurred during local daytime is presented below (Tab.2). In both periods a similar amount of X and M solar flares was observed with a total number of 16 strong solar flares.

Table 2 *Statistics counted in reference to local sunrise and sunset*

Solar flare class	Amount of solar flares occurred	
	12.10.2014-01.11.2014	27.08.2017-16.09.2017
X	3	4
M	13	12
Total	16	16

For both study periods, Space weather monitor data for days (27.10.2014 and 10.09.2016.) with pronounced solar flare activity are shown in Fig.3.

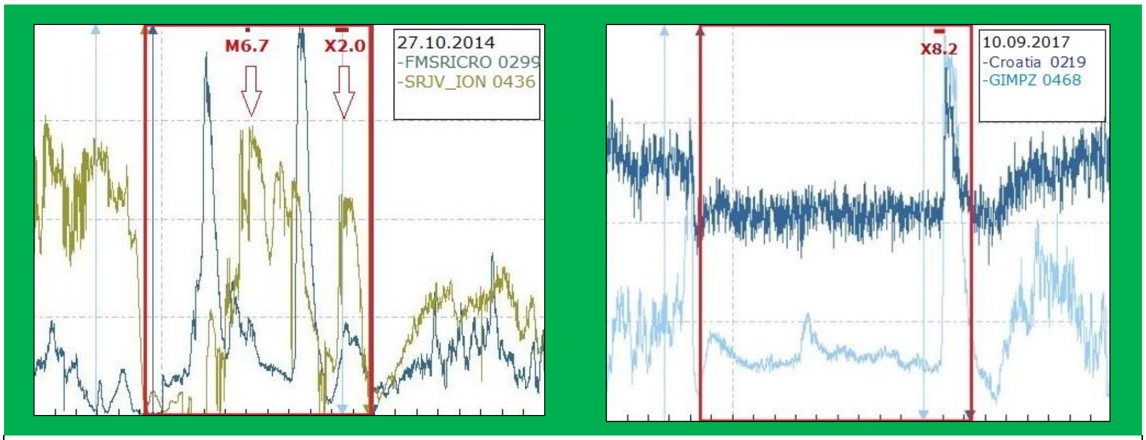


Figure 3 *One day SuperSID plots. Left: 27.10.2014, right: 10.09.2017. Daytime is marked with red boxes. For both days, monitors show a good agreement with the occurrence of solar flares detected with GOES (red labeled). (http://sid.stanford.edu/database-browser/)*

For the first period monitors FMSRICRO 0299 (Rijeka, Croatia) and SRJV_ION 0436 (Sarajevo, Bosnia and Herzegovina) were taken into account. The monitors Croatia 0219 (Zagreb, Croatia) and GIMPZ 0468 (Pozega, Croatia) were used for the second time frame. For all monitors, data from the VLF transmitter DHO (Rhauderfehn, Germany) was collected.

3.2.1. GNSS-based VTEC variability

Ionosphere VTEC variations during the two study periods are presented on Fig.4 In October 2014 VTEC values are mostly about 30-40 TECU, with a maximum >50 TECU, while in September 2017 VTEC variability is ~2 times lower with values mostly <20 TECU. This shows an impact of different phases of SC on the ionospheric VTEC variability.

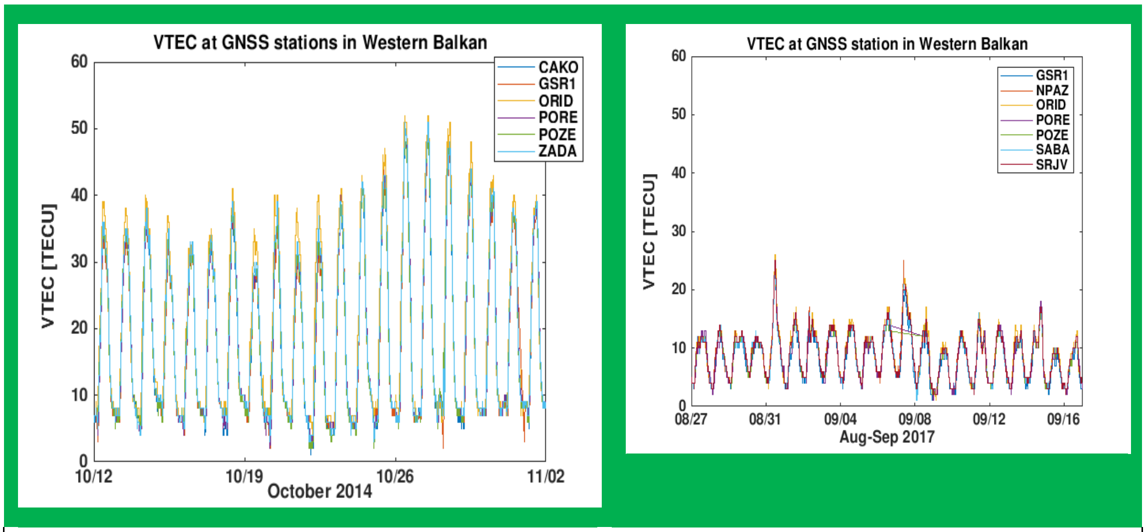


Figure 4 *VTEC values estimated from GNSS observations. Left: 12.10.2014-01.11.2014, maximum values are mostly 30-40 TECU. A significant VTEC increase can be noticed from 26th to 28th October (>50 TECU). Right: 27.08.2017-16.09.2017, maximum values are mostly around 15 TECU. Two short-term VTEC increases can be noticed on 31st August and 07th September (~25 TECU), followed by decrease (<10 TECU) the next few days.*

Increase of VTEC values in the first study period, starting from 23th October and reaching maximum on 26th and 27th, coincides with the occurrence of strong solar flares. As this period was characterized by quiet conditions in geomagnetic field, a higher amount of electrons in the ionosphere is produced by higher solar radiation. During the second study period, VTEC shows higher variability on 31st August and from 07th September until 11th September. These periods coincide with geomagnetic storms. Therefore those variations are induced by temporary disturbances of the Earth´s magnetosphere.

3.2.2. GNSS positioning solutions

In Fig.5 differences of the static PPP solution w.r.t. the weekly EPN combined solution in the Up component are presented. Stations shown below are chosen based on the availability of observation files. After 22nd October, higher deviations can be noticed for stations GSR1, CAKO, POZE and ZADA (~15mm). The differences remained higher until the end of the month, which coincides with higher VTEC values during this period, as well as with the occurrence of stronger solar flares of class M and X. A similar behavior is not visible for the second study period. Higher differences, which are visible for stations SABA and SRJV on the 10th September, might be correlated with the occurrence of one of the strongest solar flares of SC 24. However, these deviations are not visible in the static coordinate solution for GSR1 and ORID. It can be observed that on 04th and 5th September higher coordinate deviations are observed at all stations, when the solar radiation increased rapidly and reached at least twice higher values then the average amount of radiation for this period of solar cycle. Remained higher coordinate deviations for both periods can be addressed to the higher order ionospheric (HOI) effects.

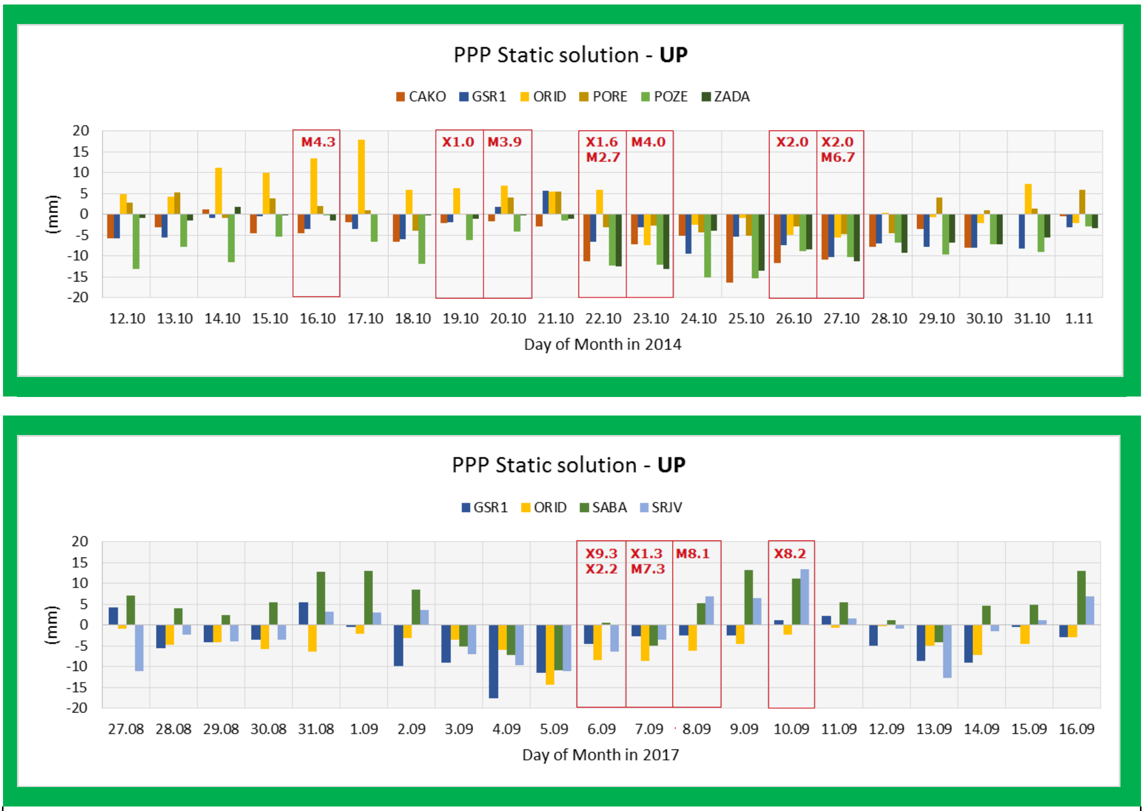


Figure 5 *Comparison of the static PPP coordinate w.r.t. the weekly EPN combined solution in Up component for the period. Top: 12.10.2014-01.11.2014 and bottom: 27.08.2017-16.09.2017. Days marked with red boxes refer to periods of stronger solar flare occurrence. Those days are labeled with the corresponding solar flare class.*

4. CONCLUSIONS

In this study two periods of higher pronounced solar activity and solar flares within the SC 24 were investigated. The second half of October 2014 was not influenced by geomagnetic storms, while the first half of September 2017 was under influence. During the first study period, stronger solar activity affected the ionosphere, which was further mapped into higher TEC variability during periods of stronger solar flare occurrence. Similar behavior can be noticed in the static PPP results, where GNSS stations showed higher coordinate variations in the second half of October.

The second timeframe, as mentioned, was affected by the presence of geomagnetic storms, as well as by unexpected stronger solar flares. The VTEC variability was twice as lower compared to October 2014, which is due to the effect of the SC phase (in 2017 the SC was heading towards its solar minimum). The sudden VTEC variability was mainly influenced by geomagnetic storms which happened during September 2017. The coordinate differences of the static PPP solution showed periodical variations throughout this whole period and while higher coordinate variations might have been affected by stronger solar flares, still a high variability could be noticed during days without strong solar flare activity as well. Pronounced coordinate deviations in both periods were caused by remaining HOI effects.

5. RECOMMENDATIONS

In order to have a better understanding on activities in the ionosphere, a larger period of observations should be used.

Instead of using only static PPP, it would be recommended to combine it with a kinematic PPP solution.

Applying a local ionosphere TEC model of high spatial and time resolution for the observed area on one-frequency GNSS observations would help to check the accuracy that could be achieved compared to the usage of global models, which have limited accuracy and precision. This model is currently under development for Bosnia and Herzegovina. The effect of solar flares could be observed in periods free of geomagnetic storms, in order to reduce their influence.

For better understanding and mitigation, further and detailed study of space weather is needed in the area of Western Balkan, because of the limited amount of existing research. Finally, local/regional ionospheric models need to be implemented in the local geodetic positioning service infrastructure, to transmit corrections for users in real time.

6. LITERATURE

[1]. **National Space Weather Strategy**, *Product of National science and technology council, Space weather operations, research and mitigation (SWORM) task force, USA, October 2015.*

[2]. **Lang,K.R.,** *The life and death of stars, Cambridge University Press, ISBN 978-107-01638-5, 2013.*

[3]. **Schaer, S**., *Mapping and predicting the Earth's ionosphere using the Global Positioning System, PhD thesis, Bern University, Switzerland, 1999.*

[4]. **Horozovic, Dz**., *Investigation of ionosphere and space weather and their application in positioning and navigation, MA thesis, Faculty of Civil Engineering, University of Sarajevo, 2014.*

[5]. **Natras, R**., *Research of ionosphere with geodetic methods and estimation of TEC from GNSS observations, MA thesis, Faculty of Civil Engineering, University of Sarajevo, 2016.*

[6]. **Mulic, M., Natras, R., Horozovic,Dz., Krdzalic, Dz.,** *Investigation of Ionospheric Variations and Sudden Disturbances as a Source of GNSS Errors and Earthquake Precursor, SJCE- Scientific Journal of Civil Engineering, Vol. 6, Issue 2, ISSN 1857-839X, pp 61-68, 2017.*

[7]. **Horozovic, Dz., Natras, R., Mulic, M.,** *Impact of geomagnetic storms and ionospheric dis-turbances on mid-latitude station's coordinates using static and kinematic PPP, Poster: European Geosciences Union, General Assembly 2018 (EGU 2018), Vienna, in: "EGU General Assembly 2018", Geophysical Research Abstracts, Vol. 20, ISSN: 1029-7006; 9009, 2018-04-08 - 2018-04-13.*

[8]. **Natras, R., Magnet N., Boisits, J., Weber, R**., *GNSS-based Regional Ionosphere Modeling over Bosnia and Herzegovina; Poster: European Geosciences Union, General Assembly 2018 (EGU 2018), Vienna; 09.04.2018 - 13.04.2018; in: "EGU General Assembly 2018", Geophysical Research Abstracts, Vol. 20 (2018), ISSN: 1029-7006; p. 661, 2018*

[9]. **Ciraolo,L., Azpilicueta,F., Brunini,C., Meza,A., Radicella,S.M**., *Calibration error on experimental slant total electron contents (TEC) determined with GPS, J. Geod., 81 (2), pp 111-120, 2007.*

7. AUTHORS BIO

MSc.Eng. Dzana HOROZOVIC; MSc in Geodesy is a PhD student and University Assistant at the Vienna University of Technology, Department of Geodesy and Geoinformation in Austria. She earned her Master degree in Geodesy at the University in Sarajevo, Faculty of Civil Engineering in 2014. Her work focuses on the estimation of earth rotation parameters based on a network adjustment of globally distributed GNSS stations using multi-GNSS solutions and the investigation of ionospheric and space weather effects on ground-based GNSS station observations utilizing precise point positioning (PPP) and regional network solutions.

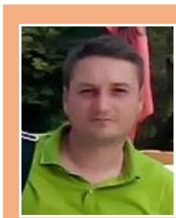
MSc.Eng. Randa NATRAS; MSc in Geodesy from University of Sarajevo, Bosnia and Herzegovina, with distinction „The Charter of the University of Sarajevo“ awarded in 2016. Randa was research scholar at Vienna University of Technology, Austria from 11/2017 to 07/2018 under Ernst Mach Grant worldwide awarded by the Austrian Agency for International Cooperation in Education and Research (OeAD-GmbH) for research project “Regional ionosphere modelling over Bosnia and Herzegovina using Global Navigation Satellite System”. Randa does research in the field of GNSS-based ionosphere modelling, investigation of space weather and atmospheric effects on GNSS signals as well as their impact on the accuracy and reliability of GNSS applications.

MSc.Eng. Alma TABAKOVIC; MSc in Geodesy is currently employed at geodetic company BNpro d.o.o. Sarajevo, as a licensed geodetic engineer. She studied Geodesy on Faculty of Civil Engineering, Department of Geodesy at University of Sarajevo, where she earned her master diploma. Among everyday surveying works, her main focus is on estimation of parameters of transformation for Bosnia and Herzegovina-field works, harmonization data between cadaster and land book, as well as Trimble equipment dealership. Alma is a member of GEOWEB project.

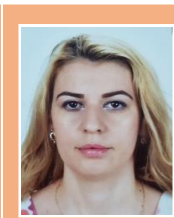
THE HISTORICAL DEVELOPMENT OF GLOBAL MAPPING

Cand.Dr.Sc. Milot LUBISHTANI[1]; Assoc. Prof. Dr. Bashkim IDRIZI[2]; Cand.Dr.Sc. Fitore Bajrami LUBISHTANI[3]

[1]Department of Geodesy, Faculty of Civil Engineering, Polytechnic University of Tirana, Albania.*E-mail: milot.lubishtani1@hotmail.com; Tel: 0038344720210*
[2]Faculty of Civil Engineering and Architecture, University "Mother Teresa", Skopje; Macedonia.
E-mail: bashkim.idrizi@unt.edu.mk; Tel: 0038975712998
[3]Faculty of Civil Engineering and Architecture
University of Prishtina"Hasan Prishtina" Prishtinë, Republic of Kosovo.
E-mail: fitore.bajrami@uni-pr.edu; Tel: 0038344710371


Milot LUBISHTANI


Bashkim IDRIZI


Fitore B LUBISHTANI

ABSTRACT

A map is a graphic representation or scale model of spatial concepts. It is a means for conveying geographic information. Maps are a universal medium for communication, easily understood and appreciated by most people, regardless of language or culture.
Global map was borne as a product to replace previous IMW (1:1.000.000) with a new map in digital form with the homogeneous standards for entire globe.

Non-contemporary standards of International World Map in a scale of 1:1,000,000 dating from 1891, the development of digital technology, the need for recognition of global geospatial data, and using updated datasets, in 1992 in Rio de Janeiro in Brazil was proposal for establishing of Global Map (GM) in scale 1: 1,000,000 and 30" spatial resolution.

Global Map with its consistent quality and data standards is a handy tool to monitor the environmental status at regional and global scale, which may have limited uses at national and local scales.

In order to promote the Global Mapping Project, as well as to develop global geospatial information needed to solve global-scale issues, to provide them widely, and to promote the use of global information in cooperation with the respective countries, in year 1996 the International Steering Committee for Global Mapping (ISCGM) composed by representatives of geospatial information authorities of respective countries and by the experts in this field was established.

The primary objective of Global Mapping project was to contribute to the sustainable development through the provision of base framework geographic dataset, which is necessary to understand the current situation and global changes of environment in the world. With the Global Map dataset being in digital form, it lends itself to various data manipulation and for modeling real life situations. Global Map dataset may have limited uses at national and local scales, however Global Map dataset is needed to address global, regional, and trans-boundary and in many cases national concerns.

From September 2016, due to decision of ISCGM for transfer of GM data to UNGIS database, GM data set has been migrated to the United Nations Geospatial Information Section (UNGIS), which has been formalized on August 2016 in New York, during the final (23rd) meeting of ISCGM.

Key words: Global Mapping, ISCGM, UNGIS, GM datasets.

