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GEODYNAMICS AND GEOSPATIAL RESEARCH

Book of Abstracts and Articles

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GEODYNAMICS AND GEOSPATIAL RESEARCH

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The conference "Geodynamics and Geospatial Research" organized by the University of Latvia Institute of Geodesy and Geoinformatics of the University of Latvia addresses a wide range of scientific studies and is focused on the interdisciplinarity and possibilities of research in this wider context in the future to reach more significant discoveries, including business applications and innovations in solutions for commercial enterprises. The research presented at the conference is at different stages of its development and presents the achievements and the intended future. The publication is intended for researchers, students and research social partners as a source of current information and an invitation to join and support these studies.

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PREFACE

The Institute of Geodesy and Geoinformatics (GGI) of the University of Latvia were hard working since the reestablishment of the Institute of Geodesy in 1994. The researchers of the Institute of Geodesy (1924–1944) concentrated on the research and education in many advanced topics of that time – development and adjustment of National Geodetic networks, photogrammetry, studies of vertical Earth movement and research in gravimetric and magnetic measurements. Currently the research areas are developed in satellite geodesy and geoinformatics. In this context the main topic of GGI activities is concentrated on development of satellite laser ranging systems (SLR), both the hardware and control software.

The Conference is concentrated on several recommended topics but not only:

- Geodynamics and geospatial research;
- Gravity field, Geoid models and height systems;
- Astrogeodetic measurements;
- GNSS and satellite geodesy;
- Leveling networks;
- Survey Engineering;
- Photogrammetry, Remote sensing;
- Geographical Information Systems (GIS);
- Unmanned aerial vehicles (UAV).

More than 20 presentations by the researchers of Latvia, Poland, Azerbaijan, Russia, Turkey, and United States of America are focused on the interdisciplinarity and possibilities of research in this wider context of Geodynamics and geospatial research, and promised in the future to reach more significant discoveries, including business applications and innovations in solutions for commercial enterprises.

The GGI Institute's research is well-known in the professional field in the world, but in Latvia it is an institution that unites and involves leading researchers from all over the country, regardless of their primal work and has become a sort of informal coordinating centre for research in this field. This is also confirmed by the Organizing Committee of the 78th International Scientific Conference of the University of Latvia, section "Geodynamics and Geospatial Research". The conference is a place to be present results of current studies, covering all the main directions of the research. More than a hundred specialists from a large number of countries came to participate and hear particularly the reports from this section of the Conference, conforming actuality of proposed topics. Especially noteworthy is the very wide representation of the institutions and the repeated gratitude to everyone who participated and supported the conference. The high scientific quality and applied nature of many studies should be highlighted, which will allow to use in the economy this knowledge and numerous scientific solutions already in the next few years, including site development planning and use of the Earth mineral resources.

Particular "Abstract and articles" book is pre-publication of new ideas and results of studies, but the best of full text papers will be published in the peer reviewed journal – Baltic Journal of Modern Computing.

Professor Dr. geol. Valdis Segliņš
March 19, 2020

CONTENT

LATVIAN DIGITAL ZENITH CAMERA – 2019 STATUS REPORT

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Regular zenith observations in behalf of ERAF project, aimed at regional geoid model improvement, were continued using already established methodology. At the end of the project in March 2020 observations at more than 400 sites are acquired, covering all territory of Latvia with average spacing of about 20 km. Besides that, a new improved design of zenith camera was finished and 3 copies of it manufactured, one of them sold to the Louisiana State University, two remaining in our possession. Improvements include optimization of mechanical design, more powerful control computer, a number of additions and modifications of control software. The new design has proved to be more convenient to use, have better accuracy and smaller thermal drift. Availability of extra instruments greatly increases our measurement capacity and makes possible multi-instrument measurements, needed for research of influence of refraction effects and instrumental errors on vertical deflection measurements.

PROGRAM FOR ASTEROID DETECTION ON DIGITIZED SCANS OF BALDONE SCHMIDT TELESCOPE ARCHIVE

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Many years of data of sky objects are stored in astronomical photo plate archives. That large archive was saved at the Baldone Astrophysical observatory. The archive contains more than 24000 wide-field direct and spectral images of the North sky. Archive data can be used to solve many astrophysical problems. One of them is finding observed asteroids from the archive. Manually it means to go through the observations of tens of thousands of objects to find what you're looking for. To save time, energy and to get more information about the asteroids, a program was needed.

The goal of the program was for it to be easy to use and help new users to work with it. Now the program can do the following – give clear instructions how to use the NASA webpage (used to get the coordinates for archive asteroids) and give information to copy in there, autocorrects the values from NASA page, displays the info of archive file and finds the needed asteroid, finds similar objects and after that can show the location of all them graphically either in decimal degrees or hexagonal degrees.

The result is a program which can be used by any employee in the Institute of Astronomy of the University of Latvia to find specific asteroids or to try and find new ones. The next steps are to find as many asteroids as possible and search the similar properties of them, and to automatize the input and output of the webpage.

In conclusion, the program grants the possibility to gather data of the old and unused archives and to find asteroids that have not been approved yet. The goal of the program is reached, although it can be only used for Baldone Schmidt telescope archive digitized data for now.

This research is funded by the Latvian Council of Science, project: Complex investigations of Solar System small bodies, project No. lzp-2018/1-0401

AUTOMATIC IDENTIFICATION OF DRAINAGE DITCHES IN FOREST USING LIDAR DATA

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Keywords: LiDAR, forest, ditch

Research into the identification of the hydrological and man-made surface runoff network in a digital elevation model began as early as the last century, when the first water flow direction and accumulation algorithms were developed (Quinn et al. 1991; Tarboton 1997). In recent studies, conducted in the early part of this century, some authors (Heine et al. 2004; Tarboton, Daniel 2001; Lashermes et al. 2007) have pointed to the need for a more sophisticated view of watercourses and ditches in terrain, not only in terms of surface runoff but also in terms of their morphological characteristics. In the last decade, research in this area has mainly been carried out using aerial laser scanning data and also taking into account the morphometric characteristics of ditches. In the study (Roelens et al. 2016), LiDAR point clouds in the Netherlands have been used to identify agricultural ditches and their parameters.

The aim of the study is to develop an algorithm for decryption of forest ditches and to evaluate its use in Latvia by using LGIA aerial laser scanning data available in Latvia. The study area is located in Kalupe parish, Daugavpils region and it is 25 km^2 large. The elaborated algorithm is used to identify local depressions in the digital terrain model, as well as a method for filtering the results obtained, resulting in a correct ditch network. To evaluate the accuracy of the data in relation to the LSF database, an error matrix was created and the Jaccard index is calculated. The obtained results show that by the method created 92% of forest ditches were identified in the 5 m buffer zone around the ditches in the LSF database, as well as 4443 km ditches which are not included in this database. The Jaccard index for ditches in the 5 m buffer zone is 0.87. It is concluded that the developed method can successfully identify forest ditches in high accuracy, which can be used for hydrological modelling, as well as for supplement of the database.

