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CURRENT STATUS AND ACTIVITIES OF SATELLITE GROUNG-BASED SYSTEM EUPOS AND EUPOS-BG

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Abstract: *The project EUPOS is briefly presented. The state of the BULiPOS stations network in Bulgaria and the problems associated with it are outlined. The activities related to EUPOS-BG as projects CERGOP, EUMETNET, Geodynamics of the territory of Bulgaria, Current projects - Archaeology, Floods, Engineering projects and other activities are summarized.*

АКТУАЛНО СЪСТОЯНИЕ И ДЕЙНОСТИ НА СПЪТНИКОВАТА ЗЕМНО-БАЗИРАНА СИСТЕМА EUPOS И EUPOS-BG

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1. General

EUPOS (EUropean POsitioning determination System) is already established, recognized and used within Central and Eastern Europe and new countries from Eastern Europe gradually integrate to it. Configuration and the number of stations in particular countries have been little changed. Cross-border stations operate successfully between neighboring countries. The use of network and system for solving scientific and applied problems and projects is extremely versatile and effective. Here the project EUPOS is briefly presented and the state of the BULiPOS stations network in Bulgaria and the problems associated with it are outlined. The activities related to EUPOS-BG as projects CERGOP, EUMETNET, Geodynamics of the territory of Bulgaria, Current projects - Archaeology, Floods, Engineering projects and other activities are summarized.

2. Current status of *EUPOS*

2.1. Description

EUPOS ground-based system covers about 25% of the territory of the European Union and more than 60% across Europe. The *EUPOS* reference network consists of about 900 stations (Fig. 1).

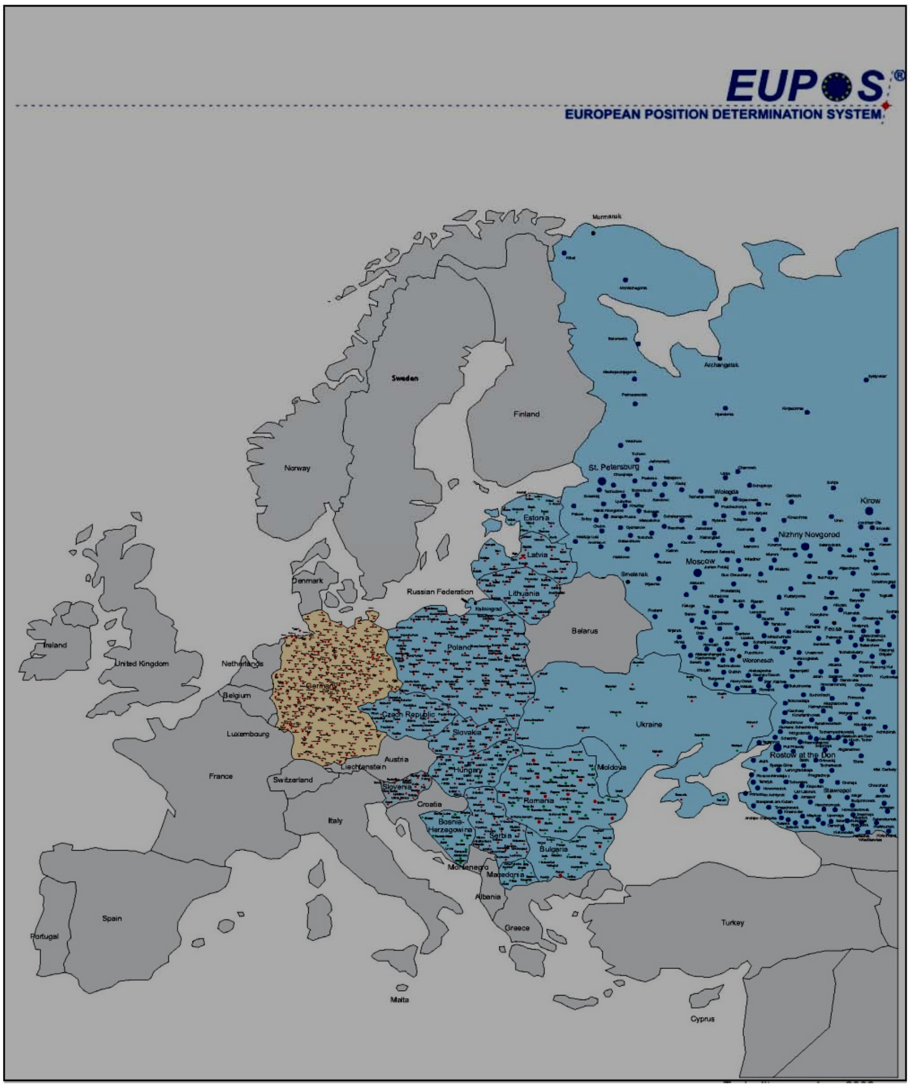


Fig. 1. *EUPOS* reference stations

Country – members of *EUPOS* are 20 by March, 2012 :

- Bosnia &Herzegovina,
- Bulgaria,
- Czech Republic,
- Estonia,
- Georgia
- Hungary,
- Kazakhstan
- Latvia,
- Lithuania,
- Macedonia,
- Moldova,
- Montenegro,
- Poland,
- Romania,
- Russian Federation,
- Serbia,
- Slovakia,
- Slovenia,
- Ukraine.
- German Land Berlin.