1. INTRODUCTION

Global Map is a set of digital maps that accurately cover the whole globe to express the status of global environment. It is developed through the cooperation of National Geospatial Information Authorities (NGIAs) in the world. An initiative to develop Global Map under international cooperation, the Global Mapping Project, was advocated in 1992 by Ministry of Construction, Japan.

World map with a scale of 1: 1,000,000 dating from 1891 and the development of technology and the need for recognition of global geospatial data and these data are as update, in 1992 in Rio de Janeiro in Brazil was proposal creation world global digital mapping in scale 1: 1,000,000.

GM database contains four vector layers (population centers, transportations, drainage and boundaries) and raster layers (land cover, land use, vegetation and elevation) at scale 1:1.000.000 with spatial resolution of 30" (arc seconds of longitude and latitude).

State Authority for Geospatial Information (ASIG) and geodesy department of the Polytechnic University of Tirana as represent from PHD Candidate realized vector and raster data for GM version 2 for Albania and these data published on 21st July 2016 in www.iscgm.org.

2. GLOBAL MAPPING

Global Map World is an international project which states, namely state agencies dealing with geospatial qualified data apply for membership on a voluntary basis, of course applying established standards for membership.

The primary objective of Global Map project is to contribute to the sustainable development through the provision of base framework geographic dataset, which is necessary to understand the current situation and changes of environment of the world.

Global mapping is an international collaborative initiative through voluntary participation of national mapping organizations of the world, aiming to develop globally homogeneous geographic data set at the ground resolution of 1km for raster data and vector data in scale 1:1.000.000, and to establish concrete partnership among governments, private sectors, data providers and users to share information and knowledge for sound decision-making.

The purpose of the Global Map is to accurately describe the present status of the global environment in international cooperation of respective National Mapping Organizations (NMOs) of the world, aimed for (Idrizi, 2007a):

- Monitoring and early warning systems for natural disasters;
- Developing ecosystem, drainage basins framework for environmental assessment;
- Monitoring and management of natural resources;
- Quantifying trans boundary issues;
- Assessment of the trends of environment changes;
- Rapid response capability/early warning;
- Local, national and multinational physical development planning;
- Environmental priority setting, analytical studies over large areas and
- Informed decision-making of policy makers with a strategic database.

Increasing demand and the need to be qualified data geospatial and their use for achieving a result set and necessary and cost as little as possible, many European countries and the Balkans have handed over the data as geospatial on the global map with a scale of 1:1.000.000 and as such as Macedonia in 2006, Romania in 2009, Bulgaria in 2009, Kosovo in 2010 and Albania in 2016.Despite the maps prepared in local/national standards, GM dataset enable (Idrizi, 2006):

- All data of Earth to be in one place;
- With the same attributes;
- In the same format;
- In the same coordinate system;
- In the same scale and
- With similar accuracy.

The main objective of this global project is to bring all nations and concerned organizations together to collaboratively develop and provide easy and open access to worldwide geographic information at a scale of 1:1,000,000. The use of these data will facilitate the implementation of global agreements and conventions for environmental protections; will support the monitoring of major environmental phenomena; and will encourage economic growth within the context of sustainable development.

The benefits of participation in Global Mapping for: include: Joining the world community of surveying and mapping organizations will facilitate the acquisition of the latest information and knowledge of digital geographic data development and service; it would also facilitate to raise the status of the organization by active participation in international activities and the contribution to sustainable development which is the final goal of Global Mapping Project.

Figure 1 *World Map*

Global Map is fundamental digital geospatial information being developed to cover the whole land of the globe. It is an effort central to the Global Mapping Project. Global Map data have been developed under the cooperation of National Geospatial Information Authorities (NGIAs) of respective countries and regions. Geospatial information developed and authorized by NGIAs of respective countries and regions around the world;

The ISCGM takes the central role in conducting the Global Mapping Project to develop and provide Global Map data set with the following characteristics:

- Data are updated in every five years as a target cycle;
- Fundamental geospatial information covering the whole land of the globe;
- -Digital geospatial information composed of eight layers being developed with consistent specifications.
- Freely available for download, and in case of non-commercial purposes, in principle, anyone can use the data freely;

3. HISTORY OF GLOBAL MAPPING

For the first time, the idea of compiling a world map in digital format based on GIS technology was proposed in 1992 at the international conference of Rio de Janeiro in Brazil.

In 1996, in Tsukuba of Japan, was held the second international meeting for the design of the GM, whereby the International Steering Committee for Global Map Development (ISCGM) was established.

In 1994, Geographical Survey Institute of Japan (GSI) proposed the first draft set of technical specifications. The Global Map project has grown significantly to involve the participation of many interested nations.

In 1998, with a United Nations Recommendation letter, the ISCGM invited National Cartographic Organizations all over the world to participate in the GM drafting project.

In 2000, the GM "Version 0" was compiled. In 2002, in Johannesburg was approved the action plan for the compilation of Global Map Data, according to which by the end of 2007 the compilation of the GM was to be completed.

In 2005, a new thematic layer was created within the GM, namely the Earth's cover and the percentage of land cover with wood, which on 05.06.2008 was published on the ISCGM official website (www.iscgm.org) as Global Map V1Global Version. After the moment of publication of the two thematic layers, the databases of individual states / regions were named as Global Map V1-National & Regional Version.

From 1996 to 2007, the ISCGM held 14 international meetings, including:

- 14.02.1996, Tsukuba-Japan, the first meeting of the ISCGM;
- September 16th, 1996, Santa Barbara-USA, Second Meeting of the ISCGM;
- 15.11.1997, Gifu-Japan, Third Meeting of the ISCGM;
- 8.06.1998, Sioux Falls-USA, Fourth Meeting of the ISCGM;
- November 20th,1998, Canberra-Australia, Fifth Meeting of the ISCGM;
- 24.07.1999, Cambridge-England, Sixth Meeting of the ISCGM;
- 16.03.2000, Cape Town- South Africa, the seventh meeting of the ISCGM;
- 25.05.2001, Cartagena-Colombia, Eighth meeting of the ISCGM;
- 20.09.2002, Budapest-Hungary, Ninth Meeting of the ISCGM;
- 11.07.2003, Ginowan, Okinawa-Japan, tenth meeting of ISCGM;
- 07.02.2004, Bangalore-India, Eleventh Meeting of the ISCGM;
- 17.04.2005, Cairo-Egypt, the Twelfth Meeting of the ISCGM;
- 11.11.2006, Santiago-Chile, Thirteenth Meeting of the ISCGM;
- 14.07.2007, Cambridge-England, Fourteenth Meeting of the ISCGM;
- 04.06.2008, Cambridge-England, Fifteen Meeting of the ISCGM;
- Since 1997, the ISCGM has organized several international forums for the GM, including:
- 12.11.1997, Gifu-Japan, the first form ISCGM'
- June 15th, 1998, Sioux Falls-USA, Second Forum of the ISCGM;
- 27.11.2000, Hiroshima-Japan, Third Forum of the ISCGM;
- 05.06.2008, Tokyo-Japan, Fifth Forum of the ISCGM.

4. IMPLEMENTING OF GLOBAL MAP

The ISCGM was established on February 13th 1996 in Tsukuba, Japan, by participants of the Preparatory Meeting of the ISCGM. The first ISCGM meeting was held on February 14th of that year. The ISCGM has 20 members from 17 states and 8 councilors.

The main purpose of this Committee is to examine issues prevalent by national cartographic, regional and international organizations that can assist in the development of the GM in order to facilitate the implementation of global and international environmental protection conventions and conventions as well as to facilitate natural catastrophes by contributing to encouraging the growth of the economy under sustainable development conditions.

The National Cartographic Organizations of the respective states are responsible for drafting the GM, compiling the map of their countries within the GM, in accordance with the specification defined and approved by the Secretariat of the ISCGM.

The ISCGM has so far approved and published the first GM specification version at the seventh meeting of the ISCGM at 16.03.2000, respectively Version 1.1 of the GM specification.

Subsequently, that specification has evolved as a result of which is presented Version 1.2 approved and published on 17.04.2005 at the twelfth meeting of the ISCGM, then Version 1.2.1 approved and published on 11.09.2006 at the thirteenth meeting of the ISCGM as well as the latest Version 1.3 approved and published on 14.07.2007 at the fourteenth meeting of the ISCGM. From its ongoing effort, the ISCGM has implicated GM as part of the "Implementation Plan" from the World Summit on Sustainable Development (WSSD) held in Johannesburg (August to September, 2002). At that meeting, it was decided that the GM drafting project would be completed by the end of 2007, as well as GM data will be updated every five years.

5. PARTICIPATION IN GM COMPILATION

The GM's compilation is based on non-profitable basis, participation in it is voluntary. To participate have right only institutions - national cartographic organizations, which, according to the local law of their respective countries, are the institutions responsible for the establishment of the official geospatial mapping database at the state level. Currently, 180 countries and regions have participated in global mapping project, from which 77 countries have already released their data and they are available for downloading in the web site of ISCGM.

Table1 *List of Countries*

Nr	Year of publishing	Country/Region	Nr	Year of publishing	Country/Region
1	2000	Japan	41	2007	Algeria
2	2000	Laos people's Democratic Republic	42	2007	Lebanon
3	2000	Nepal	43	2007	Sudan
4	2000	Thailand	44	2007	Brazil
5	2000	Sri Lanka	45	2007	India
6	2000	Philippines	46	2007	Indonesia
7	2001	Columbia	47	2007	Niger
8	2001	Australia	48	2007	Uruguay
9	2001	Bangladesh	49	2007	Dominica
10	2001	Mongolia	50	2008	Mozambique
11	2002	Panama	51	2008	Georgia
12	2002	Kenya	52	2008	China, Hong Kong SAR
13	2003	Botswana	53	2008	Romania
14	2003	Burkina Faso	54	2008	Chile
15	2003	Kazakhstan	55	2008	Palestine
16	2003	Kyrgyz	56	2008	Brunei Darussalam

17	2003	Mexico	57	2008	Pakistan
18	2003	Myanmar	58	2008	Papua New Guinea
19	2004	Swaziland	59	2008	Oman
20	2004	Samoa	60	2008	Belize
21	2005	Iran	61	2008	Dem. Rep. of Congo
22	2006	The Former Yugoslav Republic of Macedonia	62	2008	Honduras
23	2006	Latvia	63	2008	Saint Lucia
24	2006	Tristan da Cunha	64	2008	Nicaragua
25	2006	Argentina	65	2008	Ethiopia
26	2006	Antarctica	66	2008	Senegal
27	2006	Jordan	67	2008	Congo
28	2006	Japan (version 1.1)	68	2008	Guinea-Bissau
29	2007	Bangladesh (version 1.1)	69	2008	St. Vincent and the Grenadines
30	2007	Ghana	70	2008	Republic of Moldova
31	2007	Viet Nam	71	2008	United States of America
32	2007	Malaysia	72	2008	Bhutan
33	2007	South Africa	73	2008	Syrian Arab Republic
34	2007	Bahrain	74	2008	Azerbaijan
35	2007	Canada	75	2008	Tunisia
36	2007	Singapore	76	2009	Mauritius
37	2007	New Zealand	77	2009	Bulgaria
38	2007	Cuba	78	2010	Bulgaria (version 2)
39	2007	Guatemala	79	2010	Kosovo
40	2007	Saudi Arabia	80	2016	Albania

Involvement of national cartographic organizations in general can be categorized into three levels, at levels A, B and C:

- Level A - Means that institution will prepare the data set of own country and other countries;
- Level B - Mean that institution will prepare the data set of own country and
- Level C - Mean that institution will give all necessary data, preparation will be done by ISCGM.

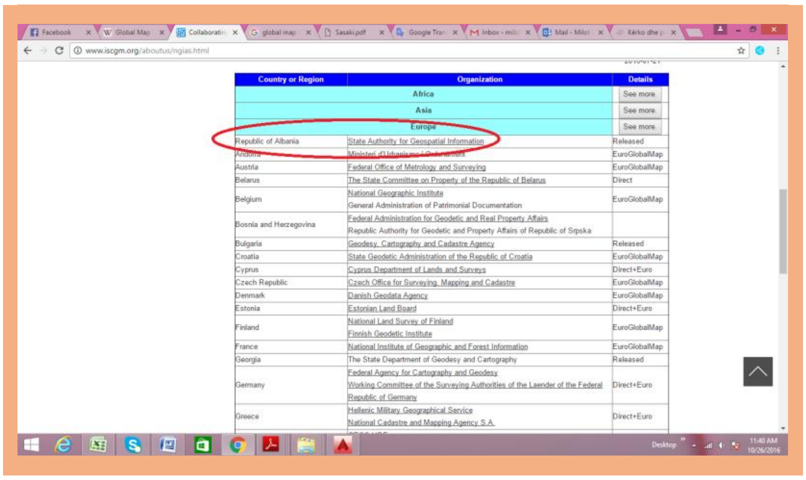
6. GLOBAL MAP DATA OF ALBANIA

The Global Map project is for noncommercial purposes, participation in it is voluntary. Eligible for participation has only the national mapping organizations, which are the governmental responsible institutions for mapping and spatial data developing on national level.

Involvement by an organization in the project in generally is categorized in three levels, i.e. as Level A, B and C.

Level A means that institution will prepare the data set of own country and other countries, the Level B mean that institution will prepare the data set of own country, and the Level C mean that institution will give all necessary data, preparation will be done by ISCGM.

The Republic of Albania participate in global mapping project since 30.06.2016 in Level B, through State Authority for Geospatial Information (ASIG).



Country or Region	Organization	Details
Africa		See more
Asia		See more
Europe		See more
Republic of Albania	State Authority for Geospatial Information	Released
Andorra	Ministeri d'Urbanisme i Ordenament	EuroGlobalMap
Austria	Federal Office of Metrology and Surveying	EuroGlobalMap
Belarus	The State Committee on Property of the Republic of Belarus	Direct
Belgium	National Geographic Institute General Administration of Patrimonial Documentation	EuroGlobalMap
Bosnia and Herzegovina	Federal Administration for Geodetic and Real Property Affairs Republic Authority for Geodetic and Property Affairs of Republic of Srpska	
Bulgaria	Geodesy, Cartography and Cadastre Agency	Released
Croatia	State Geodetic Administration of the Republic of Croatia	EuroGlobalMap
Cyprus	Cyprus Department of Lands and Surveys	Direct+Euro
Czech Republic	Czech Office for Surveying, Mapping and Cadastre	EuroGlobalMap
Denmark	Danish Geodata Agency	EuroGlobalMap
Estonia	Estonian Land Board	Direct+Euro
Finland	National Land Survey of Finland Finnish Geodetic Institute	EuroGlobalMap
France	National Institute of Geographic and Forest Information	EuroGlobalMap
Georgia	The State Department of Geodesy and Cartography	Released
Germany	Federal Agency for Cartography and Geodesy Working Committee of the Surveying Authorities of the Laender of the Federal Republic of Germany	Direct+Euro
Greece	Hellenic Military Geographical Service National Cadastre and Mapping Agency S.A.	Direct+Euro

Figure 2
Part of list of participants in GM project

Source:
www.iscgm.org, 30.06.2016

All data set of Global Map for Albania published July 14th 2016
http://www.iscgm.org/aboutus/ngias.html

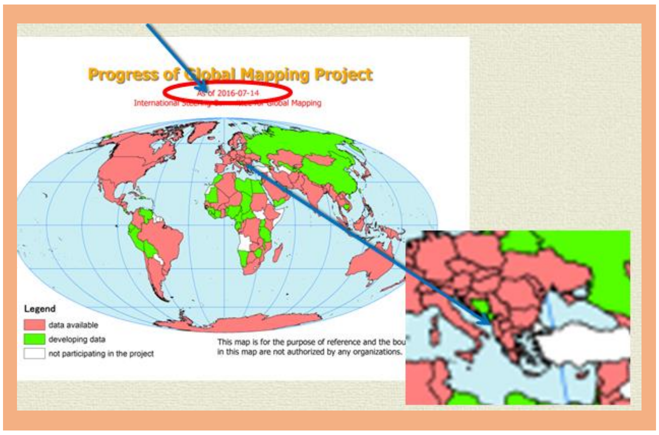


Figure 3
Data available in GM project
Source: www.iscgm.org, 14.07.2016

6.1. Data source for Global Map of Albania

We use data from governmental institutions which are responsible to supply the current and actually data. All source data have been supplied these institutions:

- State Authority for Geospatial Information (ASIG);
- Institute of transportation;
- Albanian Institute of Statistics (INSTAT);
- Military Geographical Institute of Albania;
- Ministry of Urban Development.

All received data have been modified and generalized according to GM specification. We produced vector and raster data for whole territory of Republic of Albania.

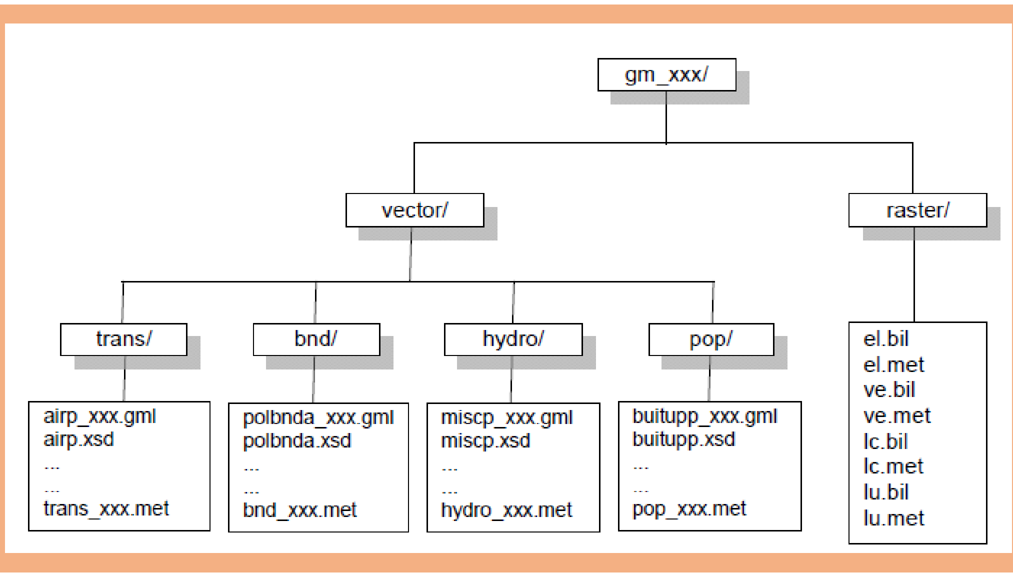


Figure 3 *Directory Structure (Global Map Specifications Version 2.2)*

6.2. Global Map raster data of Albania

Raster grid cells are arrayed on a horizontal coordinate system in degrees of latitude and longitude referenced to ITRF94 and GRS80. The following groups of features are stored as raster layers:

ELEVATION: The vertical distance between the surface of the earth and the standard sea level that the nation has defined. Vertical units represent elevation in meters above Mean Sea Level (MSL). The elevation layer is in a Band Interleaved Line (BIL) format with 16-bit elevation value and 30" horizontal grid spacing. The values of elevation are represented in meters, in which the codes -9999 are areas masked with the sea.