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TRANSFER LEARNING APPROACH FOR SHORELINE EXTRACTION FROM SENTINEL-2A IMAGERY

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Keywords: Deep learning, U-Net, image processing, remote sensing, shoreline extraction, Sentinel-2A, LANDSAT-8

Coastal zone monitoring has vital importance to detect changes which can occur due to natural and anthropogenic effects. Satellite images provide accurate and reliable information for this purpose. Land and water-body segmentation is one of the important steps for coastal monitoring. State-of-art deep learning (DL) approaches brought new opportunities for shoreline extraction. In this study, a transfer learning-based land and water-body segmentation framework has been proposed. The pre-trained model was created using modified U-Net architecture from Landsat 8 OLI (Operational Land Manager) satellite images. To train U-Net architecture, private dataset was used. The dataset consists of total 916 subsets (512 × 512) which were generated from 63 Landsat 8 OLI frames and collected from different locations of the world.

Sentinel-2A satellite images have been used to extract shoreline of Golf of Riga (GoR). Additional dataset has been collected from different locations consisting of 8 Sentinel-2A frames (blue, red and NIR bands). Total of 82 subsets (512 × 512) have been generated. Open Street Maps has been used to label dataset. The same U-Net model has been implemented to Sentinel-2A images and used to train Landsat 8 OLI images. The weights of pre-trained architecture have been used as an initial weights of our U-Net model to train Sentinel-2A images. Eight 512 × 512 subsets of GoR image has been used to test the performance of the proposed model. The shoreline length of the study area is approximately 24 km. The precision of the model has been calculated as 99.73%.

ADVANCED MEASUREMENT TECHNIQUE WITH DIGITAL ZENITH CAMERA

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The known constructions of the digital zenith camera systems (DZCS) – instruments for measuring vertical deflection, are fully automated that allow real-time measurements.

The traditional observation technique used in existing DZCS involves performing observations in two opposite positions of the telescope in the horizontal plane, differing by 180° with accuracy better than 10", and averaging the data. Observations in two positions of the telescope are designed to compensate for the tilt of the axis of the telescope relative to the axis of rotation and exclude the effect of inclinometer zero shift. The parameters of the traditional method of observation are the current values of the components of vertical deflection in latitude and longitude and calibration coefficients of DZCS: scales of the inclination sensors, shearing angle between the inclination sensors and angle between CCD sensors and coordinate system of inclination sensors.

At the same time, the measurement procedure with the traditional method does not imply the simultaneous evaluation of all model parameters and consists of the following steps:

- calibration of the device before the start of measurements, which includes the definition of the above calibration coefficients, which are further taken into account as constant values;
- the process of direct measurements to calculate the current values of the vertical deflection.

The disadvantages of the traditional measurement technique include the following:

- it is necessary to calibrate the device before the measurements, which requires additional time;
- the calibration coefficients of DZCS may vary between series of measurements, which may introduce additional error in the results of observations;
- the need for high accuracy of rotation of the device at 180° requires high-precision sensors of rotation, which complicates the design of DZCS.

Due to the shortcomings of the traditional measurement technique, a new method has been proposed. The new technique involves the rotation of the telescope, CCD camera and inclinometer around the vertical axis with a set number of steps in the horizontal plane. This process is performed twice – with a "zero" zenith angle and with a zenith angle set by the operator. The operator should set the zenith angle that does not exceed the measurement range of the inclinometer. The "zero" zenith angle is understood to mean the state of the initial alignment of DZCS in the horizontal plane according to the inclinometer readings.

The proposed technique involves performing a series of measurements of the incline together with the full orientation of the CCD, calculated from the frames of the starry sky. The estimated parameters of the new technique are the current values of the component of the vertical deflection and the instrument calibration coefficients: the rotation matrix of the inclinometer coordinate system relative to the CCD coordinate system (including both the rotation in the plane and the slope corresponding to the zero offset of the inclinometer), scale factors and shearing angle of the inclinometer axes and temperature coefficients of the inclinometer axes. The evaluation is carried out by minimizing the standard deviation of inclinometer measurements from the values of the gravity vector values projected by the instrument model and estimated parameters.

It should be noted that in the proposed method there is a simultaneous evaluation and consideration of all model parameters for each series. The main requirement for the accuracy of measurements is the rigidity of the system Optical tube – CCD camera – Inclinometer. Measurements do not depend on the accuracy characteristics of the rotating device.

Studies have been conducted to evaluate changes in the calibration coefficients of DZCS. A change in the instrument calibration coefficients between series of observations was found, which may lead to an additional error in determining the normal deviations, reaching 0,11".

In this regard, the advantages of the proposed measurement method with an DZCS are:

- higher accuracy of measurements, since in each series automatic estimation and accounting of calibration coefficients takes place ("automatic calibrtion of the device");
- higher measurement efficiency due to instrument "auto-calibration" (measurement time is reduced);
- reducing the requirements for the accuracy of determining the angles of rotation of the device, which eliminates high-precision angle sensors and thereby simplify the design of the DZCS.

Observations with the new methods were carried out in 2017–2019 years on the DZCS. According to the test results obtained the following characteristics of the DZCS:

- the time of a single series of measurements is not more than 6 minutes;
- average standard deviation does not exceed 0,2".

During testing, the possibility of creating a database of vertical deflection with discreteness and accuracy, significantly higher than the indicators of modern models of the gravitational field of the Earth, is shown.

CREATION OF KINEMATIC QUALITY MEASUREMENT MODEL USING GNSS BASE STATION NETWORKS

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Classically, in surveying, measurements are made statically – a surveyor places an instrument, such as a tachymeter, leveller or other stationary measuring device on a fixed point and performs a measurement of the object from one or more points. But as technology advances, new solutions have come to the land surveying that make it easier and faster to survey the site.

The aim of the research was defined to create a kinematic quality measurement model using GNSS base station positioning networks.

Within the framework of the research, a three-dimensional model of the object is created using parallel field kinematic measuring systems – geodesic instruments and LiDAR system. During the work, the LiDAR system was attached to an unmanned aircraft (drone) that automatically performed aerial laser scanning of the area. Data from four local GNSS receiver base stations and three positioning base stations of system LatPos were used to perform the airborne laser scanning flight in more detail and then analyse the obtained data.

