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ANALYSIS OF THE MODERN METHODS OF RESEARCH QUANTITATIVE PARAMETERS OF THE GLACIERS

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Problem setting

Glaciers play an important role in the geographical envelope of the Earth's. They influence significantly on relief, climate and weather conditions. The hydrological role of glaciers consists in the redistribution atmospheric precipitation during the year and smoothing fluctuations in annual water flows. The major value of ice is related to his high reflectivity. The substantial cooling of surface takes place on huge territories due to it. That is, glaciers are not only invaluable funds of fresh water, but also sources of cooling the Earth.

Except favorable effect, glaciers can be reason of adverse processes, phenomena and emergencies.

Monitoring the dynamics of glaciers surface will give an opportunity to educe and envisage future climatic, glaciology and biological changes that take place on a planet [4].

Relation to the important scientific and practical tasks

Processes, that occur in an atmosphere, cryosphere and hydrosphere are related to the processes in other parts of planet and influence on a global climate.

The analysis of materials recent meteorological and glaciology measurement in different places of the globe, show that monitoring of glaciers is only part of the mass investigation that can help to establish trends of global climatic changes on all planet.

Unsolved parts of general problem

Traditional glaciological, geodetic and methods of the remote sensing used for monitoring of glaciers. However, the technological schema that would allow to increase rate and accuracy of measuring, in particular changes of the glaciers surfaces is not definitively developed yet.

Paper objective

To perform the critical analysis of the literary sources, where technological aspects and methodologies of glaciers researches are presented and to make conclusion with the aim to develop optimal flowsheet in future.

Exposition of basic material

Influence of the glaciers extends beyond the area of their location. Modern continental glaciation directly and mediated affects the geographical nature of the Earth. This is reflected in the ratio of land and sea, that depends on the ice volume changes. Glaciation cools the planet's climate, reduces the middle temperatures of south hemisphere and whole planet, enhances a thermal zonality on Earth. Glacier mass changes have affected the global gravitational field, regional gravity redistributions, and earth rotation (length of day) [6].

It is necessary to investigate the dynamics change of glaciers quantitative parameters for detection and predictions of future climatic, glaciology and biological changes that take place on Earth. Such tasks decide by means of glaciology, geodetic methods and of the remote sensing.

Each of these methods will consider more detailed.

A glaciology method is presented in the works [6, 7, 11, 13, 14, 24]. The standard direct glaciological method, «traditional surveying method» commonly called «stakes and pits» method [11]. Application of such approach for monitoring glaciers of Alaska is described in a publication [13]. The traditional mass-balance method consists of annual field measurements of distributed points on the glacier. Stakes are drilled into the ice at representative sites, and accumulation and ablation are determined from stake readings. The density of the snow is measured in snow pits or from snow cores. Accumulation is often mapped more extensively by snow probing due to the complexity of the accumulation pattern. Contour maps of equal balances are determined and these are integrated for the whole glacier.

An ideal network consists of ablation poles (or stakes) installed in a pattern covering the entire glacier. Stakes should be distributed by equal elevation intervals, not equal horizontal distances. But, in many cases, logistical constraints dictate that the stakes are installed along the centerline of the glacier with occasional transverse profiles more or less perpendicular to the longitudinal profile of the glacier.

Ablation stakes of wood, aluminum, steel, plastic and bamboo have all been used successfully in mass balance investigations. Stakes are installed on the glacier by drilling holes 2–4 cm in diameter and up to 10 m in depth with a steam drill or hand auger. The location of each stake was recorded using a GPS receiver.

Ablation determinations are made by measuring the length of exposed stakes with a tape measure at the beginning and the end of the mass balance year.

Publication [6] presents the results of a reanalysis of glacier regime, including change in glacier area, mass balance, and several other characteristics. The ablation of glacial covers was determined by glaciology method of «stakes and pits» . This reanalysis covers period in the last 50 years. Thus conclusions can be drawn about changes of glaciers and polar ice caps. These glaciers

include all permanent ice bodies of atmospheric origin on the Earth surface, including peripheral glaciers around the two major ice sheets, Greenland and Antarctica. However, the tendency of changes is ambiguous for all glaciers of the planet.