VEGETATION*:* Percent tree cover data by an integer value from 0 to 100 will are as vegetation layer. For Vegetation layer, a modified water legend with 20 classes is adopted.

LAND COVER*:* GLCNMO global legend are used for land cover layer. Land cover is the observed (bio) physical cover on the earth's surface (Di Gregorio and Jansen, 1998). In Global Map specification, the codes of Land Cover Characteristics of GM V1/V2 national/regional version is adopted for International Geosphere-Biosphere Program (IGBP). IGBP has 17 Land Cover classes.

LAND USE*:* Codes developed for the Global Map are adopted. Land Use is a series of operations on land, carried out by humans, with the intention of obtaining products and/or benefits through using land resources (de Bei 2000).

The Global Map edition includes just the data fields and attribute values in the Global Map Specifications Version 2.2. These data can download free (https://www.iscgm.org/gmd/).

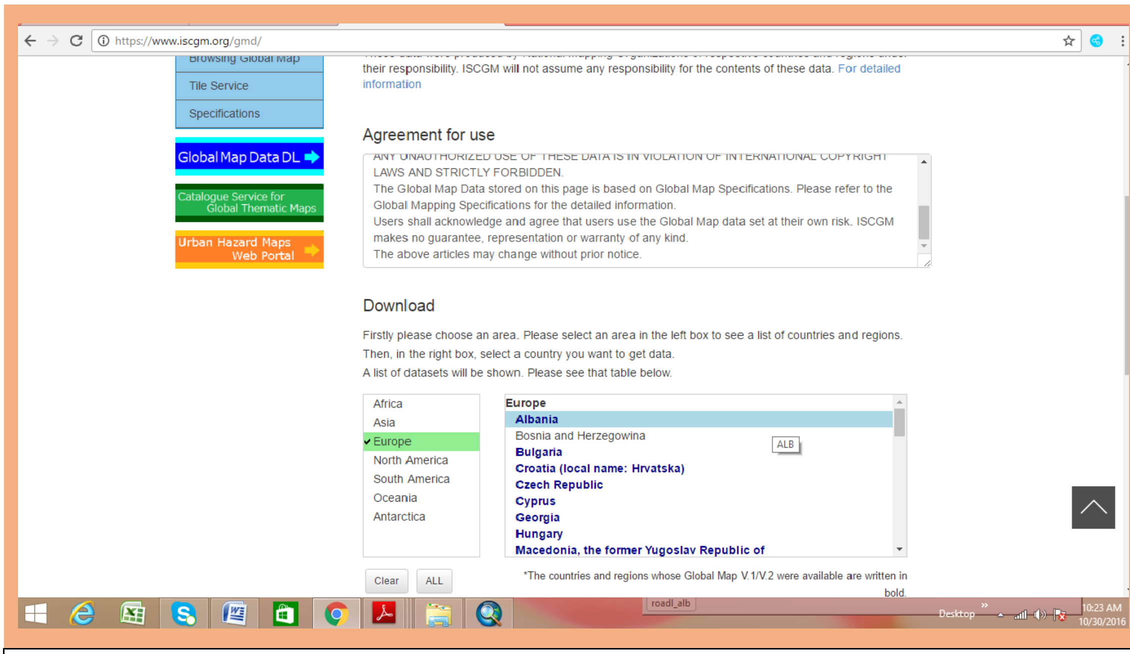


Figure 4 *Free download data*

Based on results derived from analyses and processing of land cover in Albania, include grass, asphalt, trees, bare ground, water, shrub, tree open, mixed forest, broadleaf deciduous forest, needle leaf evergreen forest, cropland, wetland, sparse vegetation etc. shown in figure 5.

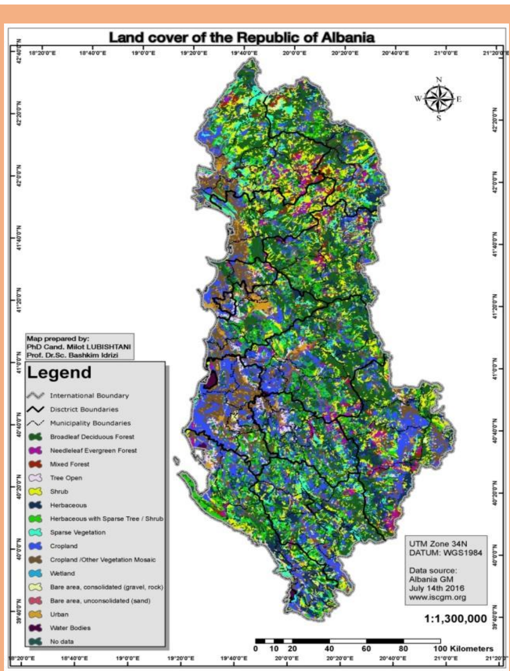


Figure 5
Land Cover within Albania's GM data

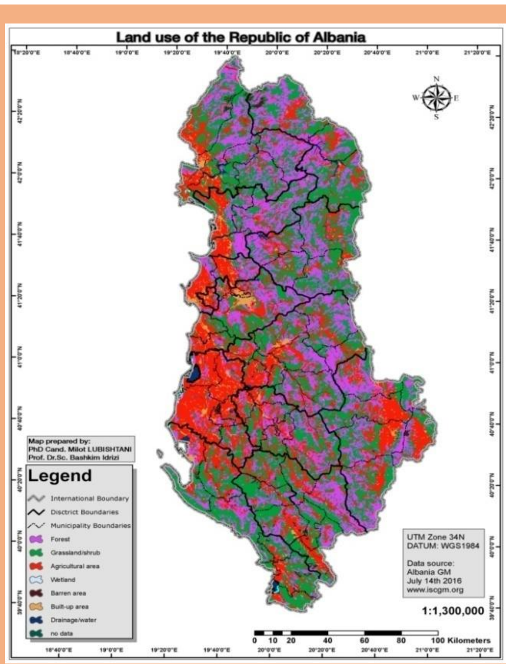
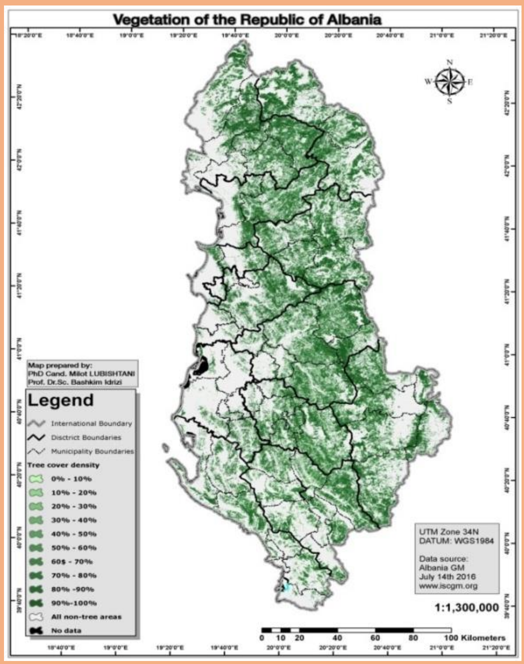


Figure 6
Land Use within Albania's GM data

Based on results derived from analyses and processing land use of Albania's GM which have been included forest, grassland, agricultural area, wetland, barren area, drainage etc., shown in figure 6. Based on results derived from analyses and processing vegetation of Albania's GM which have been included tree cover density, shown in figure 7.



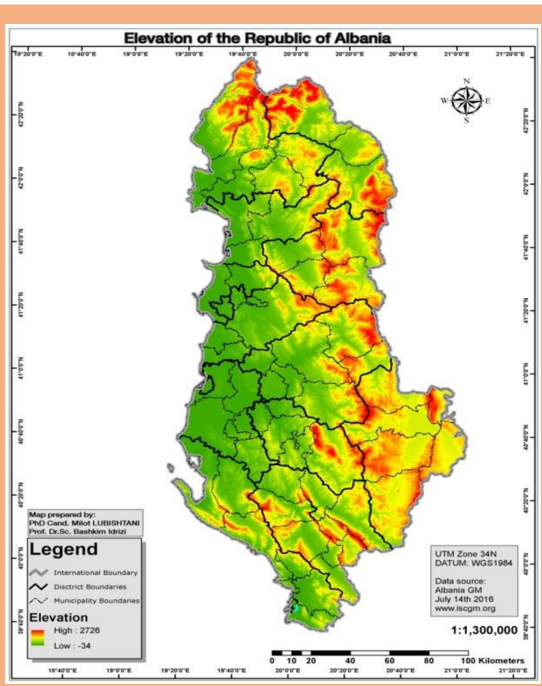


Figure 7 *Vegetation within Albania's GM data*	**Figure 8** *Elevation within Albania's GM data*

For creating of elevation of Albania use orthophoto year 2000.Based on results derived from analyses and processing of elevation of Albania's GMGM which have been included elevation of whole territory of Albania, shown in figure 8.

7. CONCLUSIONS

By continuing its' efforts, ISCGM has managed to implicate Global Map-in as part of the "Implementation Plan" of the World Summit on Sustainable Development (World Summit on Sustainable Development - WSSD) held in Johannesburg (August-September 2002). At that meeting it was decided that the project's compilation of Global Map completed by the end of 2007, as well as GM's data be updated every five years. As more states to be part of GM, as more geospatial data we have, the easier it will be the management of emergency situations.

All European countries have joined the GM unless countries like Montenegro, Belarus and Bosnia and Herzegovina are not joined GM.

Characteristic of the GCS is that all the data on the Earth are in one place, with the same structure, in the same format, on the same coordinate system, the same volume and with similar accuracy.

Modern trends in the world such as globalization, across all aspects of human life and the management of all possible techniques in the world, and in geodesy as a science, has ordered to create a single map of the world where all countries of the world will be presented with several sets data and substrates and homogeneous standards.

The GCS data covers the entire land area with a spatial resolution of 1 km for raster data and 1: 1,000,000 for vector data, and are in line with the specifications of the International Supervisory Committee for the Preparation of the Global Map of the World (MNGIGS).

Climate change is a process by which facing the world in these days, and automatically create a need that we geospatial data global of which can manage a various emergency such as natural disasters, floods, earthquakes, mudslides, volcanoes etc.

With the Global Map dataset being in digital form, it lends itself to various data manipulation and for modeling real life situations.

Global Map dataset may have limited uses at national and local scales. However, Global Map dataset is needed to address global, regional, trans-boundary and in many cases national concerns.

Global Map data's downloaded from the web site www.iscgm.org are mostly of intended for non-commercial use. If someone tries to use these data for commercial purposes must obtain permission from the relevant institution that has developed them data, otherwise, each unauthorized use for commercial purposes is in conflict with the law on copyright and related rights which is prohibited and punishable by.

Albania is one of the last European countries that has published database at ISCGM, exactly 14th July 2016 has published the vector and raster data base according to technical specification V2.2.

23th Meeting of ISCGM; New York; August, 2016 it was final meeting of ISCGM, dissolution of ISCGM and the termination of the Global Mapping Project.

GM dataset will be transferred to the United Nations Geospatial Information Section (UNGIS).

Approval from the National Mapping Agencies is mandatory for transfer!

8. REFERENCES

[1]. **Hyseni D**. (*2009): Të dhënat në trajtë vektori të Republikës së Kosovës në kuadër të hartës globale botërore në shkallën 1:1000000; punim diplome; UP-FNA; Prishtinë.*
[2]. **Idrizi B., Nikolli P., Hyseni D.** *(2010) Kosova in Global Map, 2-7.*
[3]. **Kishimoto N**. *(2005): Global Map specifications; handout; Geographical Survey Institute; Tsukuba – Japan.*
[4]. **Idrizi B**. *(2005): Global map in scale 1:1.000.000based on GIS; Seminar of Faculty for construction and architecture; Prishtine.*
[5]. **H. MARUYAMA, H. SASAKI and T. OKATANI** *(2005) Global Mapping –Global Geo-information for Sustainable Development, 2-5.*
[6]. **Idrizi B**. *(2005): Global map in scale 1:1.000.000based on GIS; Seminar of Faculty for construction and architecture; Prishtine.*
[7]. **Xhila K**. *(2012): РАСТЕРСКИТЕ ПОДАТОЦИ ВО СКЛОП НА ГЛОБАЛНАТА КАРТА НА СВЕТОТ; Skopje-Macedonia, 12-18.*
[8]. **Idrizi B. , Meha M., Nikolli P. Kabashi I.,***OVERVIEW ON GLOBAL MAP AS CONTRIBUTOR OF GSDI, 260-269.*
[9]. **http:***//www.iscgm.org.*
[10]. **Geospatial Information** *Authority of Japan; http://www.gsi.go.jp/kankyochiri/globalmap_e.html)*
[11]. **Global** *map specifications; www.iscgm.org*
[12]. **http:***//www.globalmap.org/english*
[13]. **http**:*//www.gsi.go.jp*

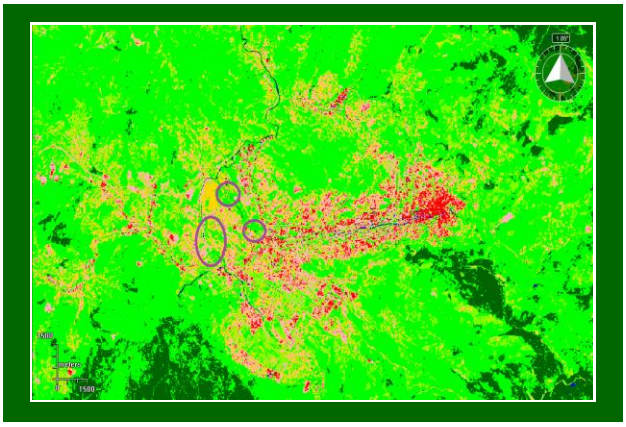
[14]. **http**://www.esri.com
[15]. **https**://en.wikipedia.org/wiki/Metadata
[16]. **www**.iscgm.org
[17]. **https:**//github.com/globalmaps/specifications/blob/master/gmspec-2.2.pdf
[18]. **https**://landcover.usgs.gov/globallandcover.php

9. AUTHORS BIO

MSc.Eng. Milot Lubishtani, was born on 10.05.1987 in Gjilan-Kosova. He graduated in geodesy department of the University of Prishtina – Faculty for Civil engineering and Architecture-Prishtina, on November 2008. His diploma thesis was “Alternative variants of state map projection of the Republic of Kosovo”. In July of 2012 graduated for master degree in department of geodesy in Faculty of Civil Engineering in Polytechnic University of Tirana. Actually he is in PHD studies for geodesy in department of geodesy in Faculty of Civil Engineering in Polytechnic University of Tirana. Actually he has private company for geodesy and cadastre.

Prof.as. Dr. Bashkim Idrizi is full time university lecturer at the geodesy and Geoinformatics department of the University “Mother Teresa” in Skopje, part time lecturer at geodesy department of the University of Prishtina “Hasan Prishtina” in Prishtina, and president of the Geo-SEE Institute in Skopje. His research interests are cartography, map projections, coordinate reference systems, SDI and GIS

MSc.Eng. Fitore Bajrami, was born on 10.11.1986 in Gjilan-Kosova. She graduated in geodesy department of the University of Prishtina – Faculty for Civil engineering and Architecture-Prishtina, on November 2008. Her diploma thesis was “Projecting of the territory of the Republic of Kosovo in Gauss-Kruger’s projection”. In July of 2012 graduated for master degree in department of geodesy in Faculty of Civil Engineering in Polytechnic University of Tirana. Actually she is in PHD studies for geodesy in department of geodesy in Faculty of Civil Engineering in Polytechnic University of Tirana. For a few months on years 2004 and 2005 she worked voluntarily in cadastral office of Gjilan municipality. From February 2009 till December 2010, she works in Kosovo Cadastral Agency-Prishtina. From September 2012 till October 2013, she worked as a Professor in professional high school for Geodesy in Prishtina. Actually is working as teaching assistant at geodesy department of the University of Prishtina “Hasan Prishtina” in Prishtina.



BENEFITS OF THE REMOTE SENSING DATA INTEGRATION

MSc. Nedim KULO

Department of Geodesy and Geoinformatics, Faculty of Civil Engineering
University of Sarajevo, Sarajevo, BOSNIA AND HERZEGOVINA
e-mail: nedim.kulo@gf.unsa.ba; Tel: +38761517047

ABSTRACT

Remote sensing is the process of detecting and monitoring the physical characteristics of an area by measuring its reflected and emitted radiation at a distance from the targeted area, and nowadays it's an indispensable source of information about Earth's surface. The technological revolution improved spatial, temporal and radiometric resolution of satellite images, which allowed time datasets analysis, combining (integrating) data from various sensors, combining images of different scales and better integration with existing data and models. The integration of data becomes an increasingly important factor in numerous aspects of remote sensing, and the results of this technique are used in solving everyday problems.

This paper presents the process of multi-temporal data integration that is used to detect changes between two time periods, which in today's dynamic age is very important for proper updating of existing cartographic maps or existing spatial databases. Furthermore, the process of multi-resolution data integration, which aims to improve the spatial resolution of multispectral images, is presented. This process allows as much as possible of the spectral properties of original multispectral image to be maintained, with the goal of discovering new information and more precise image classification.

***Keywords*:** Remote Sensing, Data Integration, Data Fusion, Multi-temporal integration, Multi-resolution integration, Multi-sensor integration

1. INTRODUCTION

An increasing number of Earth surface images are a direct consequence of Remote Sensing, which has become an inevitable method of data collection. Remote Sensing is the science and the way (or the skill) of collecting information about objects, areas or different phenomena through the analysis of data obtained by a device that is not in direct contact with an object, area, or phenomenon of interest. (Lillesand, Kiefer, & Chipman, 2004).

Since the beginning of the 1990s, the number of satellites has dramatically increased, and the trend of a steady increase in the number of such satellites is expected to continue in the future. This development brings the coverage of the planet Earth with images that are characterized by an ever-expanding spatial and temporal resolution, and an expanding electromagnetic spectrum. Remote sensing systems, mostly satellite ones, provide a repetitive and consistent view of the Earth, and in order to meet different needs, they offer a wide range of spatial, spectral, radiometric and time resolutions. In the past, data or images were available in only a few spatial and conclusive resolutions, while today there are images whose spatial resolution varies in values from less than one meter to several kilometers. The recorded images are accompanied by a better (finer) spectral resolution as well.

Data collected during the observation of the Earth was created as a result of the action of various sensors: optical sensors, SAR, altimeters, LIDARs and so on, and that is the reason why new possibilities are created when it comes to researching the planet Earth. This results in a multitude of information, which can be quite difficult to manage for users, and for that reason the idea of combining available information sets in the most efficient way possible (via data integration) has emerged. Traditionally, the analysis of data collected on a particular area was based on the analysis of the data from one satellite image. The technological revolution brought very good coverage in spatial, time and radiometric terms, which resulted in the possibility of analyzing time data sets, combining (integrating) data of different sensors, combining images of different scales, and better integration with existing data and models. From all of the above, it is clear that the integration of data from different sources is becoming an increasingly important link in more and more aspects of remote research.