Kinematic measurements seem to have many advantages, which is why the authors carried out practically all the preparatory work and necessary field measurements to analyse and evaluate the developed kinematic quality measurement model. The quality of the point cloud is significantly influenced by GNSS base station data. The accumulation of GNSS base station data for joint LiDAR flights is used to calculate the total system error correction for the entire system. The research uses various GNSS base stations located at different distances and positions relative to the object to compare and analyse the quality of the resulting kinematic measurement model.

For the purpose of the research, the object was selected and surveyed on the road section from Jelgava city South border to Latvia–Lithuania border, along the Jelgava-Šiauliai highway. The total length of the object is 32.1 km. Seven points of the national geodetic network in the territory of Latvia and one in the territory of Lithuania were used for geodetic connection. To obtain the kinematic quality measurement model, the object was surveyed using the aerial laser scanning method.

Prior to the aerial laser scanning procedures, preparatory work was carried out, which included inspection of the national geodetic network points near the road, marking the object and levelling the marked marks with respect to the geodetic network points. A photogrammetric inspection was performed on the selected road section. Measurements were made with geodetic GNSS instruments. National geodetic network points were used as reference points for accumulation of GNSS base station data correction. GNSS receivers were used on geodetic network points in the vicinity of the object as base stations for storing flight data corrections. Later data of these stations are analysed and compared, both with each other and with LatPos base station corrections, so that the overall quality of the resulting 3D models can be compared. GNSS base stations were installed and turned on at least one hour before the start of the airborne laser scan, thereby contributing to the stabilization of the resulting corrections.

The object was surveyed using a DJI-produced Matrice 600 unmanned aircraft to which a YellowScan 3D laser scanner Surveyor was attached. The LiDAR system used has an accuracy of 3 cm and is capable of taking up to 300 000 measurements per second. The object was surveyed for two days, at different times. A total of eight flights of 30.8 km were made.

Summarizing the average accuracy of the obtained cloud of point of aerial laser scanning, it was concluded that the closer the base station is to the object, the more accurate the results of the obtained model are. Better result is obtained, if GNSS receiver as base station is within 3 km of object. Accuracy of the result of the obtained aerial laser scanning cloud is within +/– 5 cm. If the GNSS receiver, as a base station, is within 3–15 km from the object to be surveyed, the point accuracy is within +/– 10 cm, whereas if it is within 15–35 km, the accuracy is +/– 60 cm. Basically, an independent base station beyond this distance (15–35 km) would not be desirable, as the model will result in too large deviations. It also means that for aerial laser scanning of long linear objects, it would be desirable to locate the base station in multiple locations for a better result every 5 km or more, depending on the required model accuracy.

The result:

1. The three-dimensional model of the object can be obtained by aerial laser scanning method, which is based on kinematic and laser light reflection rules.
2. Accuracy of GNSS base station corrections, which directly affects the quality of the model, is important for the development of the kinematic measurement model.
3. The accuracy of the model is characterized by the point cloud density of the LiDAR system and its compliance with accurate, geodetic network-linked control measurements.
4. For aerial laser scanning of long linear objects, the base stations of the GNSS receiver are preferably located in several locations, for better results every 3 km or more, depending on the required model accuracy.
5. Fixed base station network LatPos data corrections are able to provide +/– 5 cm deviation within 35 km of the facility. Accurate results can also be obtained using a mobile GNSS receiver base station, but the distance should not exceed 3 km from the object.

CHARACTERISTICS OF SEASONAL VARIATIONS AND NOISES OF THE LATVIAN CORS STATIONS DAILY PPP SOLUTIONS

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Long term GNSS observations provided by network of the reference stations allows for determination of the global and local tectonic plate movements and seasonal variations of coordinate components. The most accurate stations' positions and velocities in the European territory are provided by multi-year combination solution of the EPN weekly SINEX files. In recent years, PPP technique has become increasingly popular and probably in the future will replace positioning with the CORS stations [1, 2]. In this paper authors determined seasonal components and noises of 27 Latvian CORS stations (26 LatPos stations and EPN station RIGA, Fig. 1) on the basis of daily GPS-PPP solutions provided by the NGL (Nevada Geodetic Laboratory) [3].

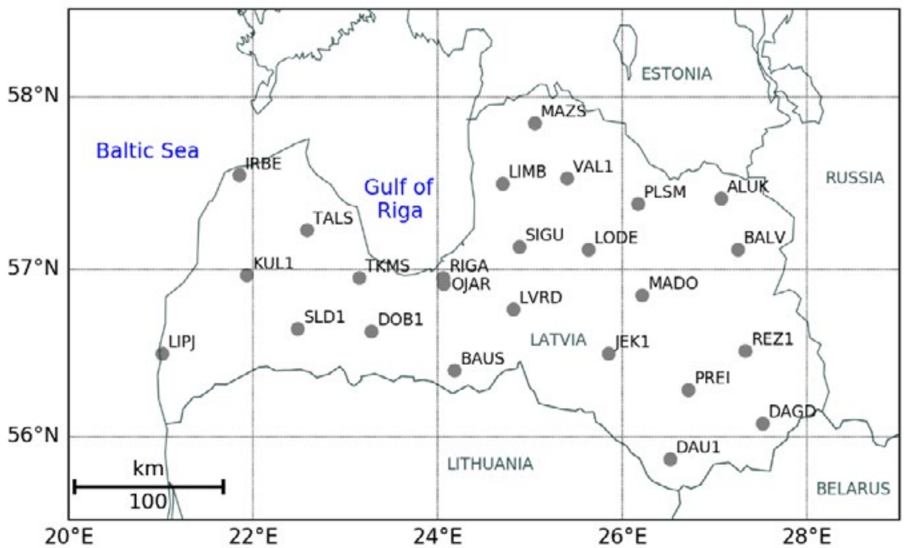

Fig. 1. Latvian CORS selected for the study.

NGL provides daily and 5 min solutions for global references stations which provides observations for free. In this paper authors analysed PPP time series for years 2011-2019.6 in ETRF2014 reference frame and local NEU coordinate system. Times series of each coordinate component were determined by the usage of the *tsview* software [4] and seasonal existence of linear, annual, semi-annual factors and its uncertainties were assumed. At this part breaks in time series were also taken into account (antenna changes, receiver changes and other factors).

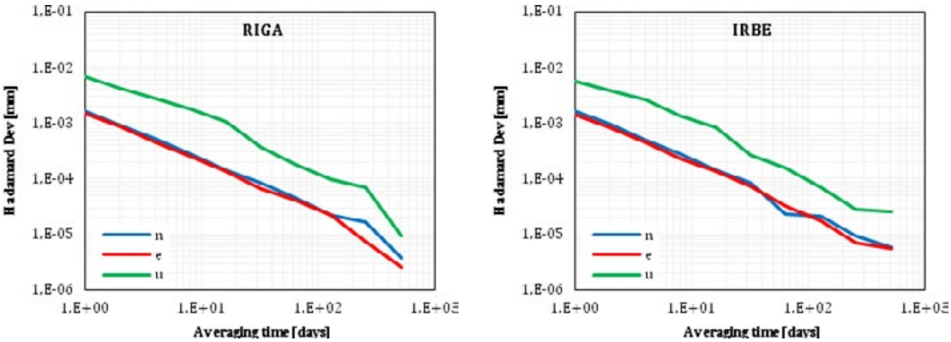

Fig. 2. Hadamard variation of IRBE and RIGA stations.