The analysis of these paper allows to draw conclusion, that the use of glaciology methods for monitoring glaciers needs much time on realization field measurement, and also for an analysis and statistics of the obtained data. Except that, the use of method, is not possible in inaccessible places on the glacier surface.

A geodesic method for monitoring of glaciers is considered in works [11, 13, 14, 24, 26]. The geodetic mass balance is determined from glacier surface elevation data obtained from, for example, global positioning system (GPS), geodetic surveys or topographic maps [14]. The change in ice volume over the period between measurements is found by subtracting the surface elevations. The volume change can be converted to water equivalents if the density of the glacier mass is known.

Methodology of application GPS for determination displacements and area of glaciers the National park of Alaska is proposed in the process [13]. The technological schemes for monitoring glacier terminus change with GPS mapping consists of data collection, post-processing, and GIS analysis. Observations performed both in static and in kinematic mode. If the GPS receiver supports real-time differential correction, it should be employed during data collection. After the GPS data is collected, it is downloaded to a computer and differentially corrected using data collected simultaneously at a GPS base station.

Data is imported into the GIS for inspection and quality control. Any points that severely deviate from the general trend of the track log and represent obvious errors should be removed from the data set. The GPS points collected in the track log are used to construct a line representing the terminus position of the glacier.

The GIS is used to compare the current terminus position with those collected in previous and subsequent years.

The analysis of the above-mentioned works allow to draw conclusion that a similar technique of moderate cost that requires a moderate level of specialized training and equipment. However, it very labor intensive, uneffective and in most cases dangerous method of large glacier monitoring. Also, a geodetic method is applied for the assistive measuring today, for example, for providing of geodetic network.

Methods of the remote sensing such as aerial photography, air laser scanning, space and radar imagine are widely used for monitoring of the glaciers.

The archived aerial photos proposed to use for research changes in the Antarctic Peninsula in publication [19]. These data are an only method to renew the changes of glacier surface during the last 50 years for part of peninsula. However, extracting information from historical data to compare it to recent data is not trivial, and to-date, this data source remains largely untapped, despite its rich potential. Often such imagery is stored in non-digital format and may have degraded over time. Other problems relate to insufficient metadata or ground control. Typically these difficulties result in poor registration of multi-temporal digital elevation models (DEM), which degrade subsequent measurements of surface change.

In this research a least squares surface matching technique is introduced to overcome these challenges and achieve reliable registration of multi-temporal DEMs. Historical imagery is processed to extract DEMs, which are subsequently compared to DEMs derived from modern ASTER satellite data and aerial photography. The ASTER data was processed in ITT ENVI. Through the surface matching approach, it is shown that the registration accuracy of the historical and modern-day datasets can be improved significantly.

It should be noted that the main limitations of these studies is the quality of historic image. However, results of this study allow a better understanding of historical volumetric glacier changes of the Antarctic Peninsula and provide an efficient and automated method for improved DEM co-registration.

In [12] the geodetic mass balance is determined from digital terrain model (DTM). Combination of data of aerial photography and laser scanning is proposed. DTMs constructed from aerial photographs were used to obtain the geodetic mass balance of the western Svartisen ice cap in the periods 1968–85 and 1985–2002. Obtaining the geodetic mass balance from aerial photography is cheaper and less time-consuming than the traditional method. However, the absence of signalized GCPs reduces the accuracy. Additional inaccuracy is caused by the lack of field data regarding additional melting, and firndensity and firn-thickness measurements.

The use of unmanned aerial vehicles (UAV) as alternative way of data obtain is presented in publications [28, 31]. Changes of environment are the consequence of the global warming of climate, especially this change is much stronger in the Polar Regions, and these regions are keys to understanding the processes causing this change and the consequences for our planet. One of the major problems for polar researchers is the scarcity of data. For an area much larger than Europe there are only a handful of permanent research stations. The Polar Regions are mapped by a number of different satellite sensors, but these data also have their limitations both in spatial and temporal resolution and in the kind of measurements that can be done. Hence, use of airborne measurements yield a perfect bridge between the continuous point measurements of research stations and wide area satellite measurements. Operating manned airplanes in these environments are both extremely costly and in many instances very dangerous due to the nature of the data needed (low altitude, bad weather). This has severely limited the use of aircraft in polar research in the past.