2. REMOTE SENSING

"Remote Sensing is a science of obtaining information about the surface of the Earth, without making physical contact. In this process rejected or radiated electromagnetic waves are detected, processed, analysed and used in different applications." (Oštir & Mulahusić, 2014)

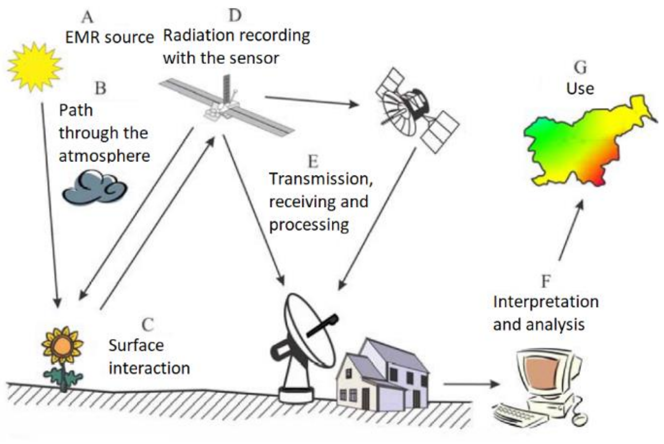


Figure 1 *Process of Remote Sensing (Oštir & Mulahusić, 2014, p. 14)*

1. *Electromagnetic radiation source (A)* - The first requirement for Remote Sensing is the source of electromagnetic radiation, which illuminates the observed objects or that radiation is created by the objects themselves. The most frequent source of radiation is the Sun, artificial sources of

radiation (e.g. radar antennas) and thermal radiation of objects themselves.
2. *Path through the atmosphere (B)* - While traveling through the atmosphere, waves react with the atmosphere.
3. *Surface Interaction (C)* - When a wave arrives to the Earth's surface, interaction occurs and the way of interaction depends on the surface properties and the characteristics of the waves.
4. *Radiation recording with the sensor (D)* - After the radiation is sprayed over the surface or emitted by the surface, it must be detecting with the sensor. Sensors detect electromagnetic radiation and convert it to the appropriate recording.
5. *Transmission, Receiving and Processing (E)* - Signals recorded by the sensor should be converted to the radio waveforms and electronically transmitted to the receiving station on Earth. The data is processed in the receiving station and from it images are created in printed or (and) in digital form.
6. *Interpretation and analysis (F)* - Recorded image must be interpreted, visually or (and) digitally, and in that process as much information as possible about the observed object is obtained.
7. *Use (G)* - The last, but probably the most important element in the process of Remote Sensing is to use the information obtained by interpreting certain studies or solving a specific problem.

Seven elements described above represent the process of Remote Sensing from beginning to the end. (Oštir & Mulahusić, 2014)
The process of Remote Sensing is based on the detection and recording of rejected or radiated electromagnetic energy (waves). To achieve this, sensors must be placed on stable platforms and they must not be in direct contact with the object or surface of interest. Usually, the platforms used in Remote Sensing are (Oštir & Mulahusić, 2014):

- *On the ground*, sensors on such platforms are usually used to collect data that are compared with surface data obtained from a satellite or aircraft.
- *In the air*, i.e. sensors are mounted on planes, balloons or helicopters that are specifically prepared for these purposes. Very precise data on the surface of the Earth can be obtained from the plane.
- *In space*, sensors in this case are mounted on spacecraft, or more often on satellites[1].

There are many criteria for choosing a platform, but the most important ones are the desired resolution, the coverage of the surface and the price of the system. Sensors used in Remote Sensing can be classified into two basic categories: *active* and *passive* sensors. Active sensors use their own source of electromagnetic radiation (energy) for data recording. Such sensors emit radiation towards the object of interest, and then detect and measure the intensity of the reflected or rejected radiation. The vast majority of active sensors operate in the microwave part of the electromagnetic spectrum, which allows them to penetrate the atmosphere in almost all weather conditions. On the other hand, passive sensors detect the already existing, natural energy emitted or rejected by objects on the surface, or by the very surface of the Earth itself. In most cases, this is solar energy, which is either reflected or radiated by objects (surface) in the form of thermal energy. Passive sensors include various types of

[1] A satellite is an artificial object which has been intentionally placed into orbit. Such objects are sometimes called artificial satellites to distinguish them from natural satellites such as Earth's Moon. (Satellite, 2018)

radiometers and spectrometers, and the vast majority of passive sensors act in the visible, infrared, thermal part of the infrared and microwave segments of the electromagnetic spectrum. (Remote Sensors, 2018)

Since sensors used in Remote Sensing are intended to observe various objects and phenomena, the characteristics of these sensors are also different. One of the items that determines these features is resolution. According to (Oštir & Mulahusić, 2014), several types of resolution can be distinguished:

1) *Spatial*, which determines the size of the smallest objects observed,
2) *Spectral*, which tells how well different wavelengths are distinguished,
3) *Radiometric*, which gives the range and number of observed values and
4) *Time*, which determines the frequency of recording.

3. DATA INTEGRATION

"Data fusion techniques combine data from multiple sensors, and related information from associated databases, to achieve improved accuracy and more specific inferences than could be achieved by the use of single sensor alone." (Definitions of Sensor Data Fusion in the Literature, 2018). When it comes to data fusion, or data integration, usually one of the following happens: multi-temporal, multi-resolution or multi-sensor data integration. When multi-temporal data integration is in question, it is usually a matter of calculating the difference between the two images. Images taken at different times are compared and this comparison reveals changes. Simple methods such as subtraction of images or some more complicated methods such as multiple re-classification or even classification with integrated data from different periods are used. Multi-resolution data integration can be useful for different applications, e.g. combining high resolution spatial data with lower resolution data highlights detail on the images, making it easier to recognize the objects. Multi-sensor integration involves dealing with data from different sensors. A common example of this kind of integration is the fusion of multispectral optical data with radar images. (Oštir & Mulahusić, 2014).

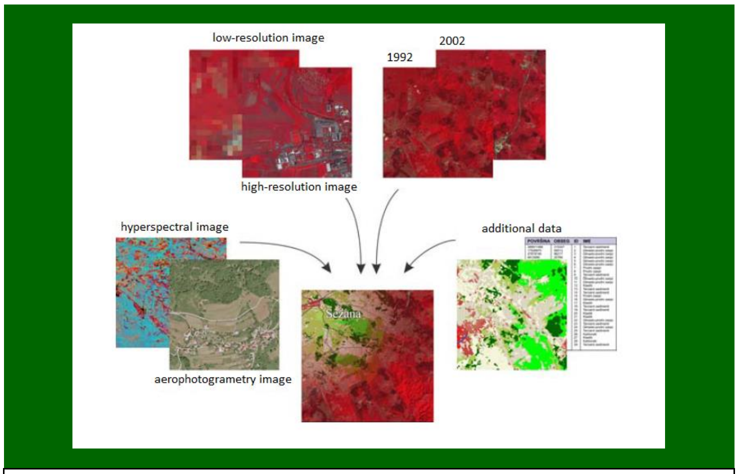


Figure 2
Data Integration (Oštir & Mulahusić, 2014, p. 219)

The integration of remote sensing data collected by differ-rent sensors can be accompli-shed at different levels of repre-sentation: *Signal* level of repre-sentation, *Pixel* level of repre-sentation, *Feature* (*Characteri-stics*) level of representation or at the *Decision* level of represe-ntation.

When integrating data at the *signal level*, signals from different sensors are combined to create a new signal that has a better signal-to-noise ratio[2] (S/N or SNR) than the original signals. Techniques used at this level of integration usually involve classic detection and estimation methods.If the data is non-commensurate, integration must be done at a higher level. *Pixel level* integration consists of merging data from different images on a pixel-by-pixel principle, in order to improve the performance of the image processing tasks, such as in case of segmentation[3] of the image. Integration of data at the *feature level* of representation consists of joining certain characteristics that are separated from different images or from different signals. At this level of integration, characteristics are taken (extracted) from images, which are created with different sensors, then merged into concatenated feature vector and classified using standard classification methods. The *decision level*, or as it is called *symbol level*, implies integrating data at a higher level of abstraction. It is based on the data from individual sensors, over which preliminary classification is performed, and then the integration is done by merging the output data of the preliminary classifications. Choosing the best integration level and the best integration method for a particular application depends on several factors, including the complexity of the classification problem, the available data and the goals that are to be achieved by analysis. (Anne H. S., 2006).

Integration of data requires consideration of many aspects. Thus, before the implementation of the integration process, it is necessary to answer certain questions, such as (Pohl & van Genderen, 1998):

- What is the goal of the user, or for what purpose the results will be applied?
- What kind of data types are the best for user needs?
- Which is the most appropriate integration technique for selected data?
- What are the necessary pre-processing steps?
- What is the best combination of data?

4. DATA PROCESSING

To perform data integration, it was necessary to select the test area and download the satellite images of the test area. The wider area of the city of Sarajevo was selected for this purpose, more precisely this relates to the political territory of the Sarajevo Canton. After the test area was defined, two Landsat 8 satellite images were downloaded from *Earth Explorer* on-line service (https://earthexplorer.usgs.gov).

Table 1 *Part of the Landsat 8 images metadata*

Scene ID number	Sensor	Date of origin
LC81870302017191LGN00	OLI_TIRS	10. 07. 2017.
LC81870302015202LGN01	OLI_TIRS	21. 07. 2015.

In order to achieve the best possible results, remotely sensed data should be properly prepared for processing. Data from the Landsat system is already corrected in the receiving station in a geometric and radiometric way. By looking at the metadata of Landsat images, it can be seen that UTM projection (zone 34)

[2] Signal-to-noise ratio (abbreviated SNR or S/N) is a measure used in science and engineering that compares the level of a desired signal to the level of background noise. SNR is defined as the ratio of signal power to the noise power, often expressed in decibels. A ratio higher than 1:1 (greater than 0 dB) indicates more signal than noise. (Signal-to-noise ratio, 2018)

[3] Segmentation is the process of splitting the footage into homogeneous areas. As a rule, segmentation is the first step of the subject-oriented classification. (Oštir & Mulahusić, 2014, p. 295)

is used, in relation to the WGS84 ellipsoid (datum). Images are oriented to the north and both have a total quality score of 9.

5. MULTI-TEMPORAL

For the multi-temporal data integration, and in order to detect the changes that occurred in the time period under revision, satellite images from the Landsat system were used. Two images are produced as a result of the operation of the OLI sensor on the Landsat 8 satellites. The first image was made on July 21, 2015, while the other one was produced on July 10, 2017. Both images have a total quality score of 9, and very low cloud coverage (below 10% in relation to the entire scene). As both images were subjected to the pre-processing procedure in the receiving station, they are in the same coordinate system (UTM projection, zone 34, datum WGS84), a satellite image processing software was used to fuse these images together with the goal of detecting changes.

The software contains a set of *Change Detection* tools, which allow computing changes between two satellite images through pre-implemented algorithms. In this example, two options for discovering changes were used: *Image Difference* and *Delta Cue*.

Detecting changes with the *Image Difference* option is based on comparing the pixel values of the 'before' and 'after' images. The 'before' image refers to the earlier period from the two dates, and the 'after' image refers to a later period of two dates. The 'after' image is subtracted from the 'before' image to get the differences and emphasize the changes. The resulting image displays the pixels whose numerical value has changed, either increased or decreased in relation to the 'before' image. Other option, *DeltaCue* is more interactive, and offers the possibility of setting different input and processing parameters. It is possible to choose between several change detection models and the interactive threshold allows user to set the upper and lower limits of numerical values in which the software will detect changes. The central part of this process is selecting one of the algorithms for detecting changes. (ERDAS, 2014).

After setting the parameters for multi-temporal integration of the images, images 'before' an 'after' were loaded, channel 1 (wavelength between 0.433 μm and 0.453 μm) was selected for both images and a limit of 10% was set to define the existence of a change in relation to the previous state.

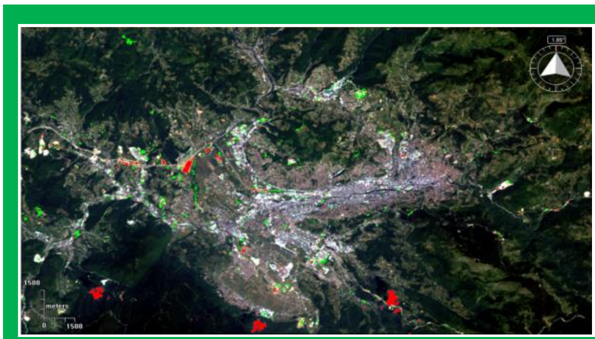


Figure 3
Changes detected using Image Difference method

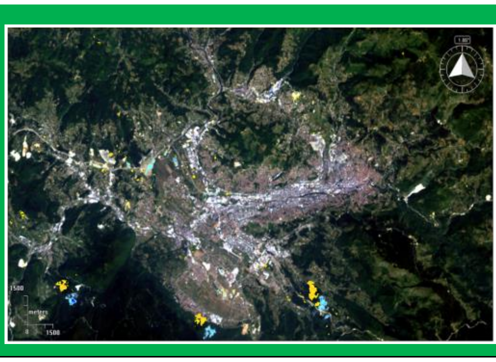


Figure 4
Changes detected using DeltaCue method

6. MULTI-RESOLUTION

The starting point for multi-resolution data integration was the Landsat 8 image from 2017, more precisely the panchromatic and multispectral image of the above mentioned satellite. Landsat 8 in the panchromatic channel collects data with a spatial resolution of 15 m, while the data collected by the multispectral sensor has a spatial resolution of 30 m. Therefore, it is obvious that the spatial resolution of the panchromatic image is much better than the resolution of the multispectral image, and thus the goal is to combine the spatial resolution of the panchromatic image with spectral information contained in a multispectral image.

In order to integrate multi-resolution data satellite image processing software was used. The software contains the *Pan Sharpen* tools, which are part of the *Resolution* group, with several predefined procedures for integrating multi-resolution data, which are characterized by different algorithms, i.e. methods of data fusion. Four different methods have been used to perform the integration of all spectral channels of a multispectral image with a high resolution panchromatic image. These methods are *HPF Resolution Merge*, *Ehlers Fusion*, *Hyperspherical Color Space Resolution Merge* and *Resolution Merge*. Each of these methods, in their
own way, perform the fusion of multi-resolution images. (ERDAS, 2014).

After the multi-resolution data was integrated, the quality of the results was evaluated. Using the open source code, which is available online in the *MATLAB Central File Exchange*, quantitative quality assessment was performed. The code is the implementation of the so-called *Image Quality and Index Analysis* graphical interface (GUI), version 1.25, which is used to evaluate the quality of the images. (Image Quality - Index Analysis GUI, 2017)

Table 2 *Results of the quantitative quality assessment of the integrated images*

Quality parameter	*HPF Resolution Merge*	*Ehlers Fusion*	*HCS Resolution Merge*	*Resolution Merge*
CC	0,873	0,829	0,899	0,575
Entropy Difference	0,182	0,199	0,156	0,364
ERGAS	12,418	15,373	9,347	23,711
UIQI	0,856	0,806	0,889	0,527
RASE	25,437	32,467	19,340	92,144
RMSE	10,743	11,833	7,757	18,855

Since the integration of the multi-resolution data was done with the goal of gaining a more precise image classification, and after assessing the quality of the created images, the classification and an assessment of the accuracy of the classification were made. All of the above is done using the satellite image processing software, more precisely the *Classification* tools that are intended for the operations of classifying satellite images. On the resulting integrated images, a supervised classification was made. Seven different classes, or different land use types, have been selected, among which are:

Table 3 *Classes used for classification of the satellite images*

Land use (class)	Colour of the class
Water	
Agricultural land	
Forest	
Dense (coniferous) forest	
Sward	
Urban area	
Dense urban area	

Also, the supervised classification was made over the original multispectral image, so that the results could be compared with the results of the supervised classification of integrated images. The satellite image processing software has an option to assess the accuracy of the classification using the *Accuracy Assessment* tool. This option allows the user to select an image and the number of test points.

These points can be automatically generated, by randomly selecting their positions, or they can be predefined in the tool for assessing the accuracy of the classification. For each image, 100 test points were randomly allocated. After selecting the test points, each of them is assigned a reference value, or a class to which it belongs. This is done in an interactive window which requires a fine resolution image as a background, or alternatively a thematic map. (ERDAS, 2014)

7. ANALYSIS AND DISCUSSION

The integration of various remotely sensed data plays a very important role in the interpretation and analysis of this data. Not only do they reveal new and useful information, but the resulting images greatly help users to interpret them with better quality and with more details and a greater confidence. Monitoring of changes today plays an important role in the land management system, and accurate and time wise correct images are the basis for efficient functioning of the land management system.

7.1. MULTI-TEMPORAL

Multi-temporal integration of two Landsat 8 images, one from 2015 and the other from 2017, is done with the goal of discovering changes that occurred in the wider Sarajevo area over a two-year period. Both of the options used to detect changes showed similar results.

By comparing the images from 2015 and 2017, major changes can be noticed, such as construction works on the river banks of river *Bosna* or changes in the way of land use on the territory of the municipality of *Ilidža*. Also, by visual interpretation of the two images, one can notice the change caused by the construction of a bridge above the roundabout in *Bačići* and further construction of the *A1 motorway* link with the street *Safeta Zajke*.

Detecting changes with the *Image Difference* option resulted in the discovery of changes in the way of land exploitation (use) in the territory of the municipality of *Ilidža*. Agricultural land back in 2015 was not under crops, while in 2017 the same land was under crops. Furthermore, one of the detected changes was caused by the works on the river basin of the river *Bosna* in the territory of *Ilidža* municipality, and the works on a part of the river basin of *Željeznica* river.

Changes caused by the construction of the bridge above the roundabout in *Bačići* and the part of the *A1 motorway*, which should be connected with the *Safeta Zajke* street, have been detected as well. Also, changes caused by the construction of new facilities, such as the wastewater treatment plant in *Butile*, which has been significantly renovated during the two-year period, have been detected. In addition, several objects of relatively small dimensions which were built in the period between 2015 and 2017, such as the new residential buildings in *Otoka*, were noticed. Large housing expansion was detected in the area of *Istočno Sarajevo* and in *Poljine*, with the construction of the Poljine Hills residential complex. Interestingly, the software spotted the change caused by the construction of *A transferzala* road, which is located in the urban area, and a certain expansion of the city landfill. In addition, the process revealed the differences caused by the clouds that are on the image from 2015.