The Allan variance and its modifications is widely used and accepted as a preferred method for identifying stochastic processes, such as white noise, random walk or flicker noise. In the second part of this study for each station's coordinate time series variances for each averaging times were calculated (Fig. 2) and noises types were determined by the usage of Hadamard deviation [5].

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MEASUREMENTS RESULTS OF THE HIGHEST PEAKS OF MOUNTAIN RANGES IN POLAND

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A set of the highest peaks of each mountain range in Poland is known as '*The Crown of Polish Mountains*' (CPM). This is a list of 28 the highest peaks of the all mountain ranges in Poland (Fig. 1), was established in 1997 [1]. The aim of the project was determination – based on satellite measurements – and update of the height of each summit. This kind of measurements by the use of modern techniques were made so far [2, 3], but on the different objects. As part of the project, according to newly identified mesoregions [4] of mountain ranges – which are not officially part of CPM – other peaks were also measured.

Fig. 1. CPM summits distribution on territory of Poland.

The implementation of the project began in May 2019 and became part of the 100th Anniversary of AGH University. First part of the project were analysis of the existed historical sources and digital terrain models. Field measurements were made by the GNSS receiver in RTK mode, or in case of lack of precise solution, 1^{h} static session with 1 s interval. In case of the high sky obstacles on the top of the mountain the height between GNSS receiver position and summit were transposed by the geometrical levelling. The heights of each summit were determined [5] in and compared with the currently available data (Fig. 2).

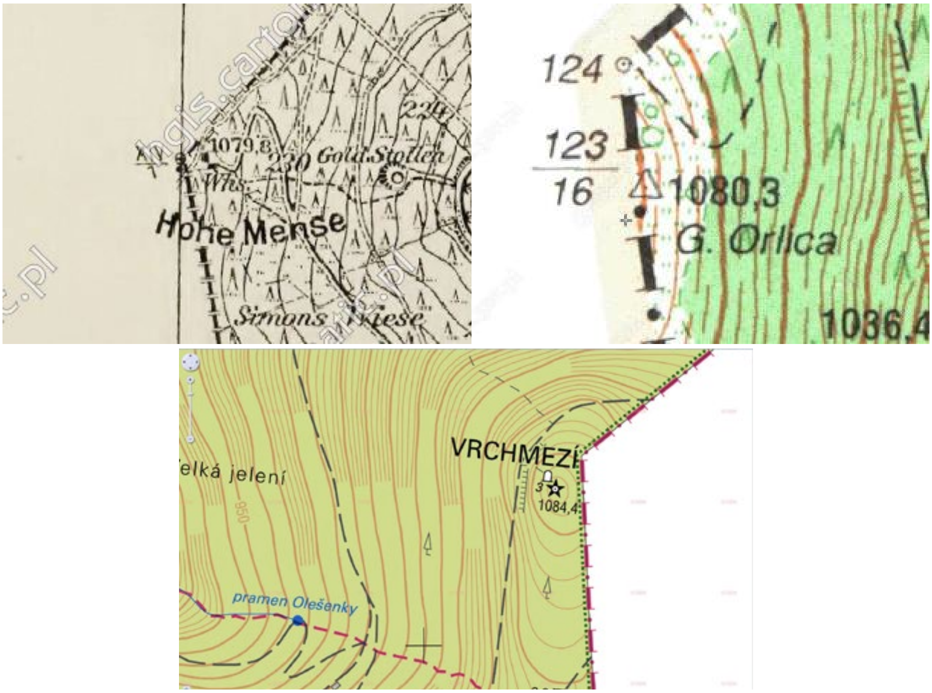

Fig. 2. Example of height changes on the different maps [6–8].

For the needs of the project, a team of over 60 people made about 30 trips and measured 39 peaks. Each height was determined with decimetre precision, the same level was determined accuracy. For each peak, its height from precise measurement has been compared with the values given on Wikipedia, MapaTurystyczna.pl [9] and official CPM heights. Most of the altitudes are within a meter with officially available values.

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PRELIMINARY RESULTS OF THE IONOSPHERIC CHARACTERIZATION BY STATISTICS ANALYSIS OF LATVIAN GBAS 11 YEAR SELECTIVE DAILY OBSERVATIONS

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The space weather impact has been recognised as a serious threat for the quality of Global Navigation Satellite System (GNSS) satellite-based positioning, navigation and timing in real time applications. The operational quality suffers for real time positioning and navigation applications for satellites, aviation, cars, trucks, farming, construction, snow removal as well as for various safety of life applications. Distortions of GNSS signals are of concern for a number of disputable traffic accidents. The idea of Latvian researchers to study the ionospheric scintillations in the region of Latvia with latitude around 57 °N was supported by ESA in a framework of PECS Latvia related contract.

The scope of this research is the ionospheric characterization by statistics analysis of Latvian Ground Based Augmentation System (GBAS) 11-year selective daily observation double-difference positioning results with special emphasis on research of correlation with geomagnetic extreme events such as geomagnetic storms and sun flares. The statistics are based on positioning results done with Bernesse and one can expect to see some degradation (if any) on the cycle slips.

The duration of the studies is one year starting in December 2019. Short overview of the performed work will be reported.

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INVESTIGATION OF KINEMATIC PPP PERFORMANCE IN HYDROGRAPHIC SURVEYING BY USING ONLINE WEB SERVICES

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Keywords: Hydrographic Surveying, GNSS, PPP, PPK.

In hydrographic surveying, the accuracy of the positioning data has been increased by using global navigation satellite systems (GNSS/GPS). Real time and post processing methods are currently used for horizontal and vertical positioning in such applications. Besides real time kinematic (RTK) method, the precise point positioning (PPP) method is preferred in many fields of hydrographic surveys. In this study, a test survey was performed near Çubuklu Bay in the Bosphorous Strait, Istanbul, Turkey. Thales Z-Max GPS receivers were used both on the vessel as the rover and on the port as the reference station. Kinematic raw GPS data were collected with an interval one second. The Canadian Spatial Reference System (CSRS) and Automatic Precise Positioning Service (APPS) were selected for PPP kinematic processes. Post process kinematic (PPK) and PPP results were compared and analysed.