Some other countries like Azerbaijan and Kirgizstan have interest to become members of *EUPOS*.
EUPOS provides *DGNSS* correction information and observation data for real time positioning and navigation and for post-processed position determination.
EUPOS transmitted correction models are as follows:

FKP – area modeled corrections,

VRS – Virtual Reference Station,

MAC – Master Auxiliary Concept.

2.2. Technical specifications

EUPOS uniform standards, guaranteed compatibility and further development give same possibilities and security for industry, users and providers. *EUPOS DGNSS* corrections are obtained in uniform coordinate system – in European Terrestrial Reference System 1989. Uniform standard environment for all subservices – internet and optimum radio environment for *EUPOS* services in real time are used. For all *EUPOS* stations are used only individual calibrated GNSS antennas. Corrections are transmitted in uniform format: *RTCM-EU*. Cross-border reference stations provide corrections for the area relief (*FKP*).

EUPOS® Services proposed are:

EUPOS® DGNSS

DGNSS corrections in real time or for post processing from code or code-phase observations with accuracy of 3.0 – 0.5 m and higher.

EUPOS® RTK networking

DGNSS corrections for precise positioning in real time from phase observations with accuracy of about 2 cm.

EUPOS® Geodetic

DGNSS static and kinematic applications from post processing of phase observations with centimetre up to millimetre accuracy.

International Steering Committee - *ISC* has been established. *ISC* established two Working Groups:

- *EUPOS* Working Group on Technical Cooperation with the Industry (*TCI*),
- *EUPOS* Working Group on System Quality, Integrity and Interference Monitoring (*SQII*).

EUPOS ISC established close cooperation with other organizations: International Committee on Global Navigation Satellite Systems (*ICG*); United Nations Office for Outer Space Affairs (*UNOOSA*); *EUREF* Technical Working Group; Radio Technical Commission for Maritime Services Special Committee 104 (*RTCM SC 104*). *EUPOS* and *EGNOS* have an agreement for cooperation**.**

Except *EUPOS* which is the largest *DGNSS* in Europe many other *DGNSS* exist usually on national level, e.g. *SWEPOS* (Sweden), United Kingdom and Ireland etc.

2.3. Applications

Potential applications of *GNSS* as well as *DGNSS* are all branches of the social life.

- Surveying and mapping
- Transport systems, fleet management, systems of management of:
- Building logistics (trucks – management of large objects (projects), reducing the heavy traffic and its optimization, management of excavators and cranes).
- Insurance of the land property by realization of the property documentation (cadastre of real estates and property register).
- Radio measurements from vehicles and helicopters.
- Water economy.
- Environmental protection (ecology of water basins, coordination in soil examination, etc.).
- Geoinformation systems (cadastre of underground facilities, systems for environmental protection, streets and roads state).
- Photogrammetry (topographic survey, 3D models in urban regions).
- Full proof of the military resources.
- Measurements in construction and engineering (deformation investigations, monitoring of buildings and constructions).
- Dangerous heavy transport.
- General transport controlling systems.
- Precise time reference
- Emergency services.
- *GPS* Tracking systems - *GNSS* are used to determine the location of a vehicle, person, pet or freight, and to record the position at regular intervals in order to create a log of movements.
- Weather Prediction Improvements — Measurement of atmospheric bending of *GNSS* satellite signals by specialized *GNSS* receivers in orbital satellites can be used to determine atmospheric conditions such as air density, temperature, moisture and electron density.
- Marketing — some market research companies have combined *GIS* systems and survey based research to help companies to decide where to open new branches, and to target their advertising according to the usage patterns of roads and the socio-demographic attributes of residential zones.
- Social network- a growing number of companies are marketing cellular phones equipped with *GPS* technology, offering the ability to pinpoint friends.

3. Current status of *EUPOS-BG* (*BULiPOS)*

EUPOS-BG segment in Bulgaria is *BULiPOS* (*BUL*garian intelegent *PO*sitioning *S*ystem) network of reference stations established in 2008 and the present configuration is shown in *Figure 2*.

Fig. 2. Recent BULiPOS stations coverage

Numbers of cross-border stations was increased as well. Total number of *BULiPOS* stations at present is 13. The most used services are in real time.

BULiPOS provides additional information for data correction in case of use of GPS and GLONASS. Total 26 reference stations on the territory of the country and surrounding neighbors provides more than 90% real territorial coverage.

4. Activities related to *EUPOS-BG*

4.1. CERGOP

The main purpose of CERGOP (Central European Regional Geodynamic Project) is investigation of zones with intraplate movements on the base of processing of data from permanent and epoch stations over the territory of Central and Eastern Europe. A particular region of study of this project is Balkan Peninsula [Milev, Dabovski, 2006].