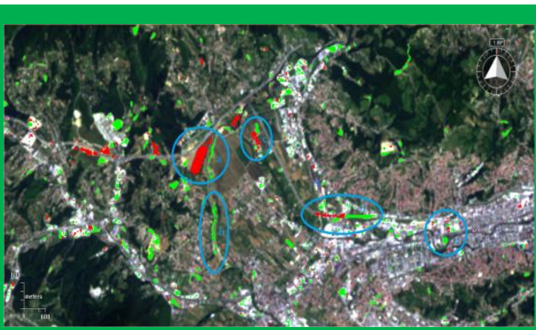


Figure 5 *Some of the detected changes using ID method, such as: change in land use (a), works on the banks of the river Bosna (b), water treatment facility (c), road construction (d), new residential buildings (e)*

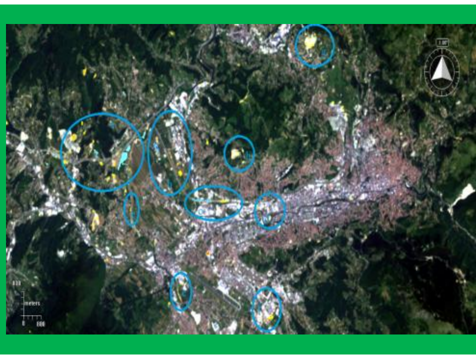


Figure 1 *Some of the detected changes using DC method, such as: land use change (a), new buildings (b) and (d), new road (c), works on the river banks (e), urban expansion (f), Poljine Hills complex (g) and city landfill expansion (h)*

The *DeltaCue* option gave similar results to those described above when it comes to detected changes, with a few exceptions. Because the upper and lower thresholds of the changes were interactively adjusted, in order to minimize the cloud impact from the image from 2015, there was a certain loss of information when it comes to changes. For example, the *A transferzala* road was not detected, residential expansion in *Istočno Sarajevo* was shown only to a lesser degree and newly constructed buildings were noticed to a lesser degree as well.

7.2. MULTI-RESOLUTION

The results of an assessment of the quality of integration must be taken with reservations, since the reference image is the result of the integration process too. What stands out is that the correlation coefficient is close to the value of 1 for all integrated images, except for the image produced by the *Resolution Merge* method, which can be explained by the difference in the tones representing a dense forest area. The absolute difference in the entropy of the images is about 0.1, which is a good result for all the images, except for the image mentioned above, which can again be justified by the difference in the tone of the pixels of the area under dense forest. The best ERGAS value (lowest) was achieved by the image integrated by the *Hyperspherical Color Space Resolution Merge* method, while the worst value (highest) was obtained by the *Resolution Merge* integration method. The results are the same when it comes to RASE and RMSE parameters. The universal quality index for integrated images ranges from 0.8 to 0.9, which is a good result. Unfortunately, the result of the image integrated by the *Resolution Merge* method is not so good (UIQI index of 0.53), which should again be justified by the difference in the tones of the area under dense forest. The interesting thing is that, although according to the quality assessment parameters, image integrated by the *Resolution Merge* method is not the best choice; the results of assessing the accuracy of the classification indicate that it represents the best option when it comes to classifying images with a total accuracy of 85%.The main goal of multi-resolution data integration was to improve the accuracy of the classification of satellite images. In order to be able to compare the classification results, it was necessary to classify a multispectral image of a spatial resolution of 30 m, which will be the basis for comparing the results of the classification of integrated images. The total accuracy of the classification, which is 79% for the multispectral Landsat 8 image from 2017, based on the assessment of the accuracy of the classification with 100 test points, suggests that the classifications can be considered almost acceptable (in general, the accuracy of the classification above 80 % is considered acceptable). A more detailed look at the matrix of errors allows for the extraction of data on the accuracy of the classification by individual classes, and what stands out is a very poor result of the classification of water surfaces. None of the test pixels is accurately classified as a water surface. By the visual interpretation of the image, water streams are to a certain extent accurately classified, but at the same time the water class includes the pixels that do not belong to that class. This is the case with pixels in the southeastern and northeastern parts of the image, and a certain number of pixels stretching along the main city road in Sarajevo. Also, Sarajevo airport runway is classified as 'water surface'. By the visual interpretation it was determined that the other classes are quite well classified, which is confirmed by the individual results from the matrix of errors. For example, the dense urban area class has 100% accuracy when it comes to both the user's and the manufacturer's accuracy. A high percentage of accuracy is also recorded in the dense (coniferous) forest class and the forest class. Agricultural land class has a high manufacturer's accuracy (80%), but a very low user's accuracy (30%). Image created as a result of the *HPF Resolution Merge* method of integration achieved a total classification accuracy of 82%, which means that this image enters the category of acceptable classification accuracy. A more detailed look at the error matrix reveals that it has achieved much better results when it comes to detecting water surfaces (100% of user's and manufacturer's accuracy), and generally good results for all classes. However, visual interpretation found that there are pixels which are incorrectly classified as 'water surfaces', but to a lesser extent than in the classification of a multispectral 30-meter Landsat 8 image. Also, dense urban areas fit better into the actual situation than in the case of the classification of the original multispectral image. Some classes scored poorer when it comes to the accuracy of the classification, such as agricultural land (62,50%), swards (57,14%) and dense urban areas (50%). In all three cases, it is the manufacturer's accuracy. Generally, it may be noted that, in relation to the multispectral image, the image integrated with above mentioned method achieves better classification results.

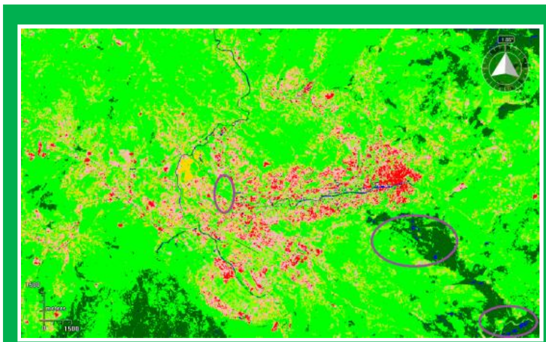


Figure 7 *Incorrectly classified areas on image integrated by HPF Resolution Merge method*

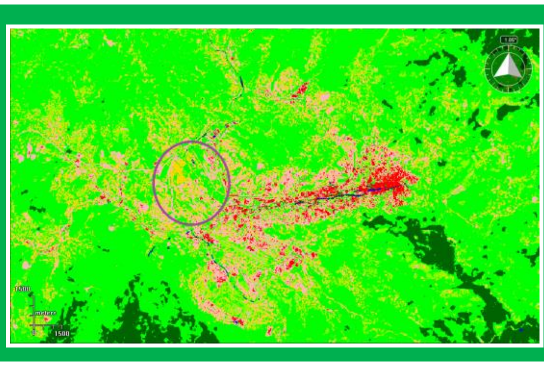


Figure 8 *Incorrectly classified areas on the image integrated by Ehlers Fusion method*

Image integrated by the *Ehlers Fusion* method has achieved a total accuracy of 79%, which is the same as the original Landsat 8 multispectral image. However, a visual interpretation indicates that water streams are not recognized to the extent that would be satisfactory. Although, it should be noted that there are no incorrectly classified areas into water class. Also, dense urban areas and dense forest areas in some parts of the image do not correspond to the real situation well. From the matrix of errors, it is noticed that the lower producer's accuracy is achieved by sward, water and dense urban area classes (interval from 45% to 50%). However, the user’s accuracy for all classes is satisfactory. Compared to other integrated images, and when it comes to assessing the quality of the classification, the image integrated with this method has achieved the poorest results. The *Hyper Spherical Color Space Resolution Merge* integration method resulted in an image that achieved a total integration accuracy of 82%, which corresponds to the accuracy of the *HPF Resolution Merge* image. Visually, both images are very similar, and they have almost identical defects such as wrongly classified areas as water surfaces. The error matrix is also very similar in both images, and 100% of the user's accuracy of classification of water surfaces and dense urban areas is achieved. The poorest producer's accuracy is recorded by dense urban areas (50%), although it is quite well suited to the real situation, while all other classes have accuracy above 60%. It should be noted that all classes on the image fit fairly well into the actual situation. Compared to the classification of the original multispectral image, it can be said that the results are better and more realistic.

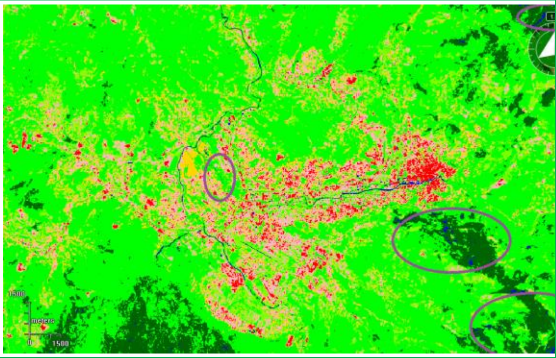


Figure 9
Incorrectly classified areas on image integrated by HCS Resolution Merge method

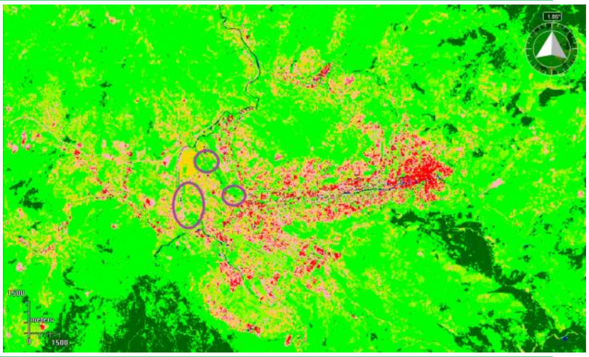


Figure 10
Incorrectly classified areas on the image integrated by Resolution Merge method

Image created by the *Resolution Merge* method achieved the best results in assessing the classification accuracy based on 100 test points. The overall accuracy of the classification of this integrated image is 85%. The error matrix reveals quite good results when it comes to user’s accuracy, over 70% for all classes, including water areas, dense urban areas and urban areas with 100% accuracy. The manufacturer's accuracy is also quite good except for swards (58%) and water (66%). But, the visual interpretation indicates that there is a problem with water streams, namely certain parts of the river Miljacka and the river Bosna are not recognized as water at all.

Other classes are pretty well representing the actual situation, and it can be said that this integrated image best reflects the real situation. Since the image integrated with this method has achieved the worst results in the assessment of the quality of integration, it should be said that justification for this is a somewhat different tonality of the dense forest areas. Moreover, since the quality assessment was performed in relation to the reference image and that the same areas are shown with slightly different tones, the results can be justified by the fact that the algorithm is not able to determine that this is the same content on both images. So, although it has the poorest ratings in the assessment of the quality of the integration, this image has the best grades for assessing the quality of the classification and shows the actual situation the best.

8. CONCLUSIONS AND RECOMMENDATIONS

Remotely sensed data is becoming the basis for solving everyday problems and tasks in the field of geospatial data. Rapidly developing technology allows data collected by remote sensing systems to become more easily attainable, and more importantly, in an increasing number of cases, it is free as well. Further development of technology will lead to better spatial characteristics of satellite images, and spectral and radiometric characteristics will surely keep up with the progress of the spatial aspect of the resolution.

In a digital environment where all data is georeferenced into a common coordinate system, the ability to analyze and discover new information is increased. An important step in this process is the integration of various remotely sensed data with the goal of recognizing new and more reliable information. It is quite logical to expect that by using and analyzing different data, better and more precise information can be collected than with just one source. Through this paper, the preceding sentence was practically proven.

Multi-temporal integration of remotely sensed data has resulted in the discovery of changes that are very important for land management. The discovered changes can be used to update the existing cartographic maps, to monitor progress of major construction projects, to monitor the urban expansion of cities or settlements, to monitor the state of agricultural areas or conditions caused by natural disasters. At the present time, accurate and location-correct information are very important, and therefore, the conclusion is that the multi-temporal integration of remotely sensed data plays a very important role in the process of detecting and recognizing time-sensitive changes in a particular area. Revealed changes can be forwarded to various departments that will record, analyze and archive them. A database, such as, a real estate cadaster can be easily maintained by this integration method, where newly built objects can be recognized from newer satellite images and entered into the system. This can also be used to follow the phenomenon of 'wild' construction, but it can also serve as a basis for legalization procedures. The fact that time appropriate information in case of natural disasters, such as floods or landslides, can be of great help to the authorities in the crisis management process and the following procedure for remedying the damage. In conclusion, the multi-temporal integration of remotely sensed data finds its application in different areas and it is considered that it will continue to be used very successfully in the future for various purposes, especially if it involves the merging of high-resolution data that also allows detection of smaller scale changes.

Multi-resolution integration of remotely sensed data is a very good technique to obtain multispectral data with better spatial resolution. This results in a better and more accurate classification of images and also provides users with a much better basis for visual interpretation of the images. The result is sharper image with spectral information that enables the recognition of different ways of using the soil, better recognition of objects and infrastructure. As shown in the paper, all integrated images have shown better results in assessing the accuracy of the classification than the original multispectral image with lower spatial resolution. The reason for this is simple, the pixel of the original image covers a larger area and takes the value of the most dominant way of exploiting the soil, while the same area on the integrated image is displayed with 4 or more pixels. Benefits are obvious, and the fact that most of the remote sensing systems, whose data can be downloaded for free, collects data in a panchromatic channel with better spatial resolution than in multispectral channels. This means that they are a fairly good alternative to commercial high-resolution systems.

Depending on the needs, the integration of multi-resolution data can be a very good basis for the classification of satellite images, or to be precise to identify the land use and land cover type. Integrated images can be used to find certain interesting phenomena, such as, landslides, open pit mines or different farming cultures. As shown by the results achieved in this paper, the integrated images represent real situation on the ground very good, and the fact that water areas are recognized with high accuracy is very important for hydrological applications. Today information about land use and land cover plays an important role in planning and managing the development of the area, and integrated multi-resolution images for the experts in these areas provide a good basis for further analysis and interpretation. With the note that those integrated images can be obtained with no extra cost, it can be concluded that multi-resolution integration is an excellent alternative to commercial high-resolution systems, to the extent that the end-use allows. If it is necessary to have really high resolution data, then commercial systems with spatial resolutions below 1 m have no alternative. For all other needs, integration is an excellent choice.

9. LITERATURE

[1]. **Anne H. S., S**. (2006). *Data fudion for remote sensing applications.* Oslo: Department of Informatics, University of Oslo.

[2]. **Definitions of Sensor Data** *Fusion in the Literature*. (2018, July 24). Retrieved from University of Bonn, Institute of Computer Science 4: https://net.cs.uni-bonn.de/de/wg/sensor-data-and-information-fusion/what-is-it/sdf-definitions

[3]. **ERDAS**. (2014). *ERDAS IMAGINE Software Documentation.* Intergraph.

[4]. **Image Quality** - *Index Analysis GUI*. (2017, August 2). Retrieved from File Exchange - MATLAB Central: https://www.mathworks.com/matlabcentral/fileexchange/41464-image-quality-index-analysis-gui

[5]. **Lillesand, T. M., Kiefer, R. W., & Chipman, J. W**. (2004). *Remote Sensing and Image Interpretation* (Fifth Edition ed.). New York: John Wiley & Sons.

[6]. **Oštir, K., & Mulahusić, A**. (2014). *Daljinska istraživanja.* Ljubljana i Sarajevo: Građevinski fakultet, Univerzitet u Sarajevu.

[7]. **Pohl, C., & van Genderen, J. L**. (1998). Multisensor image fusion in remote sensing: Concepts, methods and applications. *International Journal of Remote Sensing*, 823-854.

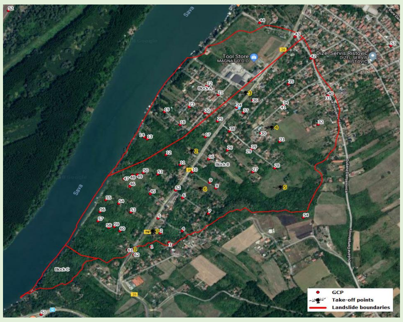
[8]. **Remote Sensors**. (2018, August 2). Retrieved from EarthData: https://earthdata.nasa.gov/user-resources/remote-sensors

[9]. **Satellite**. (2018, August 10). Retrieved from Wikipedia, the free encyclopedia: https://en.wikipedia.org/wiki/Satellite

[10]. **Signal-to-noise ratio**. (2018, August 10). Retrieved from Wikipedia, the free encyclopedia: https://en.wikipedia.org/wiki/Signal-to-noise_ratio

10. AUTHOR BIO

MSC. Nedim KULO: Born in Sarajevo, Bosnia and Herzegovina 1992. Finished study as Master of Geodetic Engineering on 2017, Master thesis on Remote Sensing Data Integration. Currently works at faculty of Civil Engineering in Sarajevo as an assistant. Field of work: Satellite Navigation, Photogrammetry, Topography and Surveying.



UAS PHOTOGRAMMETRY FOR MONITORING ACTIVE LANDSLIDE (UMKA, SERBIA)

PhD. Cand. MSc. Nenad Brodić[1]
Prof. Dr. Željko Cvijetinović[2]; Prof. Dr. Branko Božić[3]
Prof. Dr. Dragan Mihajlović[4]

[1,2,3,4] University of Belgrade, Faculty of Civil Engineering, Department of Geodesy and Geoinformatics
[1]E-mail: nbrodic@grf.bg.ac.rs; Tel: +381 11 3370 082;
[2]E-mail: zeljkoc@grf.bg.ac.rs; Tel: +381 11 3370 082
[3]E-mail: bozic@grf.bg.ac.rs; Tel: +381 11 3370 102;
[4]E-mail: draganm@grf.bg.ac.rs; Tel: +381 11 3370 082

ABSTRACT

This work analyses potentials of products obtained by using UAS photogrammetry in order to monitor movements of an active landslide. The products such as classified dense point cloud, generated Digital Terrain Model (DTM) and orthophotos may improve geomorphological and motion detection analysis. Imagery was collected by using professional Unmanned Aerial System (UAS) with mounted DSLR camera during flight campaign in 2018 under leaf-off conditions for a landslide located near the settlement of Umka.

In this area, non-ground objects are mostly some buildings and vegetation such as shrubs and trees. Different software solutions were used to obtain photogrammetric products and perform ground data filtering. Vegetation and building points were removed based on assumption that these features have higher heights than neighbouring ground points. However, in case of steep terrain, ground points may have the same height as non-ground points, which had to be considered. There was a problem with lack of ground points in areas with dense vegetation where the visibility of terrain was reduced on overlapping images. Filtering procedure also produced holes in point cloud which demanded appropriate interpolation methods to be applied. On generated orthophotos roof edges on buildings were deformed due to the height jumps between terrain and these buildings.

Keywords: Photogrammetry, Orthophotos, DTM, UAS, Umka, Serbia

1. INTRODUCTION

Recent developments of UAS-based systems, low cost imaging sensors and improvement of 3D reconstruction techniques resulted in fast data acquisition and subsequent products generation that can be used in numerous applications such as archaeology, civil engineering, industry, military and agriculture. In order to process several hundreds of overlapping images and perform automatic 3D model reconstruction, different photogrammetry and computer vision algorithms have been developed based on dense image matching techniques. In this process a dense 3D point cloud with appropriate texture is generated and used for further models derivation in order to perform data interpretation and useful analysis.

The advantages mentioned above are crucial for monitoring of active landslides and these cannot be provided by traditional ground-based geotechnical and geophysical investigations. By using photogrammetry, every measurement is performed extremely fast and usually a big area can be covered efficiently achieving high spatial resolution from a remote and safe place. This will be even more efficient in the future with the development of systems for direct positioning instead of placement and measuring of Ground Control Points (GCP) for georeferencing of imagery.