ACCURACY ASSESSMENT OF RTK GNSS AND PPP METHOD FOR DIGITAL ORTOPHOTO GENERATION

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Keywords: UAV, Orthophoto, GNSS, PPP, NRTK

Unmanned aerial vehicles are widely used for orthophoto production based on advanced GNSS Techniques. The accuracy of orthophoto production mainly depends on image quality and geo-referencing strategy. Geo-referencing by ground control points (GPCs) is required a time and cost consuming process. Geo-referencing based on GPCs critically depends on the number and spatial distribution of the GPCs. However, direct geo-referencing of the UAV images by using high accurate positioning ability of GNSS methods may overcome these limitations. In the study, Precise Point Positioning (PPP) method based on two frequency receiver observations were used for direct geo-referencing. 13 GPCs were located homogeneously at the study area for the evaluation of the orthophoto accuracy produced by direct geo-referencing. The ground control points were measured with Network RTK method. The images were taken using a professional camera mounted on UAV at 40 m flight altitude. Analysis were performed in order to evaluate the accuracy of direct geo-referencing by PPP positioning method on orthophoto generation.

BENEFITS OF MULTI-CONSTELLATION USE IN SURVEYING

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The aim of the studies is to determine how the increase in the number of satellites affects the quality of GNSS measurements. In last decade to GPS and GLONASS have joined two global satellite systems – EU's Galileo and China's BeiDou. GNSS receivers have improved as well, for example, has in-built tilting compensators, more parallel channels in receiver, has possibility to receive more than two frequencies from satellites etc. It means that surveyors can choose which system to use. As well it means they can use more than two systems at a time. That made author curious, how does the accuracy improves and differs when there is 10, 20 or even 30 usable satellites in the view.

Another goal of this studies is to determine how accurate are measurements with tilted pole of the rover in comparison to the vertical and static rover. This study is important to make the surveyors aware of possible dilution of accuracy when the tilting compensation is used.

Measurements were done in two sessions of RTK positioning and post-processing positioning with Leica GS18 GNSS receiver. Leica GS18 receiver has built-in compensator, which gave the chance to do measurements also in tilted mode. Measured point is located near Lithuanian border in Latvia, Bauska County, Dāviņi parish. The point itself is located in the middle of an agricultural field with clear horizon, 90 meters from the road. This kind of location allows to receive as much satellite signals as possible at a given moments sky plot and rover is not exposed to transportation vibrations.

Results for RTK measurements was valued by: coordinate quality standard deviation, DOP and absolute deviation from database coordinates. Results for post-processing measurements was valued by: correction error and absolute deviation from database coordinates.

Results:

1. It can be said that increasing number of used satellites improves measurement quality in RTK positioning.
2. Static RTK positioning can achieve standard deviation around 0,6 cm in horizontal plane and 1,3 cm in vertical plane.
3. Tilted RTK positioning can achieve standard deviation around 1,3 cm in horizontal plane and 1,5 cm in vertical plane.
4. Static RTK positioning is more stable than tilted RTK positioning due to poles tip movement and partial sky coverage when rover is being tilted.
5. In these measurements it cannot be said that increasing number of used satellites improves measurement quality in post-processing positioning.

MONITORING GLACIERS MELTING BY GRACE-MASCON SOLUTIONS

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Keywords: GRACE, Mascon, Glaciers, Coloured Noise, Acceleration

The glaciers in Greenland, Antarctica and Alaska have been melting for a long time due to the effects of global warming. This catastrophic event cause rise in the ocean surface about 1 mm per year and inevitably changes the climate all over the world. The ice losses in these regions have been monitored by GRACE (Gravity Recovery and Climate Experiment) mission since 2002. This study investigates these ice losses using monthly GRACE Mascon basin solutions provided by NASA-GSFC between 2003–2016.

The annual amplitudes and trends of the ice losses are estimated through the harmonic regression analysis. This analysis shows that the total ice loss in these regions is about 500 Gt per year. The next question is whether the glaciers melting was accelerated over 13 years. For this purpose, the harmonic regression is improved by the new acceleration parameter. According to the preliminary statistical tests, it is deduced that the ice loss in Greenland and Antarctica was accelerated significantly. However, it is well known that Greenland has a straight trend without any change in time. For that reason, the model is improved by considering flicker noise in addition to white noise since the log power spectral density graphics indicate negative spectral indexes. The new analysis results in no acceleration in Greenland as expected and significant accelerations in west Antarctica sheet and Rose ice shelf. The importance of this result is twofold: The analysis of a GRACE time-series should involve coloured noises, and the ice loss in Antarctica has been increased since around 2008. The obtained results are discussed and compared with those in the literature.

PRELIMINARY ANALYSIS OF SEISMIC-DEFORMATION CHARACTERISTICS OF THE NORTH ATLANTIC AND NORTHERN EUROPE

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Numerous theoretical studies and experimental results show the possibility of the emergence and propagation of strain waves at velocities of 10–100 km/year or 1–10 km/day (Kasahara, 1979; Bella et al., 1990; Harada et al., 2003, etc.). The greater the magnitude of the earthquake, the greater the likelihood of tracking such strain waves in seismic activity and geophysical fields. Especially such strain waves are characteristic of strong earthquakes at the boundaries of tectonic blocks and lithospheric plates. Such *strain waves*, reaching sections of the Earth's crust, with accumulated tectonic stresses, can become a *"trigger"* for the occurrence of new earthquakes.

As an experimental test of the possibility of the occurrence and propagation of strain waves, seismic activity in the North Atlantic and Northern Europe for 2008–2019 was analysed. Data for strong earthquakes (magnitude 5 or more) of the North Atlantic were taken from IRIS bulletins (*Incorporated Research Institutions for Seismology*). The data from the regional earthquakes of Northern Europe, for 2012–2019, were taken from the bulletins and catalogues of UHIS (*University of Helsinki Institute of Seismology*).

The epicentres of earthquakes in the North Atlantic are located along the *Divergent zone* (approximately between latitudes 52.5 °N and 83 °N) and have magnitudes from 5.0 to 7.1. The epicentres of earthquakes in Northern Europe are located mainly in Scandinavia, as well as in the Norwegian Sea and have a range of magnitudes from –0.6 to 4.4.

To analyse the seismic regime, were used the integral parameters of seismic deformation processes in both the North Atlantic and Northern Europe. One of the main parameters is the *cumulative strain release* ε, which is equal by *Benioff* (Benioff, 1951) the square root of the accumulated energy of earthquakes $\sqrt{E}$. Cumulative, released, elastic strain ε along the time axis *t* characterizes the rate of change:

$$\dot{\varepsilon} = tga = \varepsilon/t = \sqrt{E}/t$$

The results of the analysis of *cumulative strain release* for the North Atlantic and Northern Europe led to the following conclusions:

1. From 2012 to the end of 2019, 4 periods of seismic deformation regime change were determined for a significant area of research, namely for the North Atlantic and Northern Europe.
2. The most significant changes in the seismic regime for the Northern Arctic and Northern Europe are limited to the period from the middle of April 2014 to the middle of February 2015. At the end of this period, the strongest earthquake of magnitude 7.1 occurred in the northern part of the *Mid-Atlantic Ridge*.
3. The rate of *cumulative strain release* varies with time for the North Atlantic and Northern Europe. A dramatic change for the North Atlantic begins from

the middle of August. In September 2014, there was a sharp change in the rate of *cumulative strain release* in Northern Europe.