30 seconds data from five *BULiPOS* and two *CERGOP* permanent stations continue to be downloaded to the OLG Data centre for post-processing. Their horizontal velocity vectors (*Figure 2*) with respect to the stable Eurasia plate have been obtained using data since 2010 [Stangl, 2011].

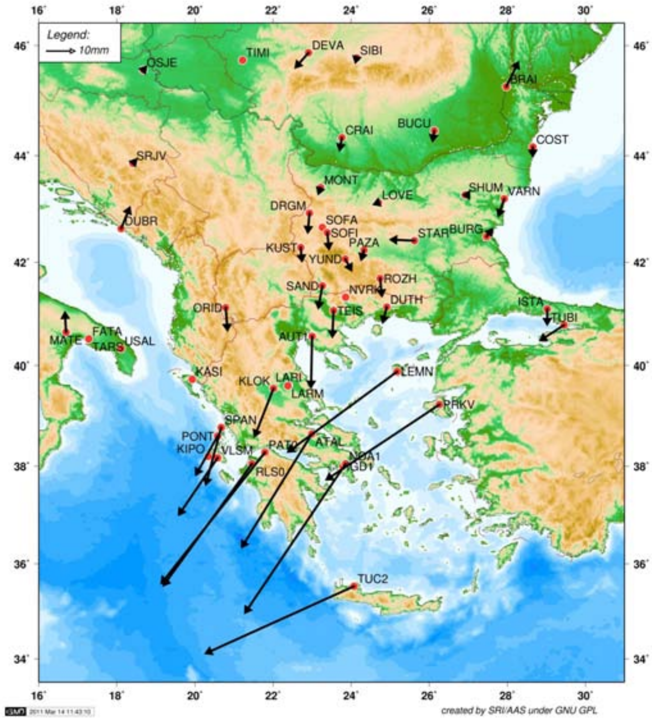


Fig. 3. Balkan Peninsula horizontal velocities with respect to stable Eurasia (after Stangl, 2011)

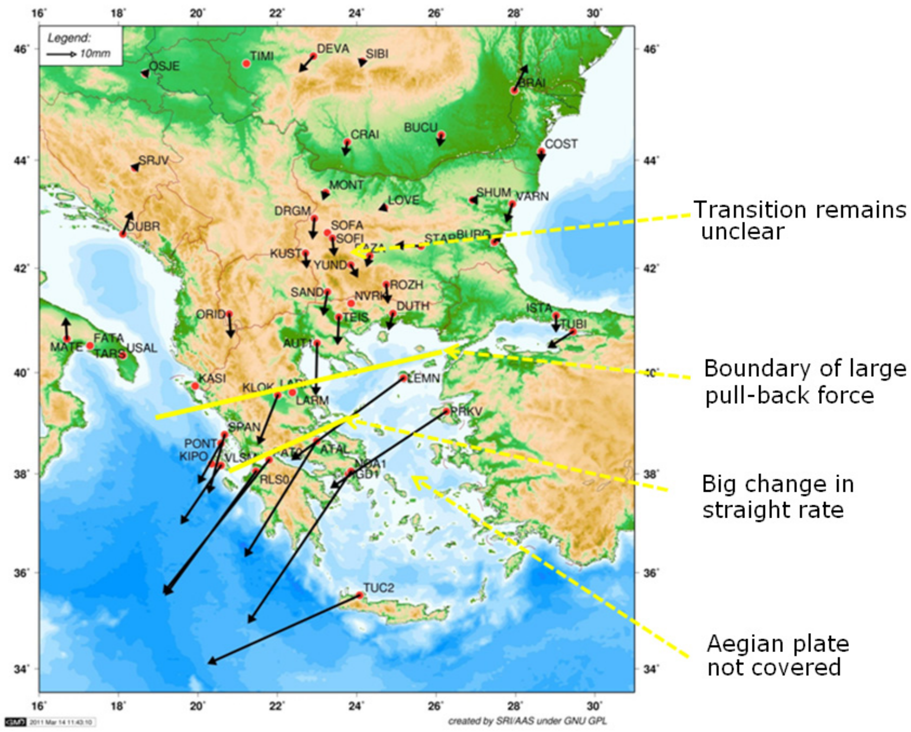


Fig. 4. Balkan Peninsula boundaries of movements (after Stangl, 2011)

The results obtained for the territory of Bulgaria show that the plate transition remains unclear [Stangl, 2011] although more stations in Bulgaria have been involved (*Figure 4*).

4.2. Geodynamics of the territory of Bulgaria

For geodynamical study of the territory of Bulgaria all *BULiPOS* stations have been processed and the results have been analyzed.

GPS data processing of BULiPOS station network

One week GPS data from three years (2009, 2010 and 2011) of *BULiPOS* station network have been processed with Bernese software, version 5.0 in ITRF2005. Estimated coordinates and velocities of the network stations have been obtained by applying the least squares method with minimum constraint conditions for coordinates and velocities of selected reference IGS stations. Eight IGS reference stations (*Figure 4*) with their coordinates and velocities in ITRS realization ITRF2005, referred to the epoch 2000.0 have been used in the combined solution. For representation the local movements of the stations the horizontal station velocity vectors (*Figure 6*) have been obtained in ETRF2000 by applying ETRF components of the Eurasia plate rotation pole to the obtained ITRF2005 velocity vectors (Boucher, Altamimi, 2008).