Similar experiment has already been performed by Niethammer et al., 2011. They monitored a landslide in the French Alps using an UAS equipped with a digital camera, from altitude of 200 m. DEM resolution of 6 cm was generated using a Structure-from-Motion (SfM) approach and with this approach they were able to detect fine details that could not be noticed using conventional airborne imagery.Airborne laser scanning (ALS) and terrestrial laser scanning (TLS) also provide high density point clouds enabling generation of high quality digital elevation models (DEMs) (Ackermann, 1999). Nevertheless, both techniques are relatively costly compa-red to the one described here.

2. SURVEY AREA AND SYSTEM CHARACTERISTICS

Measurements and flight campaign were made during early spring of 2018 under leaf-off conditions for landslide area called Duboka (44°40'11.72"N, 20°17'48.04"E), near the settlement of Umka in Serbia. This landslide is active for decades and threatens to ruin 124 houses and further to skid to river Sava. This would probably cause the flood that would seize quite big area in the near flatland and make huge damage to households near river. This landslide region covers area of ca. 75 ha with length of 1.4 km and width of 0.8 km. Terrain height varies from 117.5 m by the river to more than 200 m at the top of the landslide (Fig.1). This active landslide provides an ideal study area for investigating the potential of the UAS photogrammetry approach for assessing landslide deformations and movements through time.

In this area 65 points have been placed on ground and RTK-GNSS observations have been made with referencing to the four GNSS base stations placed on stable terrain (S1, S2, S3 and S4). These stations were planned and used for the landslide monitoring by using GNSS technology. GNSS observations for a set of points evenly distributed over the whole area of the landslide were collected. Same points have been marked as circular targets of 0.20 m diameter and highlighted centre with red paint on solid terrain.

Reason why so many GCPs were used in this area is the reduction of some of the systematic errors that may appear when using this methodology. These errors have been found to originate from various sources such as low image overlap, blurry images, flight configuration, number and distribution of GCPs, as well as the various geometric camera models used in the different SfM software (Peppa et. al., 2016).

Aircraft used for this mission was **DJI MATRICE 600 PRO**, industrial hexacopter that has maximum payload of 5.5 kg and a flight duration of approximately 20 minutes (Fig.2). System has three GNSS receivers for ensuring safe positioning during flight.

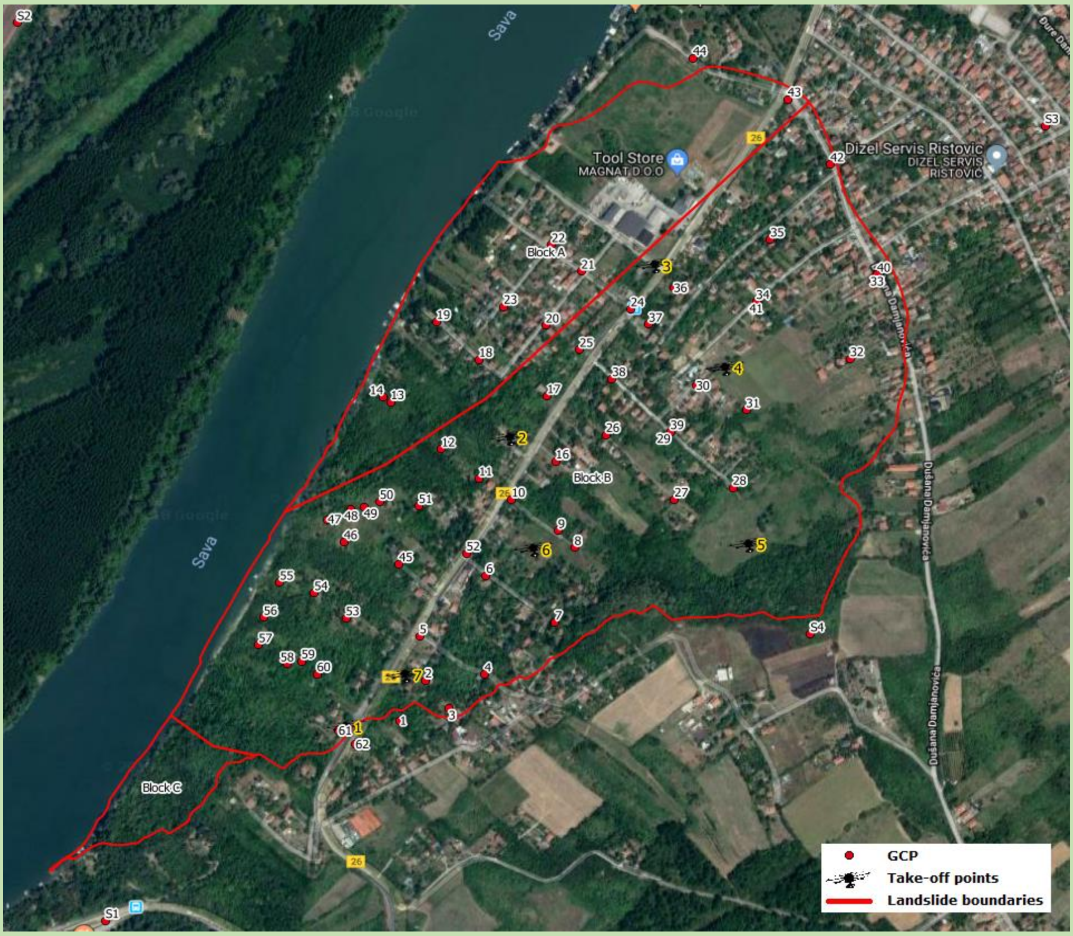


Figure 1
Area of the Duboka landslide with marked GCPs and take-off points for each of the flight missions

Figure 2
UAS used for imaging with two controllers – one for the aircraft and one for the camera control

Aircraft payload for this mission was DSLR camera **Canon EOS 6D** with full frame CMOS sensor (36 x 24 mm) and resolution of 20.2 megapixels (6.54 x 6.54 µm pixel size, creating an image of 5472 x 3648). A prime wide-angle Canon lenses with a nominal focal length of 24mm and maximum aperture of f/2.8 have been mounted on this camera. In order to obtain imaging with less vibrations and to keep it as much stable as possible during the flight, **Ronin-MX** brushless gimbal was mounted on this aircraft. Flight planning has been done using free mobile application *Pix4D Capture* (Pix4D Capture, 2018) by automatically triggering the camera every 3 seconds at flying speed around 5m/s in order to achieve optimal photo base for this project. Camera had fixed shutter speed of 1/640 s in order to decrease image blurring caused by wind, turbulence and motion of the UAV (Sieberth et al., 2014), ISO 100 sensor sensitivity to reduce image noise and an aperture of f/2.8 to ensure that sufficient light reached the sensor and that normal depth of field (DoF) was achieved on the imagery.

For this area more than two thousands of overlapping images have been made in order to cover all the landslide region for dense point cloud generation. Forward image overlap was 80-90% and around 60% of lateral image overlap. Drone was keeping an average flying height of 80 meters above take-off point and imagery with spatial resolution of 2.2cm was acquired. Seven flights were performed in order to cover the whole area because of the limits in flight time and in maximum distance from the UAS that must be complied with the flight regulations (max. 500 meters from take-off point and always having clear line of sight with no obstacles). Flights were performed during two sunny days with optimal wind conditions.

3. MATERIALS AND METHODS

The trial version of Structure-from-Motion based software *Agisoft PhotoScan* (Agisoft PhotoScan, 2018) was utilized for image-based modelling. The common workflow for dense point cloud generation includes pose estimation, image alignment, dense point cloud generation using dense stereo matching techniques, mesh generation, texture creation and orthophoto production Fig.3.

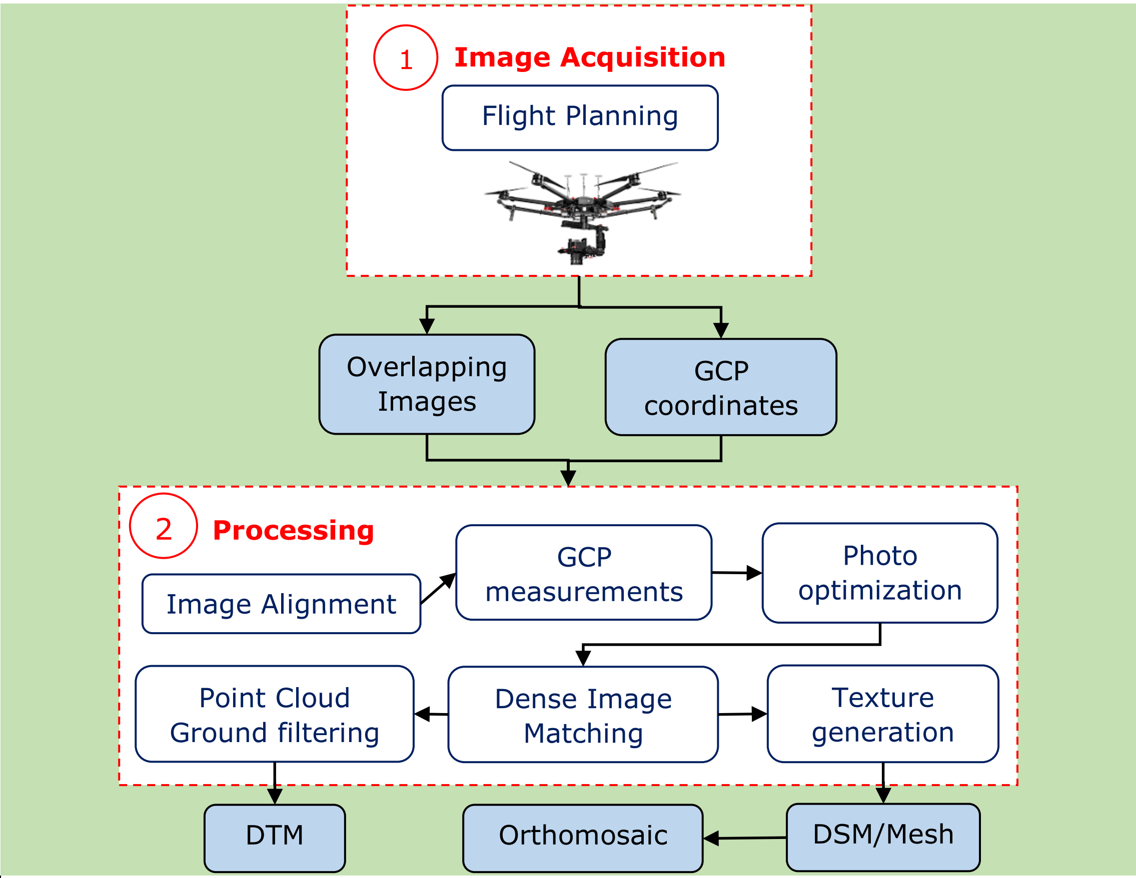


Figure 3 *SfM based processing workflow with resulting products*

Blurred images were detected by using the software and excluded from further processing. Oblique images were manually excluded from processing too. This lead to 1982 images in total that were used for processing. Because of the processing limitation of the machine, images were split in chunks in order to process the data in several processes.

GCPs were used for the registration of the sparse point cloud (tie points) in a fixed reference frame. GCP image projections were measured and processed with corresponding coordinates determined on the field within the process of photo-triangulation. In this process, a self-calibration parameters have been determined and these are used as internal orientation parameters of the camera.

After all mentioned steps, a dense point cloud was generated. According to Remondino et. al., 2014, in PhotoScan software, a method for dense point cloud generation was implemented which is similar to the stereo semi-global matching algorithm (Hirschmüller, 2008). The algorithm for every single pixel searches along the epipolar line to find its potential correspondent disparity, by recursively assigning costs based on pixel value differences of its nearest neighbours

(Remondino et al., 2014). Point texture was collected based on the projected image pixels to points and further a mesh model (Triangulated Irregular Network – TIN) based on reconstructed dense point cloud was created also. Orthomosaic with high spatial resolution was generated based on orthorectification process using mesh and assigned texture.

Afterwards the ground classification algorithm implemented in trial version of *TerraSolid* solution *TerraScan* (Terrasolid TerraScan, 2018) was used for dense point cloud ground filtering, noise reduction and data thinning needed for DTM generation of the landslide, so that only ground elevation would be tracked for terrain movements. Terrascan ground filtering is based on algorithm proposed by Axelsson, 2000. It starts from a sparse TIN established with local minimum points and iteratively refines it to the laser point set. At every iteration, points are added to the TIN if they meet certain criteria. Following the procedure, all ground points can be added to the final TIN.

4. RESULTS

After image alignment and measurements of GCPs on images, camera optimization has been made in order to georeference the model and remove blunders. After several iteration of bundle adjustment, only measurements from 45 GCPs have been adopted in order to achieve smallest RMSE and sufficient coverage of measurements on the whole landslide area. Reason why so many measurements were discarded was uncertainty in their stability because those were placed in parts of the landslide where movement is quite intense and rapid. This movement were possible to happen for time past from GNSS observations till UAS imaging. Final RMSE was 2.5 cm.

By using medium settings for building dense cloud, reconstructed point cloud had 188 103 597 points in total. This shows how detailed model can be for an area of comparable size, but also how hard it is to manipulate and work with this amount of data. Having this kind of product, major concern is then how to reduce the amount of data in areas where there are no significant changes detected, but also to preserve important details of the surface. After ground point filtering, there was 4 896 664 points left with label class ground.

The cleaned dense point cloud with points that belong to the class ground was imported back to the Agisoft PhotoScan to generate a raster elevation model. The grid elevation model (DEM) with a 50 cm spatial resolution was calculated. The DEM resolution was chosen according to the geomorphologist's needs.

Ground filtering check was made by calculating height differences between DTM and GCPs. Analysis showed that no larger deviations are present. This indicates that all of the measured GCPs are on the ground, that ground classification algorithm worked fine and that interpolation technique did not produce surface curving which would result in bigger differences on these points.

Orthomosaic was generated based on the textured mesh reconstructed by using points of the whole dense point cloud (Digital Surface Model – DSM). Spatial resolution achieved for this topographic map was 2.23 cm. By using orthomosaics, quite small detail can be spotted, such as the GCP marks, and these can be tracked by measurements on maps generated in different time series. The only problem may be occlusion of nearby objects so the orthomosaic must be generated by using aerial images on which place of interest is seen from the best angle. In this case, seemliness of the orthophotos should be wisely digitized.

5. DISCUSSION

Problems with DTM appeared in areas with a lot of vegetation. There were some of the low vegetation points classified as terrain. Additionally, in areas where the vegetation was not penetrable, holes in the data appeared after ground filtering algorithm was applied. In this case an interpolation method was used to fill the holes which led to unnatural estimation of the terrain surface (smoothing effect on Fig.4.

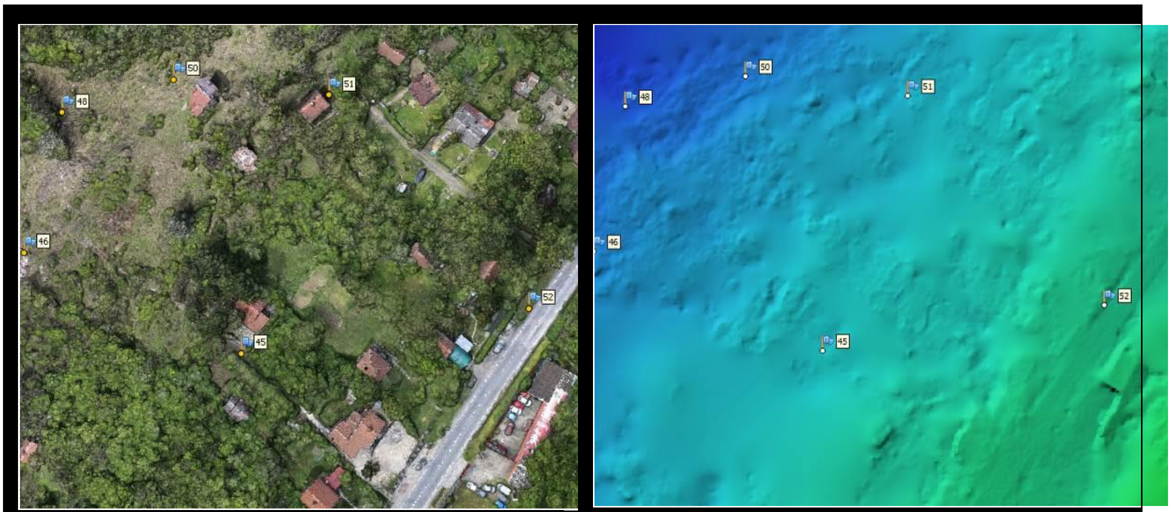


Figure 4
Holes in the DTM in vegetated areas (left) produced smoothing effect in the DTM (right

Orthophotos were good in areas where the terrain is visible and where the texture is not repeatable so that image matching technique works normally. Problems appeared on the roof edges and near other objects where height changes happened suddenly. When draping texture to mesh during orthophoto generation, long mesh triangles produced deformed edges of this objects in zigzag shape (Fig.5)

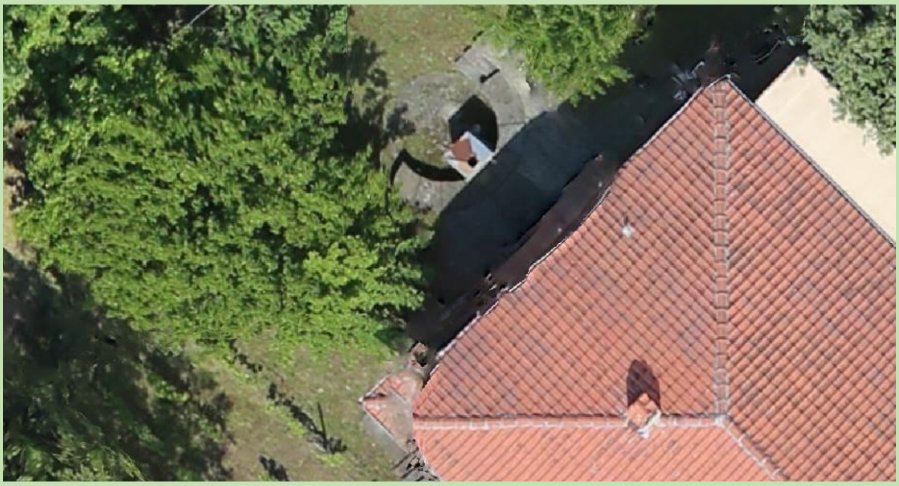


Figure 5
Zigzag shape of roof edges formed due to sudden mesh changes in height

6. CONCLUSIONS

UAS complemented by photogrammetry and modern dense image matching algorithms can deliver landslide elevation models through time in an automated and inexpensive way. Proposed methodology offers quite fast data collection with high spatial resolution. Procedure would become even quicker if the GCPs would be replaced with direct georeferencing – so that each camera acquisition would have known coordinates and orientation acquired from GPS and IMU units. Establishment of GCPs is labour intensive and can be hazardous in steep and unstable terrain, or even impossible for inaccessible areas so here direct georeferencing has much greater advantage.

The most useful products obtained by using this methodology certainly are DTM and orthophotos. Analysing just the terrain of the landslide without vegetation, manmade and other non-ground objects, professionals may interpret characteristics of the landslide. This morphology may be tracked through time and analysed based on height changes. According to the features from orthophotos, movements of the segments of the landslide can also be tracked. This is especially true for the features recognizable on the terrain surface level because elevated objects may look different if they are imaged from different camera positions.