The articles focuses on using UAVs, which will enable continuous measurements of glaciers. During the period of study were done five projects. For period of researches five projects were executed. However, concrete technology it was not presented for each of projects.

In paper [30] investigated the feasibility of UAS based elevation measurements of inaccessible glaciers on Svalbard. The glacier elevation profile is measured utilizing a payload consisting of a FAE-LS1501 laser altimeter in combination with a high precision L1/L2 GPS receiver. The glacier terminus is mapped using a digital camera post processed with multi view stereography.

The accuracy of the surface elevation profile retrieved from laser altimetry is directly related to the accuracy of the onboard GPS receiver. The mean and standard deviations have been calculated for data recorded throughout the whole flight. Ground control points are essential to generate an accurate DEM from multiple view geometry. Preferable measurements should be collected in a grid pattern covering known points located on the lateral moraines on both sides.

In this work used a laser altimeter, that worked in the short range and surface height was low. This caused difficulties in the data registration. Thus, an important step is study of locality and choice of equipment with corresponding technical specifications.

UAS can be a valuable tool for glacier measurements in remote areas like Svalbard, where the only real alternative to measure glacier elevation in the ablation zone during the melt season is by manned aircraft. Imagery from repeated observations within a few days can be used to estimate dynamic mass loss rates when coupled to 3D modeling and feature tracking. Retrieval of these data is valuable, especially for glaciers terminating in the sea and surging glaciers.

In papers [17, 20, 23, 36] proposed to use the method of removing the space. Monitoring of glaciers Mongolia as indicators of climate and freshwater resources are presented in [17]. The purpose of the research study is to determine area Glaciers and Snow Coverage in Western part of Mongolia. Landsat satellite information was used to compare data. Performers underline that it is needed take analysis with synergy of climate data. This is important information to resolve the pure water resource and the balance between glaciers and snow coverage.

The monitoring of the variation in glacier areas is increasingly important with the apparent trend of global warming. In [20] one of the major ice sheets on the planet, the main glaciers of Southern Patagonia Icefield were mapped using a set of images obtained in 1973, 1976, 1979, 1986, 2005 and 2009 by the ETM + sensor onboard the Landsat 7 satellite. The images were calibrated to planetary radiance and reflectance, where the supervised classification of each image sought to obtain the physical limit of the snow with each glacier.

Maps were generated with the terminal position of the glacier tongue for the dates analyzed. The results were compared with previous publications and showed peculiar behavior of each glacier, especially from the images of 1986, where there was a pattern of decrease in surface area of glaciers. And the temporal analysis will show the behavior of glaciers to the present day.

It should be noted that results do not allow to predict the future trends of the glacier change.

In paper [36] presents a research on monitoring of glacier volume variation over the Geladandong area in Qinghai-Tibet plateau between 2000 and 2007 by integrating Landsat5 TM images, multi-source DEM and the Geoscience Laser Altimeter System (GLAS) data from NASA Ice, Cloud, and land Elevation Satellite (ICESat). Landsat TM images acquired in 2000 and 2007 respectively are used to extract glacial area of the two dates. SRTM DEM are used to extract the thickness variation of glaciers between the year of 2000 and 2007. The IceSat GLAS data is employed to correct the penetration and refine the glacier's elevation of SRTM DEM. Glacier volume variation of Geladandong region is estimated by integrating the area and elevation changes.

Is considered only the period of study (2000-2007 years) at work. Not references to previous data for the region. The results show that each of the parameters studied glaciers varies in different ways, that it is difficult to identify trend changes.

The using of Optical image for monitoring Iran's glaciers described in [23]. In order to measure glacier displacement map, Spot 5 and multispectral Quickbird images respectively acquired at September 2003 and 2005 from study site are chosen.

It should be noted that in the course of the study there were difficulties associated with noise remained noticeable. The apparent displacement of the shadows is negative and oriented mainly parallel to image lines.