Fig.5: Location of BULiPOS network stations (in red) and IGS reference stations introduced (in black)

Fig. 6: ETRF2000 horizontal velocities of BULiPOS network stations

The magnitude of the obtained *BULiPOS* horizontal station velocities varies from 0,2mm/yr up to 3,8mm/yr. Such small magnitudes of movements of points over the territory of the country have been also obtained by other researchers (Burchfiel et al., 2006; Kotzev et al., 2006).
The effect of datum definition changes on the estimated station horizontal velocities has been also studied. Six slightly more or less different datums defined by different number of the involved IGS reference stations have been applied in the combined solutions of three year's one week solutions of the network as follows:

1) Case 1 - GLSV, GRAZ, ISTA, MATE, POLV, ZIMM;
2) Case 2 - GLSV, ISTA, MATE, POLV, SOFI, WTZR;
3) Case 3 -ISTA, MATE, POLV, SOFI, WTZR, ZIMM;
4) Case 4 - ISTA, MATE, POLV, SOFI, ZIMM;
5) Case 5 - GLSV, GRAZ, ISTA, MATE, SOFI;
6) Case 5 - GLSV, GRAZ, ISTA, MATE, ORID, PENC, SOFI, POLV, WTZR, ZIMM.

Comparison and analysis of the station horizontal velocities

Obtained horizontal velocities from all six cases have been compared for the identical stations. Comparisons of the horizontal velocities of the *IGS* stations and *BULiPOS* stations are shown for all stations in Figure 7. Differences between all six cases are almost with the same magnitude of 0,2÷0,4mm/yr for the majority of the stations. For some stations BURG, LOVE, SHUM, SRED) the differences are comparable to the magnitude of the station velocities themselves. Only for station SOFI in Case 1 the estimated velocity deviates (1mm/yr) a lot from the velocity estimations in other cases. In this Case 1 station SOFI is not included as reference station and in all other cases it participates in datum definition.

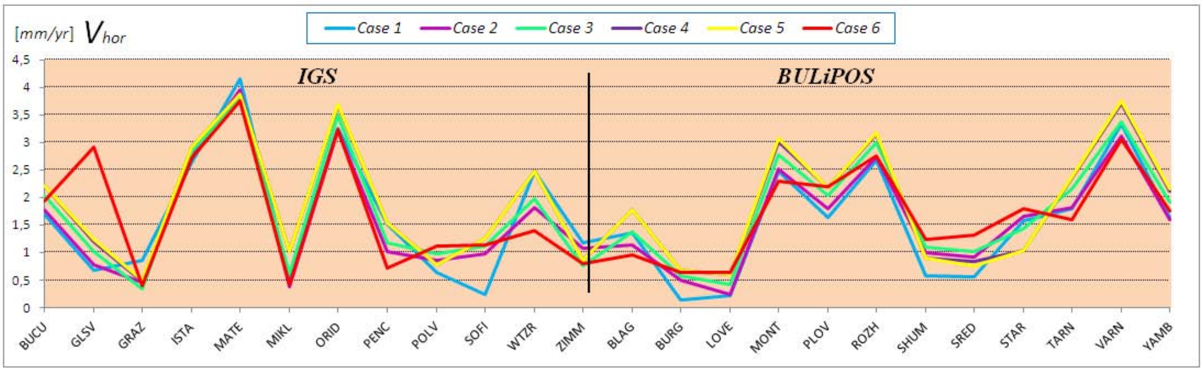


Fig. 7: Comparison of the horizontal velocities of the IGS and BULiPOS stations in ETRF2000

The obtained differences of amount 0,4÷0,6mm/yr for the horizontal velocities of stations with slow movements (0,2÷0,6mm/yr) show that the effect of the datum definition changes is considerable. The problem arises due to the similarity of the magnitudes of differences and velocities themselves. For the other stations this effect is not significant regarding their velocity magnitudes. A reason for that is the less or more symmetric distribution of the introduced IGS reference stations around the territory of the country in all six cases. The effect would be greater if the reference stations are on only one side of the region. By this reason they are selected preferably symmetric to the study region but it is not always the case. Nevertheless it is not correct to be compared directly velocities of identical stations from different studies. Otherwise the results obtained will be not reliable and correctly usable for further applications. In Milev et al., 2010 it is also mentioned that the reason for velocity differences of identical stations is the selection of different IGS reference stations in datum definition

The case study of the Bulgarian *GNSS BULiPOS* network processed by applying the least squares method with minimum constraint conditions to several IGS reference stations shows that changes in datum definition result different estimations of the station velocities and the effect is very important and significant in combined use of velocities from different sources as input data in geotectonic and/or in geophysical investigations and interpretations. For reliable comparison and validation of horizontal velocity estimations from different studies it is necessary to be taken into account datum definitions.