4. It is likely that in section 2 (Fig. 1) there is a *strain wave* effect originating from the North Atlantic region, which became a *"trigger"* for increasing the rate of *cumulative strain release* in Northern Europe.

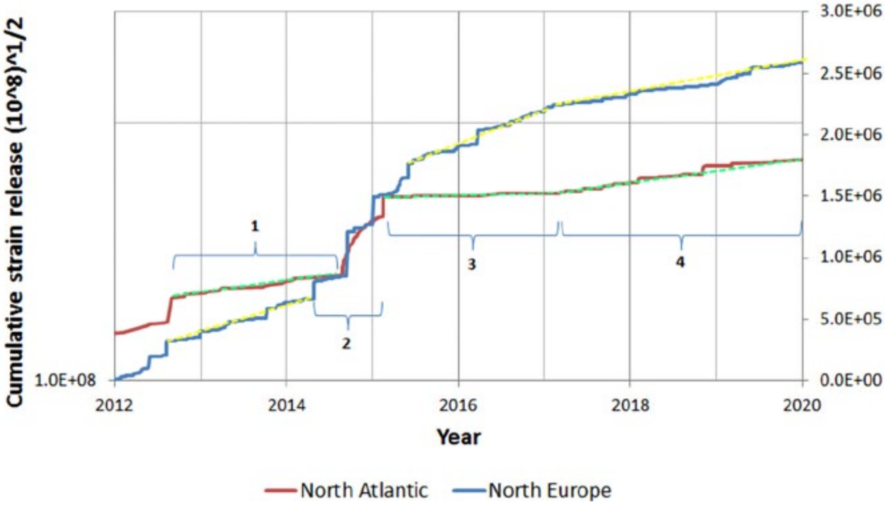

Fig. 1. Cumulative strain release curves for the North Atlantic (red line) and Northern Europe (blue line)

Designations: green dashed lines – approximation of three sections of the graph for the North Atlantic; yellow dashed lines – approximation of three sections of the graph for Northern Europe; curly brackets and numbers – time intervals on graphs.

The following suggestions should be considered as recommendations:

1. Use a longer period of seismic regime for both regions studied, that is, for the North Atlantic and Northern Europe.
2. To study the properties of the seismic regime and *cumulative strain release* for smaller zones in the North Atlantic and Northern Europe and their relationship.

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THE USE OF GIS TOOLS IN MENTAL MAP ANALYSIS

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Mental maps are used to learn about the perception of space (in particular urban space) by man. The mental image of space is saved during the experiment on a sheet of paper, creating a sketch / mental map. The analysis of sketches was traditionally carried out analogously and mostly at the qualitative level. The use of GIS tools enables their quantitative analysis. ArcGIS ArcMap tools were used in the research. Polish Database of Topographic Object (BDOT10k) was used as reference data on the actual location of buildings and streets. After collecting maps from respondents, the objects on the sketch were assigned to the objects in the database. This approach allows one to perform a quantitative analysis of mental maps.

Two cartographic methods were used in the work: choropleth maps and proportional symbol maps. Instead of reference regions, diagrams and colours were used for buildings and streets. In relation to individual buildings, it is possible to statistically analyse the indications of their location. If various social groups were taken into account when collecting surveys, the above-mentioned analysis allows for their comparison.

The obtained results and conclusions on the perception of the city space by various social groups can be used for both urban and psychological analyses. The described methodology is presented on the example of two research areas: the campus of the AGH University of Science and Technology in Kraków and the town centre of Tarnów.

STRUCTURE-FROM-MOTION ANALYSIS OF SMALL-SCALE GLACIER DYNAMICS CASE STUDY ON THE USE OF BENTLEY'S CONTEXT CAPTURE AND AGISOFT METASHAPE

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Observations of marine-terminating glaciers show rapid increase of ice mass loss due to global climate changes. There are various means of glacier terminus observation including satellite imagery a GPS based survey of base points, terrestrial or airborne laser scanning (LIDAR) and photogrammetry, that differ in terms of accuracy and number of details. The monitoring of small calving events and variability in glacier's front velocity is difficult. Glaciers are often placed in remote areas with changeable weather conditions. Installing measuring devices can be challenging due to lack of stable ground areas in close proximity to the glacier. For those reasons there is a need to develop a survey method that would mitigate all the mentioned problems and produce data with accuracy allowing to document small-scale glacier dynamics. This article presents an introduction of Structure-from-Motion (SfM) algorithms into glacier survey methods and evaluation of its effectiveness. Although SfM studies on glacial processes have been conducted giving promising results, the estimation of the accuracy of those methods is usually limited. This paper focuses on comparing the results of two SfM softwares: (1) Agisoft Metashape (AS) and (2) Bentley Context Capture (CC) that implement different versions of these algorithms in terms of accuracy, number of details, range and visual effect. Comparison allowed for producing methodology needed in proper planning of the survey, control points design and control points' placement. We used nine series of photographs of Hans Glacier, a marine-terminating outlet glacier located in Hornsund fjord, South Spitsbergen, done between 10.08.2016 and 22.08.2016. The paper presents the strengths and limitations of each software and the SfM method implementation in glacier monitoring and concludes that ContextCapture is better suited for glacier movement analysis.

THE CONVERSION OF HEIGHTS INTO THE PL-EVRF2007-NH FRAME FOR POLAND

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Keywords: height conversion, detailed vertical reference network, PL-EVRF2007-NH, PL-KRON86-NH

The paper describes the problem of conversion of heights to the European Vertical Reference Frame 2007 for Poland (PL-EVRF2007-NH). The subject of the study is height data, and especially the detailed vertical reference network, which belongs to local authorities. The Polish Head Office of Geodesy and Cartography (GUGiK) is responsible for the state reference network and recommend the methods of conversion for a detailed network (Somla, 2018). The paper presents those recommendations, analyses advantages and disadvantages (Banasik & Borowski, 2019) and shows an alternative method (Borowski & Banasik, 2020).

The topic is important to local authorities – the conversion has to be done till the 1st of January 2021 (Council of Ministers, 2012).