Radar imaging are based on the use of the waves removed from earthly objects in a microwave range. Application of such approach is proposed in the article [37]. This paper will discuss the application of the SAR, optical and altimetry data in Grove Mountains. Firstly, the improved DEM is generated. It is still difficult to get the accurate DEM of the whole Grove Mountains which is about 8000 kilometers square because the sloping terrain and the baseline error exist.

The applied methodology allows to calculate the parameters of glaciers on the separate sources of data and monitor the extensive territory, and also to classify the surface of glaciers. But, the technological schema of the compatible use of data has not worked yet.

In paper [10] a method for determination of glacier surface area Taku (Alaska) using multi-temporal and multi-angle high resolution TerraSAR-X data sets is presented. In order to achieve this goal features such as coherence map, texture information, and pre-estimated velocity maps are used for a classification of the glacier surface.

In process could not to classify all surface of glacier, that it is related of noises and insufficient information content in some zones of images. Approximate value of area was also calculated.

Accurate monitoring of the glacier changes is essential to evaluate the environmental-ecological health in the scenario of global change. In [32, 35] using interferometric SAR images to obtain information about surface of the glacier. The main objective are to correct the topographically induce distortions inherent in SAR image of rugged terrain and to map glacier facies in the corrected polarimetric (PolSAR) image. In [32] methods for terrain correction of PolSAR developed which base on the coherency matrix data, utilize polarimetric signature to refine the location accuracy

and perform the pixel size normalization on each element of the coherency matrix using the backward integration method. Moreover, azimuth-slope correction is immediately following after radiometric correction. A supervised classification is performed on the orthorectified image to map the spatial distribution of snow and ice.

In a study [35] analyzed images for the monitoring of glacier change in Geladandong area, the head of the Yangtze River. 8 texture features were analyzed based on gray level co-occurrence matrix (GLCM), including mean, variance, homogeneity, contrast, dissimilarity, entropy, second moment, and correlation.

Analyzing these publications can be concluded that SAR has great potential in monitoring glaciers. However, it is difficult to distinguish glacial area from non-glacial area when their coherence is similar, especially for short wavelength radar. That is, when this difference is not apparent need another approach.

The contribution of Polarimetric Synthetic Aperture Radar (PolSAR) images described in publication [8]. However, despite a number of recent studies focusing on single polarized glacier monitoring, the potential of polarimetry to estimate the surface velocity of glaciers

has not been explored due to the complex mechanism of polarization through glacier/snow. In this paper, a new approach to the problem of monitoring glacier surface velocity is proposed by means of temporal PolSAR images, using a basic concept from information theory: Mutual Information (MI). The proposed polarimetric tracking method applies the MI to measure the statistical dependence between temporal polarimetric images

It should be noted that the accuracy of data acquisition is not marked.

Application of airborne laser scanning (LIDAR) of the glaciers surface discus in the studies [18, 38]. In study [38] presents the processing of both aerial and oblique images as well as LiDAR data in the European Alps due to the height, steepness and ice coverage of the rock wall. New techniques of airborne LiDAR data acquisition are combined with established photogrammetric processing methods of aerial images to develop high-resolution DEMs for different epochs since 1956. Furthermore, a novel approach for DEM generation from helicopter-based oblique photos is introduced. Different software solutions for image processing and DEM generation are used and evaluated for applications in such steep high-mountain terrain. to improve the DEM.

In publication [18] a new approach to glacier inventory, based on airborne laser-scanner data, has been applied to South Tyrol, Italy during 2005- 2006 years. Resolution of DEM was 2.5 m. Using the results of previous studies (1997) determined the changes of the glacier.

Analysing these works, it follows to mark that the use of LIDAR is a perspective method. Errors are due to the fact that laser rays reflected from the ice surface, especially in mountainous areas, and there are occlusions in the images. The loss of data mainly meets in areas with little ice cover.

Glaciers are investigate of modern ground remote tools today. This makes it possible to increase the rate and accuracy of measurements to obtain quantitative parameters of objects. These methods are terrestrial laser scanning (TLS) and digital photogrammetry.

Application of digital photogrammetry for determination of quantitative descriptions of glaciers the Argentinas islands is offered in publications [1-3]. The field measuring envisaged such stages: to choose areas and planning project; to fasten control and base points, determination of coordinates; capture; a position-fix with GPS in the static mode. Office processing the data was to processing digital images on a digital photogrammetric station (DPS) Delta-2.