The horizontal velocities estimated from processing of *GNSS* data in different studies are usually obtained with respect to the stable part of Eurasia plate but not always the introduced IGS stations for reference are given and further combined used of the velocities can affect not correct results.

4.3. EUMETNET

At the 20th Conference of the International *EUPOS* Steering Committee in Berlin, Germany, 2011 Bulgaria proposed *EUPOS* to be integrated to the system of *EUMETNET* and for this purpose to be prepared a Memorandum of Understanding between *EUPOS* and *EUMETNET*. The proposal was approved by the Steering Committee and included in the resolutions of the *EUPOS* symposium held at the same time in Berlin. At the 21th Conference of the International *EUPOS* Steering Committee in Bratislava, Slovakia, 2012 Bulgaria proposed a Memorandum of Understanding (MoU) for collaboration with EUMETNET, which was voted and adopted by the *EUPOS* member countries. Since then the main achievement is the signed MoU (May 2013) by both bodies – *EUPOS* and *EUMETNET*. In this respect Bulgaria intends to realise transfer of GNSS data from several *BULiPOS* stations to *EUMETNET* data centre.

Application of ground-based GNSS tropospheric products in operational meteorological and climate observing systems in Bulgaria/Southeast Europe was initiated in 2011 with development of the Sofia University Atmospheric Data Archive (SUADA). The motivation is to use the synergy between independent ground-based observations from GNSS and radiosonde to establish an archive for long-term monitoring of atmospheric water vapour. This archive will: (1) serve as a reference for the validation of numerical weather prediction models and satellite data; (2) facilitate the cross-validation of ground-based observations and derivation of systematic instrumental biases; (3) facilitate the evaluation of the present climate of Bulgaria/Southeast Europe of state-of-the-art climate models. SUADA was developed in close collaboration with the Institute of Applied Physics, University of Bern (IAP-UniBe) Switzerland.

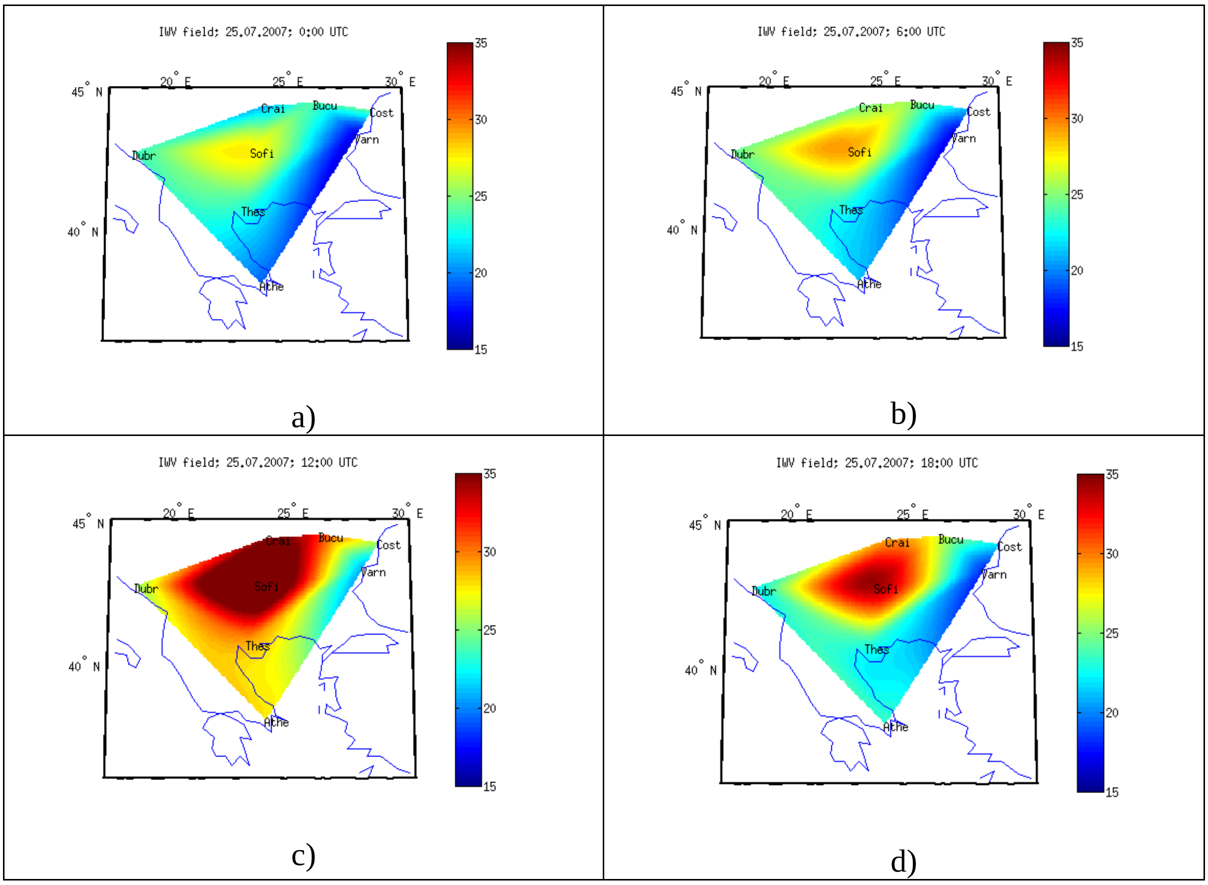


Fig. 8. 2D maps of IWV in Southeast Europe on July 25 2007 at: a) 00 UTC, b) 06 UTC, c) 12 UTC and d) 18 UTC