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THE CREATION METHOD AND STRUCTURE OF THE DIGITAL TERRAIN MODEL OF THE ABSHERON PENINSULA

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In this article are presented a digital model of the terrain (DMT) and digital model of relief (DMR) of Apsheron Peninsula which built as the result of processing timeliness space information. The results of various international and regional projects have been applied to create DMT and DMR, in which the authors of this article took part. During the realization of those projects, digital base of dimensional is collected, (vector, raster, results of on-land dimensions, processing of spatial information). The applied input and output data have been existing in different scales and cartographic projections, both in paper and digital versions. It is clear that the existence of such various data did not contribute the management of information and taking operational decision for definite thematic challenges. Here the challenge has been set: to develop the structure of the unite digital model of Apsheron Peninsula based on the results done projects. Consequently, it is necessary to developing technologies of analysis of spatial digital information combination and access to them for solving ecological and other problems. Having systemized the results of done projects and additional spatial information, the authors have combined the digital model of various vector and raster based thematic layers, developed for Apsheron Peninsula.

Input information has been airspace images: GEOEYE1, PLEIADES1, SPOT6/7, AZERSKY, IKONOS, LANDSAT 7/8, TERRASAT, EROS A and CARTOSAT 2. Cartographic materials contained of topographic maps of 1 : 100 000, 1 : 10 000 scale and various thematic maps. All output and processed data are presented in a united cartographic projection. The data base is presented as 5 separate structures: MAP, SATLLITE, VEKTOR, TOPOLOGY and FIELD DATA.

Digital vector Data Base «VEKTOR» accounted for vector layers, classified according to various subjects: a group of vector maps on the process of desertification, vegetation/land use, lithology, tectonics, geology, on the process of soil salinization, social-economic maps, on the oil fields on the land and sea.

The base model «TOPOLOGY» is the group of vector layers of elements of topographic maps: roads, channels, populated places, geosystems, ecosystems, social-economic systems. All data are reliable and have exact coordinates. This fact allows fast geo-referencing for new input information.

A separate block is a digital terrain model for the oil fields of the Absheron Peninsula. A number of licensed oil fields operate on the peninsula. For each oil field, thematic layers are compiled, which include the following layers: oil wells, roads, channels, derricks, oil shakers, electrical substations and lines, buildings, sedimentation tanks and other contaminated sections of the oil field territory. Information is divided into two types: archival information obtained by vectorization topographic maps and current information obtained by processing satellite images.

Thus, the thematic layers form the digital model of the area of the Apsheron Peninsula and serve as the basic basis for the interpretation of aerospace images.

Processing and decryption of aerospace information includes stages of preliminary and thematic processing. A digital terrain model is necessary at the thematic processing stage when classification procedures are carried out. With its help more accurate determination of training fragments of investigated classes of objects is achieved.

Also, a digital relief model has been created with a high resolution (DEM and TIN). The DEM model is based on satellite information with a resolution of 8 meters. The TIN model is based on topographic maps of scale (1 : 10 000). This made it possible to create a digital relief model more close to reality as it possible.

The advantage of digital technologies in the field of cartography is the possibility of creating spatial models in three dimensions.

In turn, it is possible to quickly create a series of various thematic maps (for example, slope, exposure, curvature and hypsometry of the terrain) on the basis of digital relief model. Development of a large united digital model is actual for the dynamically developing region of Azerbaijan, which is the most densely populated with a developed road infrastructure, with oil-producing and other industry. The built digital models of relief and terrain contribute to the extension of practical implementation scale of spatial information into informational structure of Apsheron Peninsula. The presented digital models of different subjects can be used to increase the efficiency of regional management and evaluation of ecological-social-economic condition of the given region.

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LOCAL QUASI-GEOID MODEL FOR THE CITY OF KRAKOW

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The local quasi-geoid model KR2019 was developed for the city of the Krakow. The model is based on GNSS levelling with 5-hour static GNSS observations made at 66 points and normal heights obtained by referring to the national height network. The calculated height anomalies from two independent determinations on 22 points are within –8.3 mm ÷ 8.7 mm, with a standard deviation of 5 mm. The anomalies obtained from the development of observations were base to construct a polynomial fitting the quasi-geoid as a function of plane coordinates of the PL-2000 system. Based on the conducted comparisons and determined accuracy characteristics, it can be estimated that the accuracy of the local quasi-geoid model KR2019 in the city of Krakow area is higher than the accuracy of the official quasi-geoid model in Poland PL-Geoid2011.

EVALUATION OF THE ACCURACY OF HEIGHT MEASUREMENT USING GNSS RTN

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The research presents the results of a measurement experiment aimed at determining the accuracy of the ellipsoidal heights difference using GNSS RTN technique. Height measurement using GNSS RTN technique was conducted with the aid of ASG EUPOS reference station network and SmartNet station network which operate in Poland. Accuracy of measured ellipsoidal heights was determined by its comparison with the results of precise levelling. The analysis of the measurement results was carried out in two variants. Based on the results of the experiment, the accuracy of height in GNSS RTN measurements was determined depending on specific measurement conditions.

THE RESULTS OF THE PROJECT ON QGEOID DETERMINATION AND ITS ANALYSIS

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Since 2017 Institute of geodesy and geoinformatics was dealing with a project "Development of the high accuracy gravity field model for Latvia including sea territory" and its main task was to compute gravity field and precise quasi-geoid model up to 1 cm accuracy using all available data.

In 2016 quasi-geoid model for Eastern part of Latvia has been completed based on parametric modelling and computation of height reference surfaces (HRS) from geometric and physical observation components in a hybrid adjustment approach (DFHRS) [1]. In order to compute the quasi-geoid for the whole Latvia in addition to GNSS/levelling measurements, vertical deflection observed by Digital Zenith Camera were obtained. Digital-Zenith camera and processing software was developed by GGI, the instrument has also been tested during half a year before starting the observations in the studied area. The current amount of VD observations is equal to 420 and the precision of these measurements are evaluated as 0.10 arcsec mostly for all observations. In terms of a project, 276 GNSS/levelling points were observed by GGI and 1st and 2nd order levelling data and 147 GNSS/levelling points were provided by Latvian Geospatial Information Agency (Fig. 1). Global Geopotential Model (GGM) EGM2008 was used to spherical harmonic degree and order 2159, and contains additional coefficients extending to degree 2190 and order 2159 [2]. In comparison to some other GGM models like EGG97 or EIGEN6C4 it was better fitted to GNSS/levelling points in the studied area.