A lack of ground points in areas with dense vegetation where the visibility of terrain was reduced on images was a problem. It leads to unreliable reconstruction of the terrain because of the holes produced during ground point filtering. Thereby this technique should be applied in non-vegetated areas or during the leaf off conditions of the year. Orthophotos should be made from images made from different flight directions in order to avoid occlusion of the terrain and objects of interest.

7. ACKNOWLEDGMENTS

UAS with the camera was procured with the funding from Erasmus+ Programme of the European Union-*561902-EPP-1-2015-1-SE-EPPKA2-CBHE-JP Modernizing geodesy education in Western Balkan with focus on competences and learning outcomes (GEOWEB)*. The authors would wish to thank companies of Agisoft and Terrasolid for providing the trial versions of software packages.

8. LITERATURE

[1]. **Ackermann, F.,** 1999. *Airborne laser scanning - Present status and future expectations*, ISPRS Journal of Photogrammetry and Remote Sensing, Volume 54 (2/3), 64-67.

[2]. **Agisoft PhotoScan**, 2018, http://www.agisoft.com (01 July 2018).

[3]. **Axelsson, P**., 2000. *DEM Generation from Laser Scanner Data Using Adaptive TIN Models*, The International Archives of Photogrammetry and Remote Sensing, XXXIII. B4/1, 110-117.

[4]. **Hirschmüller, H.,** 2008. *Stereo Processing by Semi-Global Matching and Mutual Information*, IEEE Transactions on Pattern Analysis and Machine Intelligence, 30 (2), 328-341.

[5]. **Niethammer, U., Rothmund, S., Schwaderer, U., Zeman, J., Joswig, M**., 2011. *Open source image-processing tools for low-cost UAV-based landslide investigations*, International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences, Volume XXXVIII-1/C22, Commission I, WG I/V, ISPRS Zurich 2011 Workshop, Switzerland.

[6]. **Peppa, M. V., Mills, J. P., Moore, P. , Miller, P. E., Chambers, J. E.,** 2016. *Accuracy assessment of a UAV-based landslide monitoring system*, The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Volume XLI-B5, XXIII ISPRS Congress, Commission V, WG V/5, 12–19 July 2016, Prague, Czech Republic.
[7]. **Pix4D Capture**, 2018, https://pix4d.com (01 July 2018).
[8]. **Remondino, F., Grazia Spera, M., Nocerino, E., Menna, F., Nex, F.,** 2014. *State of The Art in High Density Image Matching*, The Photogrammetric Record, 29 (Issue 146), 144–166.
[9]. **Sieberth, T., Wackrow, R., Chandler, J. H**., 2014. *Motion blur disturbs - the influence of motion-blurred images in photogrammetry*, The Photogrammetric Record, 29 (148), 434-453.
[10]. **Terrasolid TerraScan**, 2018, http://www.terrasolid.com (01 July 2018).

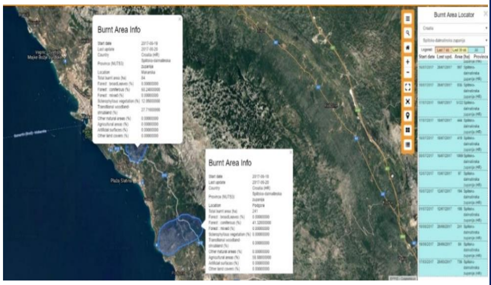
9. AUTHORS BIO

Nenad Brodić is Teaching Assistant at the Faculty of Civil Engineering, University of Belgrade in Serbia. He is teaching on courses of Photogrammetry and Remote Sensing, Digital Image Processing, Digital Terrain Modelling and Digital Photogrammetry on studies of Geodesy and Geoinformatics. His PhD research is based on Airborne Laser Scanning point cloud classification. He has been awarded and holds a lot of scholarships for great achievements during his studies and career. Nenad is involved in projects of Serbian Ministry of Education, Science and Technological Development and EU Erasmus + program GEOWEB project for modernizing geodesy education by using new technologies.

Željko Cvijetinović is Associate Professor at the Faculty of Civil Engineering – University of Belgrade responsible for courses such as Geoinformatics, Digital Terrain Modelling, GIS, Digital Photogrammetry and others. He has been working as a researcher in photogrammetry, digital mapping, GIS and related disciplines since 1989. He is the co-author of several software applications, technology and legislation supporting acquisition, processing, maintenance and analysis of large scale cadastral and topographic data in Serbia and the neighbouring countries. He has been also involved in numerous projects of building large spatial datasets and projects of development and implementation of complex GIS solutions. He is the co-author of more than 50 papers published in national and international scientific journals and conferences.

Branko Božić was born in Ub (Serbia). He graduated on the Military Academy - Department of Geodesy in 1982, as a first in a range of students with an average score of 9.56. The Faculty of Civil Engineering - Department for Geodesy he finished with an average score of 9.50. Professor Branko Božić obtained magister's degree at the Department of Civil Engineering, University of Belgrade in 1993 and received his doctorate from the same university in 2000. From 2002 he is employed at the Faculty of Civil Engineering. He became assistant professor in 2001, associate professor in 2008 and full professor in 2013. During his career he was director of the Institute of Geodesy and Head of the Department of Geodesy and Geoinformatics. From 2012 to 2014 he was Vice Dean for Finance and Faculty Dean from 2015 to 2018.

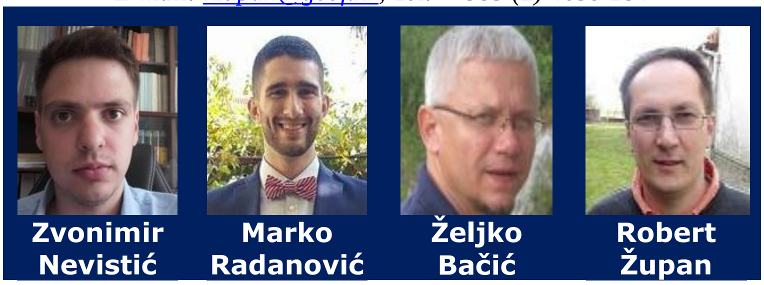
Dragan Mihajlović is Associate Professor at the Faculty of Civil Engineering – University of Belgrade responsible for courses such as Photogrammetry and Remote Sensing. Since 1980. he has been working as a researcher in photogrammetry, remote sensing, digital mapping, GIS and related disciplines at the Faculty of Civil Engineering – Department for geodesy. At the same faculty professor Dragan Mihajlović obtained magister's degree in 1985. and received his doctorate in 1991. He is the co-author of several software applications, technology and legislation supporting acquisition, processing, maintenance and analysis of large scale cadastral and topographic data in Serbia and the neighbouring countries. He is the co-author of more than 70 papers published in national and international scientific journals and conferences.



WILDFIRE MAPPING WITH SENTINEL-2 SATELLITE MISSION DATA

Msc. Zvonimir Nevistić[1]; Marko Radanović[2];
Prof. Dr. Željko Bačić[3]; Prof.as.Dr. Robert Župan[4]

[1,2,3] Institute of Geomatics, Faculty of Geodesy, University of Zagreb; Kačićeva 26, Zagreb, CROATIA
E-mail: znevistic@geof.hr; Tel: + 385 (1) 4639 379; E-mail: maradanovic@geof.hr; Tel: + 385 (1) 4639 339
E-mail: zbacic@geof.hr; Tel: + 385 (1) 4639 280
[4]Institute of Cartography & Photogrammetry, Faculty of Geodesy. University of Zagreb
Kačićeva 26, Zagreb, Croatia
E-mail: rzupan@geof.hr; Tel: + 385 (1) 4639 184



ABSTRACT

Every year an area of 350 million hectares is affected by a fire, of which 90% are forest fires. With economic losses, fires can result in human and animal losses and cause damage to health and the environment that cannot be fully compensated. Therefore, it is necessary to detect fires more efficiently, reliable and faster, and also to improve fire management and analyze affected areas.

Remote sensing methods can provide a quick and efficient response to this problem and can provide better estimates and fire detection. Today, remote sensing methods are most commonly used in the post-fire management for the wildfire maps production, which can contribute to strategies for preventing, predicting, mitigating and better response to fire. By developing new systems, such as the European Copernicus program, the application of these methods has become publicly available in full extent with no charge.

This paper presents the wildfire map-making procedure for the Makarska Riviera area in the Republic of Croatia based on Sentinel-2 satellite data and open source software using the normalized burned ratio (NBR) technique. Except for improving fire management and obtaining information on location and extent of damage, this procedure also allows monitoring the recovery of the affected environment.

Keywords: Wildfire, mapping, sentinel 2

1. INTRODUCTION

Natural disasters are an inevitable occurrence in today's world and it is almost impossible to completely compensate for the various damage that they cause. With the advancement of technologies, especially in the domain of Geoinformation systems and remote sensing, it is in some extent possible to reduce the risk of natural disasters by developing early warning strategies and providing better disaster management and faster recovery. It is estimated that in 2016 the economic loss caused by natural disasters amounted to $264 billion (Aon Benfield 2017). In addition to floods and earthquakes, the greatest economic losses are caused by wildfires. Every year an area of 350 million hectares is affected by fire, of which 90% are forest fires (Dun 2005). In addition to economic losses, forest fires cause damage to human and animal welfare and greatly affect society and the environment. They have a negative effect on human health and biodiversity, mainly by releasing greenhouse gases and damage to the infrastructure. The use of Geoinformation systems and remote sensing techniques provide powerful tools for monitoring, analyzing and managing forest fires, and their development has enabled the collection and analysis of data in ways that were previously impossible.

The European Union, through its Joint Research Center and the Directorate-General for Environment, established a special working group (the Forest Fire Expert Group) in 1998, whose main task was to find a model that would improve the efficiency of fighting against forest fires. Also, this working group aimed to encourage the development of technological innovations that could help in timely detection of forest fires and prevent their spreading. One of the results is the European program for the Earth observation - Copernicus. Copernicus provides various services that enable better management and control of forest fires. Its satellites provide viable tools for tracing active forest fires and continuous monitoring of woods and forests at a regional and global level, including the monitoring of the consequences of wildfires.

2. FOREST FIRES

Forests have several crucial functions for humans and life in general such as maintaining climate balance, preserving soil, water and biodiversity. Nevertheless, they are exposed to a large number of natural destructive factors such as droughts, diseases, infestations by insects, but also threats caused by human activity such as the constructions of new settlements, etc. However, considering all of these factors, forest fires represent the greatest threat to the survival of forests. Forests occupy approximately 40% of the territory of the European Union, i.e. 157 million hectares (Chuevico et al. 1999). As seen in the European framework, Mediterranean countries are in greatest danger of forest fires because of their climate conditions, especially in summer months. At this time of year, the temperatures are extremely high, and precipitation is scarce, which provides an excellent groundwork for the forest fires which are in these conditions easy to start and fast to spread. Mediterranean forests are struck by approximately 50 000 active forest fires each year causing great economic and environmental damage as well as loss of human lives. According to some forecasts, by 2030 the total amount of forest mass in the world will be cut in half by forest fires (Aon Benfield, 2017).

The total area of forest land in the Republic of Croatia is 2 688 687 ha, which is equal to 47% of the total land area (URL 1) and Croatia falls into the category of countries with greater risk of forest fires. For example, only in 2003, the county of Split-Dalmatia had 133 forest fires which burned 10 028 hectares of land in total and cause the total damage of €80 000 000 (Stipaničev 2008). This is mainly because of a type of vegetation and climate factors, but also an increased sociological risk of fires. In the more recent period between 2008 and 2016 Croatia averaged at 403 fires per year, while in 2017 there were 104 forest fires that burned a total area of 67 343 hectares (URL 2).

Due to its characteristic vegetation and climate, during the fire season (from June to October), 76% of the total number of fires in the Republic of Croatia occur in the Mediterranean area. Figure 1 shows the number of fires and the burned areas in 2017 in the Republic of Croatia divided by counties.

Development of information and high technology systems enables numerous innovations and technical solutions in forest fire control such as remote sensing methods. They can serve for efficient, reliable and fast detections of fires and improve fire management and comprehensive analysis of affected areas.

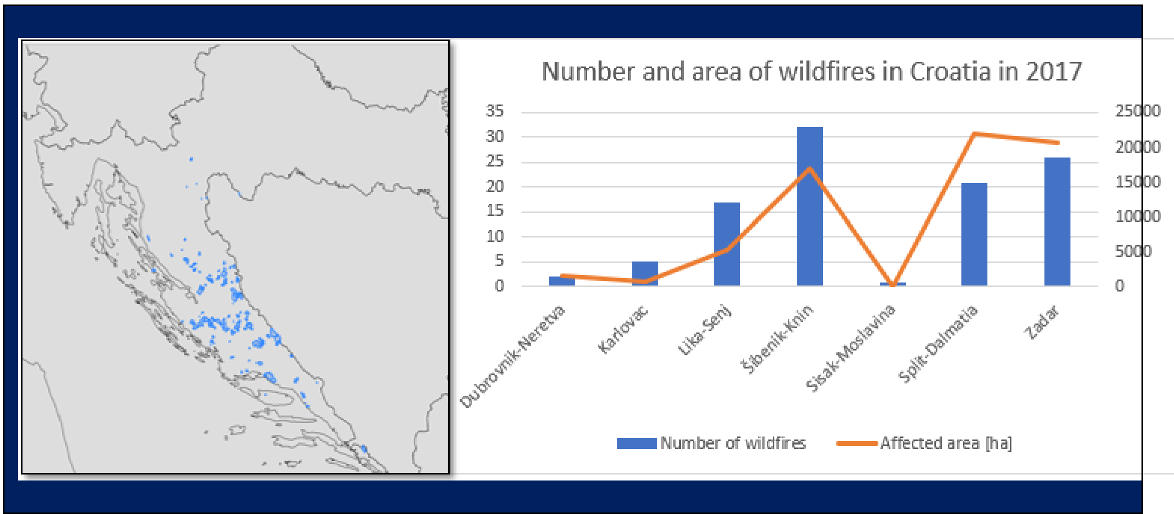


Figure 1 *Area and number of wildfires in the Republic of Croatia by the county in 2017*

3. REMOTE SENSING IN WILDFIRE MANAGEMENT

Major threats posed by the wildfires lead to the development of operating systems that contribute to fire management, like a fire danger prediction, fire detection and fire spread control. Such systems are of great importance in the economic aspect, but also in the aspect of human protection. The remote sensing supports many branches of fire management. They process and analyze data collected from sensors that are installed on satellites and aircraft, but also on terrestrial stations. Fires produce four types of spectral signals which can be observed by sensors from space and air, namely: direct radiation of flame (heat and light), aerosols (smoke), solid residue (ash and soot) and variations in the structure of vegetation (Dun 2005). By monitoring these signals, the remote sensing methods allow (in near-real time) mapping of the fire extent, detection and monitoring of the spread of fire, post-fire analysis and the determination of a potential source of a fire.

In fire management, the key task is the wildfire detection. This detection is possible by combining optical and thermal cameras (Lentile et al. 2006). Fire produces anomalies that can be detected in different parts of the electromagnetic spectrum. Wildfire produces light in the visible part of the spectrum, which can be detected by optical sensors, but this is applicable only during the night-time. Detection of the smoke created by fire is also possible, but most commonly used method is the detection of above-average temperature that creates a high reflection of the signal in infrared and thermal parts of the electromagnetic spectrum (Leblon et al. 2012). Wildfires that are detected can be monitored with high-resolution images which can contribute to their faster suppression, better assessment of its size and later, on its impact on the environment.

The mapping of burned areas and their analysis is one of the most successful applications of remote sensing in fire management. The great diversity and possibilities of optical and radar sensors allow the mapping of burned areas on a local and global scale. This is of great importance in combating and suppression of the greenhouse gases effects as well as monitoring of the restoration of vegetation, erosion and the like. The fire causes significant changes in the structure and reflection of vegetation, but also in the properties of soils within the areas affected by the fire. For this task, optical instruments and multispectral images are most often used to highlight a burned area by combining different channels with high efficiency.

Multispectral cameras can be used for observation of “scars” of vegetation caused by fire and its spectral characteristics. Near-infrared – NIR (0.7 – 1.5 μm) and short-wave infrared – SWIR (1.5 – 3.0 μm) parts of the spectrum are most commonly used for mapping of these effects because of their high sensibility on changes in vegetation that the fire causes. The technique that uses precisely these two parts of the spectrum, designed to highlight the burned areas, is called the Normalized Burn Ratio (NBR). Healthy vegetation has a very high reflection in the near-infrared part of the spectrum and a low reflection in the short-wave infrared part of the spectrum. On the other hand, burned vegetation has a relatively low reflection in the near-infrared and high reflection in the short-wave infrared part of the spectrum. NBR can be calculated from these parts of the spectrum using the expression (Norton et al. 2011):

$$NBR = \frac{\mathrm{NIR} - \mathrm{SWIR}}{\mathrm{NIR} + \mathrm{SWIR}} \quad (1)$$

The high values of NBR point to healthy vegetation while low values point to bare ground and burned area. Differentiated NBR (ΔNBR) represents a scaled index of the magnitude of changes caused by a fire in an area. ΔNBR is composed of NBR values in the same area before and after the fire, i.e. the difference between the NBR values of healthy and burned vegetation in an area (Norton et al. 2011):

$$\Delta NBR = NBR_{pre\ fire} - NBR_{post\ fire} \quad (2)$$

The meaning of ΔNBR value can vary depending on the scene, and the best interpretation of the results in each specific case should be based on field evaluation. However, the USGS FireMon program (URL 3) provides a table that can be used as the first approximation for the interpretation of the NBR difference (Table 1).

Table 1 *Interpretation ΔNBR according to the USGS FireM on program (URL* 3)

ΔNBR	Burn Severity	ΔNBR	Burn Severity
< -0.25	High post-fire regrowth	0.27 do 0.44	Moderate-low severity burn
-0.25 do -0.1	Low post-fire regrowth	0.44 do 0.66	Moderate-high severity burn
-0.1 do 0.1	Unburned	> 0.66	High-severity burn
0.1 do 0.27	Low-severity burn		

Values of ΔNBR divided into classes are used to create thematic maps of burn intensity from lowest to highest and to separate burned from unburned areas. Usually, these maps are generated immediately after the fire in order to obtain an initial assessment of the damage caused. This can contribute to the development of emergency intervention and to post-fire recovery management.

The mapping of the burned areas is most often performed using an optical sensor because they are, generally, relatively low cost and have a high degree of spatial resolution. However, these techniques also have a variety of problems, such as weather conditions (like a cloud and/or smoke cover) which can negatively affect the quality of images. Another problem is the spatial resolution because, typically, with an increase of the spatial resolution to the high and mid-levels (10 – 30 m) the revisit time of the sensor above the same area is shortened. The Sentinel-2 satellite mission of the European Copernicus program offers data with high spatial and temporal resolution and is independent of the weather and the time of day. In this paper, the data are collected by this mission and are then used to map the burned areas in the Republic of Croatia using the techniques of NBR.