The first application of *SUADA* is a study of water vapour dynamic during the July 2007 (*Figure 8*) heat wave in Bulgaria. Heat waves have become a common summer feature in the Southeast Europe. Monitoring water vapour during the heat waves is critical as the combination of high temperature and water vapour is lethal. The atmospheric circulation leading to the heat wave is characterized by subtropical African air mass reaching the Southeast Europe. In the period 19 to 25 July 2007 a hot air tongue spreads over the Mediterranean Sea and the Southeast Europe. For this study GPS data from 19 GNSS permanent stations (AUT1, NOA1, BUCU, COST, DUBR, GLSV, GRAZ, MATE, ORID, PENC, POLV, ROZH, SOFI, SULP, MIKL, WTZR, ZIMM, VARN, CRAI) from Central and Eastern Europe were processed with the Bernese software, version 5.0. Tropospheric products and IWV for 8 stations in Southeast Europe are uploaded in the SUADA and used to prepare two dimensional (2D) maps of IWV distribution in the region. The temporal variation of IWV in Southeast Europe on July 25 2007 each 6 hours at 00, 06, 12 and 18 UTC is presented in *Figure 7*. As expected the diurnal variation of IWV follows closely the increase of the temperature and has a maximum at 12 UTC. The IWV derived from GNSS is very suitable to study the diurnal cycle of IWV as it provides observations with hourly resolution. In Europe, in the framework of the EUMETNET E-GVAP project (http://egvap.dmi.dk), GNSS tropospheric products from over 2 400 GNSS stations are available for monitoring water vapour dynamic in real time. Hourly tropospheric delays delivered by 11 GNSS processing centres are used for model validation and assimilation at 10 European national meteorological services and at ECMWF. The participation of East and Southeast Europe in the EUMETNET E-GVAP project is expected to be fostered by the signature in May 2013 of the EUPOS-EUMETNET Memorandum of understanding. Initiated in 2012 by Prof. Georgi Milev and Prof. Keranka Vassileva this agreement is very timely and will be very beneficial for the new COST Action ES1206 ”Advanced GNSS tropospheric products for severe weather events and climate application (GNSS4SWEC)”. One of the objectives of the Action is improving the data processing in East and Southeast Europe. Establishment of new GNSS analysis centers is a second important objective, which is well allied with the EUPOS plans. A National agreement for data exchange between the *BULiPOS* and the newly established Sofia University GNSS Analysis Centre (SUGAC) has been drafted. It is expected to be signed by the end of 2013. For processing the *BULiPOS* GNSS data for tropospheric products the NAPEUS software will be used. A software license application is sent to

ESA. In addition, computer resources for SUGAC processing were allocated at the Physics Faculty Linux cluster.

4.4. Current Projects

Brief information about several current projects related to Archeology, Flooding, Engineering and other projects is presented here.

Underwater Archeology

Significant project related to underwater archeology was implemented in an area of 100 km2 at the Black Sea coast. For this purpose airborne laser scanning on land and underwater topography was carried out, using EUPOS-BG stations respectively BULiPOS (Figures 8, 9).
As a result, digital terrain models of land and underwater topography were created. GIS was created for the purpose of archeology. The data can also be used if necessary to solve other problems except for the purposes of the project, led by the Centre for Underwater Archaeology and funded by the Ministry of Education - Fund "Scientific Research". Project implementation continues with a tendency to develop other projects for Underwater Archaeology in the same area.