Difficulties occurred at marking control points. The problem is solved by setting marks on the edges of the glacier surface. But that was not enough for further orientation of images on DPS. Geodetic work has been done to control. The accuracy of the surface volume was 0,1%.

Analyzing the present study it can be concluded that the proposed technological schemem allows to determine the volume of glaciers quickly and accurately. Digital capture to determine quantitative parameters of glaciers without additional geodetic measurements. But in some cases it is necessary to carry out their transformation.

Monitoring of rock of glaciers using digital photogrammetry considered in publications [15, 16]. In study [15] application of terrestrial photogrammetry for glacier mapping using either consumer, semiprofessional or professional SLR digital cameras and a fully digital photogrammetric workflow. Terrestrial photogrammetric surveys were carried out at Austria in 1986, 1999, 2003, and 2008. The following camera systems were used: analog cameras, i.e., Zeiss Photheo 19/1318, Linhof Metrika 45, and Rolleiflex 6006, and digital cameras, i.e., Hasselblad H3D-39, Nikon D100, and Nikon D300. Stereopairs from multiple baselines were acquired from the counter slope of Äußeres Hochebenkar rock glacier. The digital photogrammetric processing of the image data using modern techniques of computer vision, e.g., least-squares matching, is outlined. Threedimensional

flow vectors were computed for the whole area with high precision to reveal the spatio-temporal change in flow velocity.

In [16] authors propose the following workflow: a reference epoch consisting of at least 3 or even more overlapping, convergent digital photographs, taken with a pre-calibrated camera, is photogrammetrically triangulated using geodetically measured GCPs. Analog images were digitized using a software UltraScan 5000. The root mean square errors (RMSEs) obtained are in the range of ±10 cm to ±20 cm. This is mainly due to random errors which cause systematic effects and problems of visual surface definition. The latter means that points of a rough (debris-covered) surface are systematically measured too high by the photogrammetric operator.

The influence of the systematic effects is diminished by comparing photogrammetric profiles

obtained either from different camera systems of the same epoch

The advantage of such methods is the ease of data collection with a relatively limited number of personal to perform field work. However, photogrammetric data processing requires skilled operators.

The feasibility of using digital photogrammetry confirmed in [34] for monitoring ice cliff Kilimanjaro. A Nikon D2X DSLR camera was used. A Leica TCRA 1101 total station was used to define a local coordinate system and to survey all reference points. Displacement of the ice cover was calculated by DEM from PhotoModeler.

It should be noted that the proposed method can be successfully applied for long-term monitoring projects, but only small glacier or individual areas of the glacier.

Using digital cameras for determine change of ice mass is proposed in the papers [9, 33]. Two camera stations were set up to view different sections of the icing. In [33] was obtained a series of images from two cameras Canon XTi Digital Rebel with an interval of two months. Camera 1 was set up to cover the section immediately below the glacier. Camera 2 was set up near the valley constriction at the eastern end of the icing and looked north west, up the length of the icing. The accuracy of the results was 0.57 m (east direction) and 3.5 m (west direction).

The information was interpret as next way: to put the series of orthoimages for each camera together as a movie. This enabled to analyze the degree of melting ice masses.

Technological scheme has been realized from some difficulties. They are associated with changes of camera orientation. To reduce the influence of these factors is necessary to use permanent control points, calibrated camera.

The high resolution digital camera data set acquired on the Argentière glacier (France) has been processed to evaluate the temperate glacier monitoring potential [9]. For this purpose, the study has been lead on a specific part of the glacier which has been viewed by two cameras with two different viewing angles. Most developments were based on the use of software for microcontroller - Texas Instruments MSP430F149. In order to estimate the glacier-velocity map, an optimized “correlation technique” is used with one pair of images for each camera. For two specific points, velocity estimation has been computed in cm/day with three pairs for each camera.

However, the estimated displacement vectors are not expressed in threedimensions; they are only expressed in the two-dimension camera geometry. Furthermore, the global velocity field is only expressed in pixel/day because the distance between the camera

and the scene is not known.