4. COPERNICUS EARTH OBSERVATION PROGRAM, EFFIS AND SENITNEL–2

Copernicus is the most ambitious Earth observation program to date. The main goals of the program are to enable a different spatial management services, to improve the quality of life, environmental monitoring, understanding and mitigating effects of climate change, safety of life and provide accurate, timely, full, free and open data at the global scale (Aschbacher et al. 2010). The program collects data through two main components: space and in-situ. Space component comprises two types of satellite missions which are equipped with a large number of sensors that measure and register numerous parameters and occurrences: Sentinels satellites missions (six specific mission developed by ESA) and other missions, called Contributing Missions. Along with the space component, Copernicus also relies on data from in-situ monitoring networks, which consists of a series of stations on ground, sea and in the air to provide robust integrated information and to calibrate the data from satellites (Hećimović and Martinić 2015). Copernicus satellite and in-situ mission data are made available and accessible to any citizen and any organization through Copernicus services divided in six thematic areas: atmosphere, marine environment, land, climate, emergency management and security.

The Copernicus Emergency Management Service (EMS) consists of two main components: Early Warning and Mapping. EMS provides accurate maps and insight into natural and man-made disasters from satellites and in-situ data at global scale. The Service also supports crisis management, civil protection, flood and wildfire warning and assessment, and humanitarian crises. The main goals of the service are the EU's response to the needs of crisis situations within and beyond its borders. The Early warning component's purpose is monitoring the risk of floods and wildfire event. From 2015. European Forest Fire Information System (EFFIS) is a part of EMS which provides information on forest fires and their impact on the environment in Europe, the Middle East and North Africa. The system uses and process meteorological and optical satellite data on a daily basis for better fire management, early warning of fire and mapping of affected areas. The system also includes real-time active fire detection, damage estimation, greenhouse gas emissions and fire erosion estimation. Detection and mapping of active wildfires are based on the use of MODIS, Sentinel-2 and -3 and VIIRS satellite data. These data are combined with Copernicus CORINE Land Cover layer, which provides consistent information on land cover changes in Europe, to reduce the number of false alarms from industrial and urban areas and to differ forest fires from others. EFFIS provides up-to-date fire information, but it is often prone to error in the exact location and extent of fire because of low spatial resolution (250 m) of sensors. Also, EFFIS provide information only for wildfires over 40 ha on a daily basis. These disadvantages can be supplemented by the data collected with the Sentinel-2 satellite missions.

The Sentinel-2 mission comprises a constellation of two identical polar-orbiting satellites placed in the same orbit, separated by 180 degrees. Satellites are equipped with optical - multispectral cameras (MSI) for continuous land monitoring. The Mission represents a unique Earth observation program and introduces new environmental management methods thanks to an innovative camera, including the short revisit time (10 days at the equator with one satellite, and 5 days with two satellites which results in 2-3 days at mid-latitudes). Short revisit time and high spatial resolution (up to 30 m) of images provide fast and reliable delivery of images for crisis management (ESA 2012).

5. MATERIALS AND METHODS

In this paper, a wildfire map of two affected areas in Split-Dalmatia County was made using NBR technique and Sentinel-2 satellite mission data. The first wildfire started on 18. June 2017 above the town of Podgora and lasted for four days. According to EFFIS, 241 ha was affected by fire, of which 42% are forest area. The second fire started the day later, a few kilometers further, on June 19, 2017, between Tučepi and Makarska. The fire affected 84 ha of land, of which 87% is forest area.

5.1. DATA AND SOFTWARE

EFFIS, and similar systems, provides excellent and accurate information on wildfire events, however, they are often prone to errors in terms of determining the exact location and extent of the fire. Also, these systems often "omit" smaller fires (less than 40 ha). For these reasons the use of raw satellite imagery and methods of their analysis and processing gives much better results. In this paper, for wildfire map production, Sentinel-2 level C-1 products were used. These products can be downloaded from the Sentinel Scientific Data Hub (URL 4), where free registration is necessary. Downloaded images in SAFE format are very large (6 GB+) because they contain all 13 bands. As it is necessary to have only certain bands for wildfire mapping (IR and NIR), it is possible to use alternative platforms such as Amazon S-3 (URL 5) where data can be downloaded in JPEG2000 format for each band separately and merged to a multispectral image through later processing. These download data are much smaller (up to 200 MB), require less space, and shorter download and processing time. In this paper the data are downloaded from the Amazon-3 platform.

With satellite imagery, it is also necessary to download administrative boundaries in vector format (shape) which are needed to crop the area of interest. The administrative boundaries can be downloaded free from the DivaGis portal (URL 6) in Shape format. For image processing was used QGIS software that supports all the necessary procedures for creating wildfire map and is free of charge for full use.

5.2. PRODUCTION PROCESS

Wildfire map production process with Sentinel-2 satellite data in QGIS can be divided into five simple steps. In the first step, EFFIS was used to roughly determine the location and time of fire needed to download the adequate satellite imagery for processing. EFFIS also provides information about the area and type of affected vegetation as shown in Figure 5.

Figure 2 *Determining the location and time of the fire using EFFIS (URL 2).*

The second step is to download the satellite imagery (pre and post fire) from the Amazon S-3 platform. Considering revisit time and coverage of Sentinel-2 mission, both fires are on the same satellite image. Since it is not necessary to combine all 13 bands, only bands in the visible (B02, B03, B04), near-infrared (B08) and short-wave infrared (B11 and B12) spectra are downloaded, which are needed for NBR computation. In the third step, initial processes in QGIS are made. It is necessary to resample images to same spatial resolution (10 m) and merge all bands in one multispectral image. After that, sub-area, using a shape file with administrative boundaries, is created to highlight the surface affected by fire and to enable better analysis and management. In the fourth step, with different band composite, the surface affected by fire is analyzed. RGB True color composite (*R*=B04, *G*=B03, *B*=B02) is created, where, in the visible part of the spectrum, the actual (natural) surface representation is obtained before and after the fire. On these (RGB) images (Figure 2), with the naked eye is possible to detect fire affected area, but for more accurate emphasis and analysis, NBR technique is applied.

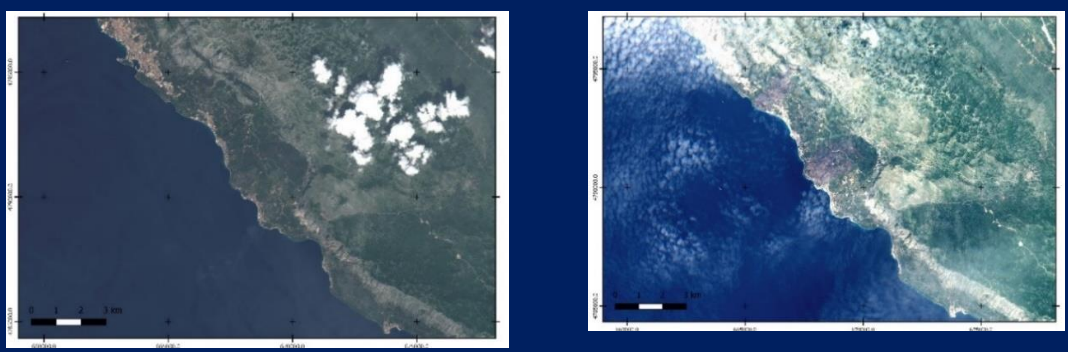


Figure 3
RGB True colour images of pre-fire (left) and post-fire (right) obtained with Sentinel-2 data

In the fifth step, NBR technique, that calculates a new image according to formula 1, was applied. As a result, an image in gray color scale is obtained from which we can read the NBR values and get valuable information. As NBR values of burned vegetation are mostly negative, it is possible to classify image and highlight them, while the rest of the vegetation, regarding the minimum and maximum pixel value, will be distributed linearly. By this procedure, the final result that clearly shows the wildfire is obtained (Figure 3).

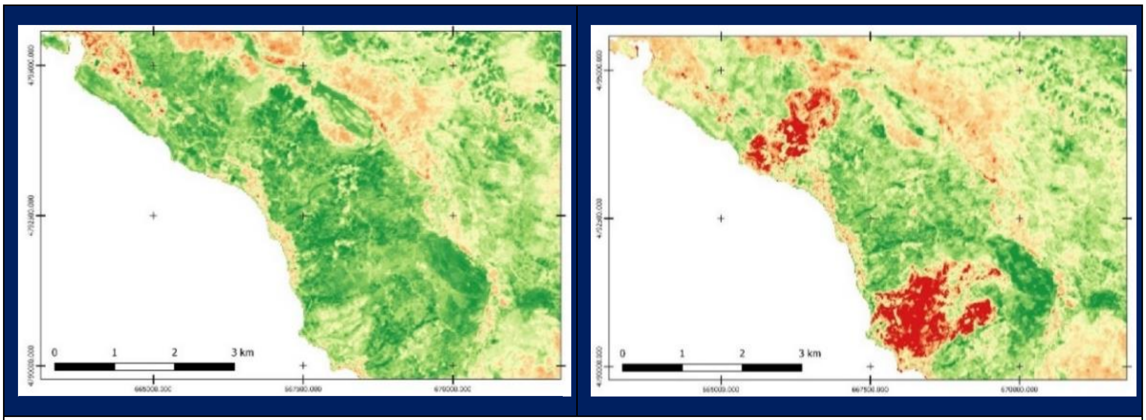


Figure 4 *Map of the area before (left) and after (right) the fire using NBR technique*

5.3. RESULTS ANALYSIS

Since the NBR negative values do not necessarily indicate the burned area, but also bare land, it is necessary, according to formula 2, calculate the difference between the NBR pre-fire and post-fire values. By calculating these differences, according to Table 2, clear insight into the post-fire surface condition and valuable information for further control and monitoring of the area affected by the fire are obtained. For the analysis, 10 characteristic points (inside, outside and in the edge of the area), shown in Figure 4, were selected and for each point, NBR was read.

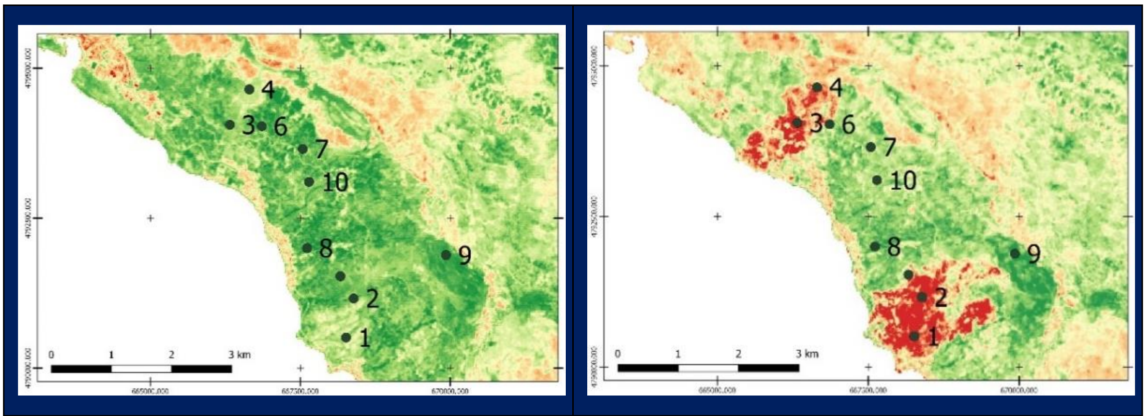


Figure 5 *Map of the area before (left) and after (right) the fire with the selected identical points where the NBR values were estimated*

Table 2. *Estimated values of NBR on identical points, their differences and the interpretation of differences*

Point	NBR_{before}	NBR_{after}	ΔNBR	Interpretation
1	0,346	-0,220	0,566	Moderate – low severity burn
2	0,403	-0,226	0,629	Moderate – low severity burn
3	0,450	-0,171	0,621	Moderate – low severity burn
4	0,261	-0,002	0,263	Low severity burn
5	0,483	-0,020	0,503	Moderate – low severity burn
6	0,153	-0,085	0,238	Low severity burn
7	0,489	0,391	0,098	Unburned
8	0,557	0,562	-0,005	Unburned
9	0,517	0,620	-0,103	Low post-fire regrowth
10	0,354	0,349	0,005	Unburned

6. CONCLUSION

Remote sensing methods, independently and in combination with terrestrial data, can play a significant role in mapping and analyzing both active fires and burned areas, but can also help in fire prevention. The most common use of these methods is in post-fire procedures, for making wildfire maps of affected areas. This paper shows a simple way of using free data to create wildfire map and thereby obtain information that can be used to carry out a risk assessment of the affected area and environment. Wildfire maps created with this method enable analysis after fire event and can be applied to strategies and policies for prevention, forecasting, mitigation and fire management.

Remote sensing methods were extremely expensive and did not provide rapid response and analyzes of disaster because of poor satellite revisit time above the same area, but today, with Copernicus programme and its Sentinel missions and services, these techniques have become available to everyone in near-real time. Beside analysis, the obtained data can contribute to the monitoring of the environment recovery, which is extremely important for the field of agronomy and forestry. Products obtained with this method can be beneficial to both, GIS and other non-GIS user, because they can be overlapped with other data depending on the interest in use. Beside fire management institutions, these methods can also contribute to the improvement of work to other institutions such as police administration, environmental protection agencies, civil protection, agricultural and forestry agencies, national parks, the local communities, insurance companies and many others.

7. REFERENCES

[1]. **Aon Benfield**, *2017: 2016 Annual Global Climate and Catastrophe Report, 75 str., London*

[2]. **Aschbacher, J., Beer, T., Ciccolella, A., Pilar Milagro, M., Paliouras, E**., *2010: Observing Earth for a safer planet, ESA Bulletin, Vol. (142):23. - 31., AG Noordwijk*

[3]. **Chuevico, E., Salas, F.J., Carvacho, L., & Rodirguez-Silva, F**., *1999: Integrated fire risk mapping, In Remote Sensing of Large Wildfires in the European Mediterranean Basin, Remote Sensing of Large Wildfires in the European Mediterranean Basin, Springer-Verlag, 61.-85., Berlin.*

[4]. **Dun, D**., *2005: Forest fire and degradation assessment using satellite remote sensing and geographic information system, Satellite Remote Sensing and GIS Applications in Agricultural Meteorology, World Meteorological Organization ,361.-400., Geneva*
[5]. **Europska svemirska agencija**, *2012: Sentinel-2, ESA's Optical High Resolution Mission for GMES Operational Services, ESA Communications, 80 str., Leiden*
[6]. **Hećimović, Ž., Martinić, L**., *2015: Utjecaj Copernicus program opažanja Zemlje na geoinformacijske proizvode i usluge, U: Racetin, I. (ur.), Opatija : Hrvatska komora ovlašteni inženjera geodezije, 134. – 142., Hrvatska komora ovlaštenih inženjera geodezije, Zagreb*
[7]. **Leblon, B., Chavez, L.B., San-Miguel-Ayanz, J**., *2012: Use of Remote Sensing in Wildfire Management, Sustainable Development - Authoritative and Leading Edge Content for Environmental Management, InTech, 55. – 82., Rijeka*
[8]. **Lentile, L., Zachary, A., Smith, A.M.S., Falkowski, M., Hudak, A.T., Morgan, P., Lewis, S., Gessler, P., Benson, N**., *2006: Remote sensing techniques to assess active fire characteristics and post-fire effects, IAWF, Vol.(15):319. – 345., Clayton*
[9]. **Norton, J., Glenn, N., Germino, M., Weber, K.T., Seefeldet, S**. *2009: Relative Suitability of Indices Derived from Landsat ETM+ and SPOT 5 for Detecting Fire Severity in Sagebrush Steppe Rangelands, str. 187 – 204, Int J Appl Earth Obs Geoinformation, Vol. (11): 187. – 204., Rochester, NY*
[10]. **Stipaničev, D.,** *2008: Holistički model integralne zaštite od požara raslinja Splitsko dalmatinske županije, Suzbijanje požara otvorenog prostora – nove metode i pristupi, Plenarno predavanje, RCADR i Ministarstvo regionalnog razvoja, šumarstva i vodnog gospodarstva, 39 str., Makarska*

URL

[11]. **URL 1**: *Hrvatske Šume, http://portal.hrsume.hr/index.php/hr/ume/opcenito/sumeuhrv, 25.07.2018.*
[12]. **URL 2**: *EFFIS, The European Forest Fire Information System, http://effis.jrc.ec.europa.eu/, 26.07.2018.*
[13]. **URL 3**: *USGS Fire Moon programme - The Normalized Burn Ratio (NBR), https://burnseverity.cr.usgs.gov/pdfs/lav4_br_cheatsheet.pdf, 26.07.2018.*
[14]. **URL 4**: *Copernicus Open Access Hub, https://scihub.copernicus.eu/, 17.07.2018.*
[15]. **URL 5**: *Amazon-3: Sentinel-2 on AWS, http://sentinel-pds.s3-website.eu-central-1.amazonaws.com/, 19.07.2018*
[16]. **URL 6**: *Diva-GIS, http://www.diva-gis.org/, 19.07.2018.*

AUTHORS BIO

Zvonimir Nevistić: Born in Bedekovčina in 1991. Finished study as master of Geodesy and Geoinformatics. He graduated from Faculty of Geodesy in Zagreb in 2015. From 2016 he is employee of Faculty of geodesy in Zagreb, institute of Geomatics, chair for satellite geodesy. Currently, he participates in several Erasmus projects such as BESTSDI and EO4GEO and he is enrolled in the 2nd year of PhD studies. His work experience includes: satellite geodesy, cartography, GIS, SDI and remote sensing.

Marko Radanović: Born in Zagreb, Croatia in 1991. Graduated as survey technician from Surveying Technical School Zagreb in 2010. Finished master's degree on Faculty of Geodesy University of Zagreb in 2015. Employed as a survey engineer in private firm Geodezija d.o.o from 2015 to 2016. From 2016 employed as a research assistant at Faculty of Geodesy, institute of Geomatics. Currently enrolled in the 2nd year of PhD studies at the same faculty.

Prof. Željko Bačić, PhD: Born in Zagreb in 1961. Graduated at Faculty of Geodesy in Zagreb and took his PhD at Technical University Graz in 1997. Employed at the Faculty of Geodesy in Zagreb since 1987. Between 1999 and 2012 was Director of State Geodetic Administration of Republic of Croatia, President of EuroGeographics between 2004-2007 and Chairmen of Regional cooperation on cadastre and SDI in Western Balkans between 2008-2012. Presently, full professor at the Chair for Satellite Geodesy at the Faculty of Geodesy and Vice-dean for science and international relations.

Assoc. Prof. Robert Župan, PhD: Born in Zagreb in 1973. He graduated at Faculty of Geodesy in 1998. In 1999, he started working at the Institute for Cartography at the Faculty of Geodesy in Zagreb, where works today as associated professor. Presently he is Vice-dean for finance. He is enrolled in several projects and his research includes cartography, photogrammetry, remote sensing and GIS. He led more than 80 students' seminar and master theses. He published many papers in journals and proceedings, produced a number of maps and participated in numerous international and domestic conferences. He is a member of Croatia Cartography Society.