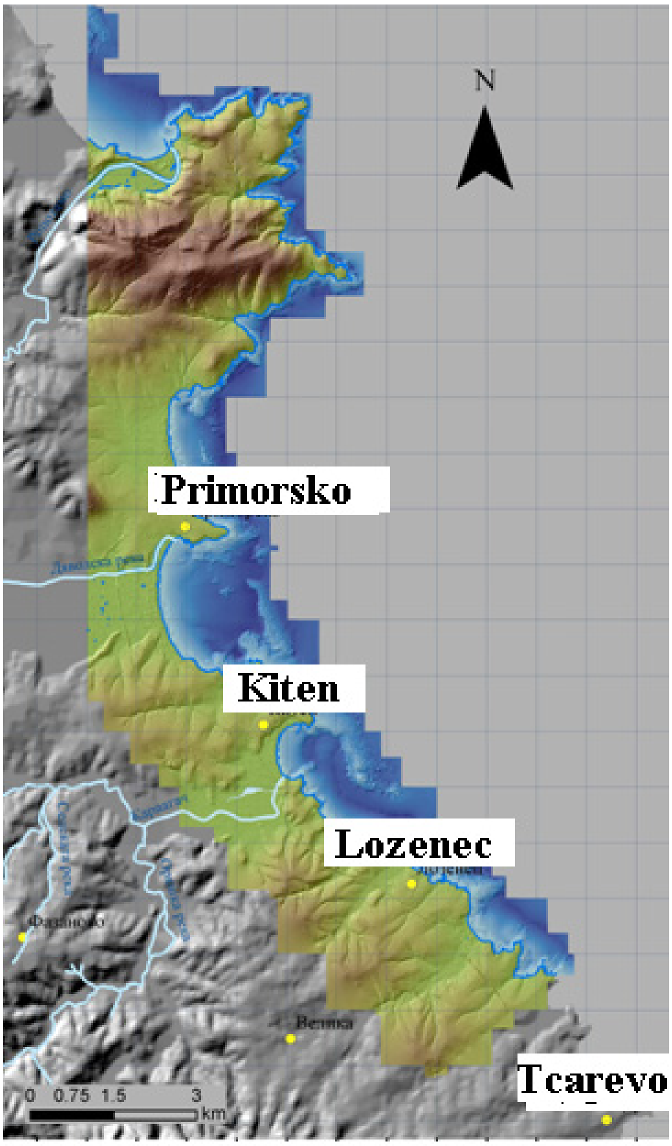
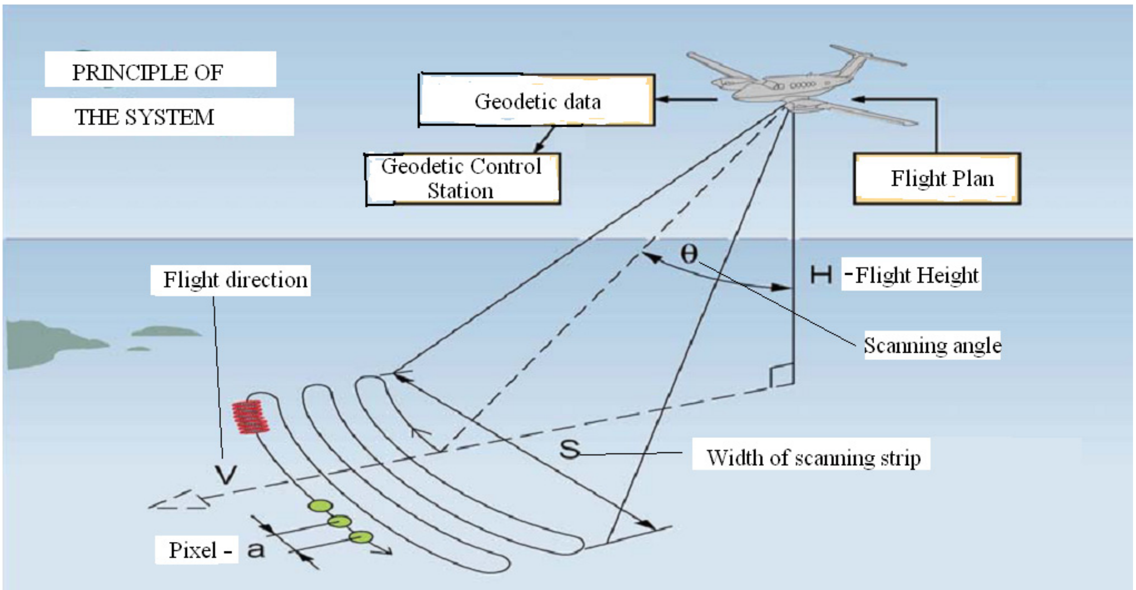