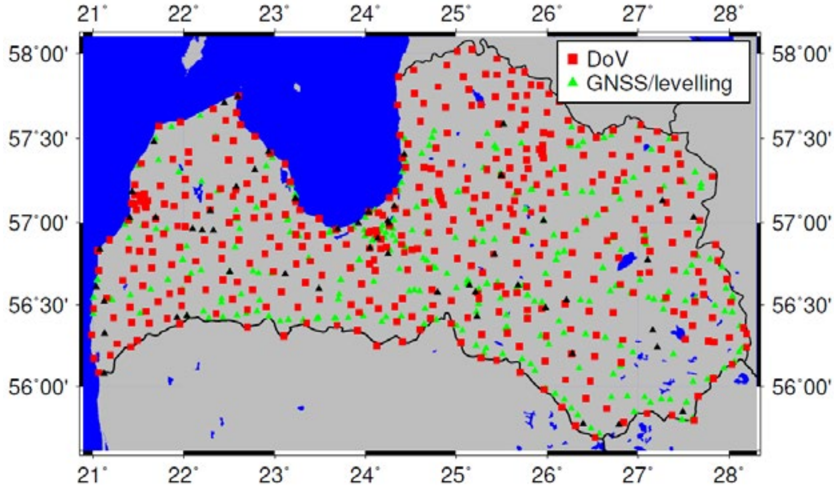

Fig. 1. Measurement scheme of GNSS/levelling points and vertical deflections

In turn, terrestrial vertical deflection observations were compared with GGM+ [3] and EGM2008. The results show a better correspondence with GGM+ model by evaluating the standard deviation: 0.314 and 0.307 arc seconds for ξ and η components respectively in comparison to 0.346 and 0.358 arc seconds for ξ and η components for EGM2008 model. The comparisons of average and minimum/maximum differences are introduced in this study for better evaluation of the results. The results of the computed quasi-geoid models using different types of data are introduced in this research, representing several solutions, as well as these solutions are compared with the national quasi-geoid model LV'14 [4]. The comparison of GGI quasi-geoid model using both GNSS/levelling points, vertical deflection observation and EGM2008 model with national quasi-geoid LV'14 developed by Latvian Geospatial Information Agency shows the minimum difference: –0.063 m, maximum difference: 0.048 m, and average difference: 0.019 m (Fig. 2).

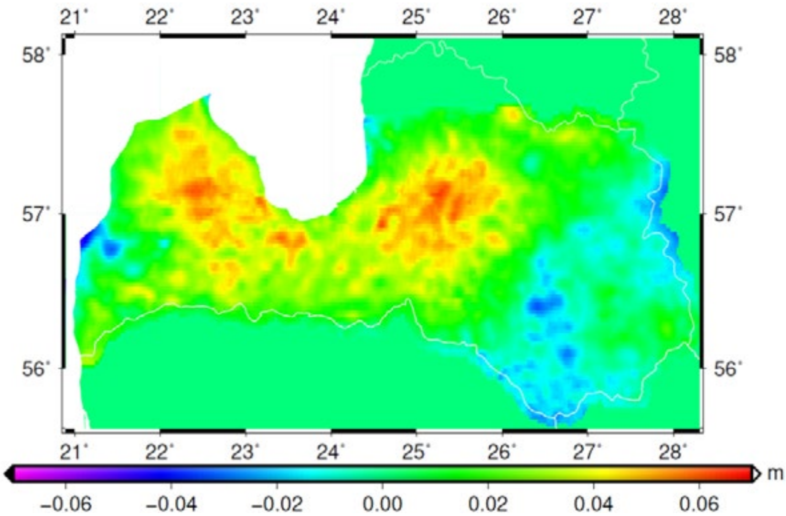

Fig. 2. The comparison of GGI quasi-geoid model and LV'14

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INTERPRETATION OF ANCIENT MESOPOTAMIAN ASTRONOMIC OBSERVATIONS RECORDS, OCCULT PRACTICE AND IMAGES FROM CYLINDER SEALS

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Ancient observations of celestial bodies in Mesopotamia have a very long history and are nowadays derived from quite rich sources of writings mostly from the collection of the British Museum. These sources mainly concern the end of the first millennium BCE and indicate that the astrologers observed the movements of the planets and stars and assigned them godlike features and powers. Each planet represented a god or a goddess and ruled over certain areas of Mesopotamians life, because the astrologers advised the rulers and interpreted the pattern of planetary movements as omens or signs for understanding the future. The practice of observations is deeply rooted in ancient Sumerian concept of Divination as important aspect of the Mesopotamian daily life, known mostly as Babylonian astronomy and astrology, currently analysed by hundreds of in-depth studies. The most important celestial bodies identified and constantly observed are Sun – god Shamash, Moon – Sin, Venus – Ishtar, Mars – Nergal, Jupiter – Murduk and Saturn – Ninib.

However, researchers often use various occult practice instructions and guides from later historical times to explain these texts. But more often images from even older period, early pictograph phase (c. 3200–2100 BCE) and boundary-stone pictograph phase (c. 1350–1000 BCE) are used, aiming to show the relationship of the divinity of kings with the highest gods, whose incarnations are represented by the most visible planets and stars. It would be wrong to interpret them as the astronomical knowledge of ancient Mesopotamians and to see there some special position of the planets. This is especially true regarding ancient Sumerian cylinder seals that are engraved with written texts and figurative scenes, used in ancient times to roll an impression onto a two-dimensional surface, generally wet clay. These are seals identifying the person and figurative scenes are not only a sign of the honesty of the signature before the gods depicted, but the complexity of these images is a way to protect these seals from being counterfeit. In this sense one must be very cautious in interpreting these seal images in a direct way, as more resemblance of these texts could be seen to witchcraft, magic and divination texts, created more than a thousand years later.

Ancient Sumerian cylinder seal showing stars, planets, and signs of the zodiac.
Uruk, 4th millennium BCE

A-GEO offers the latest and modern surveying equipment and services to legal entities and individuals throughout the Latvian territory for nearly 10 years, and actively cooperate with overseas customers. A-GEO joined also Latvian Surveyors Association to promote the development of remote sensing surveying industry.

A-GEO successfully cooperates with educational institutions by organizing workshops and training for pupils, students and for our customers and business partners, thereby promoting the surveying industry with the introduction of modern technologies and their use in everyday life with benefits.

Thanks to investments in the latest technologies, highly skilled professionals, great experience in the surveying market, A-GEO offers and are able to find the best surveying solutions for the rapid and qualitative execution of orders.

Daily the company was engaged in surveying services using modern technology and equipment, using only approved tools and softwares, as well as providing marketing services offering and LiDAR surveying equipment, computers hardware, computers and office equipment, providing training, support and full service.

Since 2019. A-GEO is the official distributor of Stonex products - surveying instruments in the Baltics, offering GNSS equipment perfectly suited to Latvian working conditions and priced to quality with accuracy up to 1mm.

Since 2019. A-GEO is French YellowScan scanners produce official dealer in the Baltic States, offering Lidar systems, 3D scanners, all the necessary equipment and software.

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