Fig. 9. Scanned region at the Black Sea coast



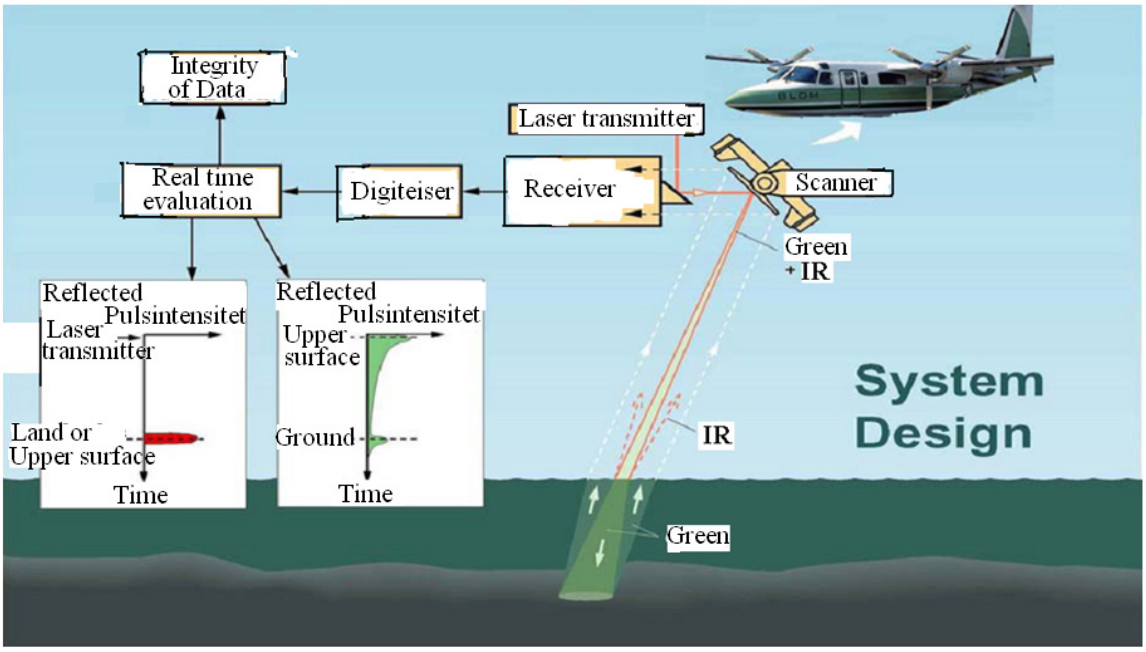


Fig.10. System for simultaneous scanning of underwater topography and land BLOM]

Floods

Floods on the territory of Bulgaria are a national problem and problem of the neighbouring countries as well. A relevant methodology was developed and adopted in 2012/2013 to assess the flood risk making appropriate forecasts and projects for their emergence and development of measures to reduce their impact. The methodology is valid for the whole country. For creation of topographic base and digital terrain models and their requirements the airborne laser scanning was chosen as the most appropriate survey method combined in case of need by other methods, including the underwater topography. To illustrate the methodology the laser scanning information from already implemented archaeological project for the region of the Black Sea coast was used.

Engineering and other Projects

A number of other engineering projects have been implemented mainly related to linear objects on the territory of Bulgaria. They concern for example documenting and designing of railways, power supply high voltage network, pipelines and more. The EUPOS-BG, respectively BULiPOS network has been used. The system has a wide application in solving problems of the cadastre of the country and many others.

5. Conclusion

The presented current status and applications of EUPOS-BG shows that BULiPOS is maintained and used effectively. It also shows the diversity of this use for scientific, applied and other purposes. The EUPOS-BG segment BULiPOS and the whole system and network EUPOS demonstrate the correctness and the vision of the idea of its establishment.

References:

1. B o u c h e r, C., Z. A l t a m i m i. (2011). Memo: Specifications for reference frame fixing in the analysis of a EUREF GPS campaign. Version 8: 18-05-2011.
2. B u r c h f i el, B. C., R. W. K i n g, A., T o d o s o v, V., K o t z e v, N., D u r m u r d z a n o v, T., S e r a f i m o v s k i, B., Nurce (2006). GPS results for Macedonia and its importance for the tectonics of the Southern Balkan extensional regime, Tectonophysics, 413, 239–248.
3. G u e r o v a, G., J o n e s, J., D o u s a, J., D i c k, G., H a a n, S. de, P o t t i a u x, E., B o c k, O., P a c i o n e, R., E l g e r e d, G., V e d e l. H. (2013). Advanced Global Navigation Satellite Systems tropospheric products for monitoring severe weather events and climate (GNSS4SWEC), Proceedings of the 4th International Colloquium - Scientific and Fundamental Aspects of the Galileo Programme, ESA Prague, Czech Republic.
4. K o t z e v, V., R. N a k o v, Tz. G e o r g i e v, B. C. B u r c h f i e l, R. W. K i n g, (2006). Crustal motion and strain accumulation in western Bulgaria, Tectonophysics, 413, 127–14.
5. M a t z a r a k i s, A., de F r e i t a s, C., & S c o t t, D. (2007). Developments in tourism climatology (Commission Climate, Tourism and Recreation, International Society of Biometeorology), 289.
6. M i l e v, G., Ch. D a b o v s k i. Eds. (2006). Geodynamics of the Balkan Peninsula. Monograph. Report on Geodesy, Warsaw University of Technology, No. 5 (80), 650 p.
7. M i l e v, G., K. V a s s i l e v a, I. M i l e v (2009). Development and applications of DGNSS in Bulgaria. Proceedings of the International symposium on GNSS, Space-Based and Ground-Based Augmentation Systems and Applications, 73-77.
8. M i l e v, G., M. B e c k e r, K. V a s s i l e v a, G. S t a n g l, I. M i l e v. (2010). Investigation of Geodynamics of Central and Eastern Europe, Balkan Peninsula and Bulgaria, In Monograph “Intelligent Data Analysis in Global Monitoring for Environment and Security”, ITHEA, Kiev-Sofia, 92-108.
9. S i m e o n o v, Tzv., K. V a s s i l e v a, G. G u e r o v a. (2013). Application of ground-based GNSS meteorology in Bulgaria/Southeast Europe: case study 2007 heat wave. Annual of University of Sofia, Volume 106, 88-100.
10. S t a n g l, G. (2011). Velocity Fields from Geodesy to Geodynamics. Presentation at the University of Vienna.