Glaciers are sensitive to climatic variation and a particular developing area of investigation is in the field of "cryoconite” [27]. In paper describes the use of close range photogrammetry to reconstruct the glacier surface at the sub-centimetre or micro scale, an approach which may allow the relationship between cryoconite and ice surface properties to be explored over either space or time. The field campaign was conducted at Svalbard during the summer of 2010 and executed using simple equipment and procedures. A simple and ageing Nikon 5400 5 MP camera was used to acquire all imagery, proving sufficiently robust for the challenging field environment. The camera was handheld approximately 1.6 m above the ice surface, providing an oblique perspective. Images were acquired at three different camera/object distances, each generating coverage occupying three different areas. All imagery was processed using the commercial photogrammetric package PhotoModeler.

The accuracy of the results was 4.5 mm in area 4 m^2 plots and 6 mm for plots $9m^2$ area. The quality of DEM varied depending on the purity of the ice and more significantly on the angle pairs of images.

Deserves more attention in [22]. This paper has addressed the important issue of coastal change monitoring, using the integration of geomatics techniques to form accurate representations of the coastline, with high spatial resolution and efficiency. The use of terrain data is seen as the optimum approach to change detection in landforms, particularly in the coastal zone where dynamic processes and lack of identifiable features are often detrimental to the monumentation of individual control points.

A solution is presented, based on two component technologies – the Global Positioning System (GPS) and digital small format aerial photogrammetry – using data fusion to eliminate the disadvantages associated with each technique individually. General flowsheet that was used in the work presented in Figure 1.

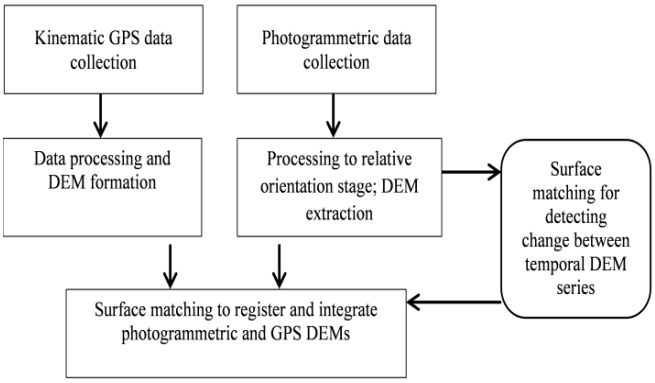

Figure 1. Technological scheme of combining data from GPS and digital camera

The advantages of such a system are readily apparent, allowing the introduction of multiple terrain data in a modular approach. The flexibility of the matching algorithm was demonstrated by its use in two stages of the monitoring methodology: in registration of the core DEM components, and in later change detection, with high levels of redundancy and reliability.

However, further issues remain and, as in all change detection methods, responsibility ultimately falls on the user to assess whether the results given by the system correspond to reality, and that errors in the data sources or registration are not falsely categorized as change. Despite this warning, the methodology

presented here has proven to be effective and flexible, suitable for many DEM sources and Earth science applications.

Determination of the velocity displacement of glaciers using digital images and aerial and terrestrial laser scanning are presented in [21]. In the paper, reported on recent measurements at three glaciers in West Greenland. For studies cameras was operated in an intervallometer mode, taking images at regular time intervals (typically 10 or 15 minutes) over time periods of 24-72 hours.

It should be noted that there have been difficulties such as camera orientation variations caused by wind effects, warming up of the tripod legs and instabilities of the ground. The processing of image sequences of a terrestrial camera allowed to build a DEM of the glacier with high resolution.

Also, glaciers displacement determined by interferometric SAR images (2004) The attention that using satellite imagery was only possible to determine long-term changes velocity.

As an alternative and addition used terrestrial laser scanner Riegl LPM- 321 (2007). The advantage of the method is its laserscanner data processing will not suffer from effects caused by moving shadows as a consequence of the rugged glacier surface and the 360° path of the sun. Disadvantages are the cost of the instrument, the electrical power requirements and the limited resolution caused by the beam divergence of 0.8 mrad and the slow scan rate.

Application of terrestrial laser scanning is proposed in [29]. Presents a new method for determining of 3D glacier surface velocity fields, which is based on processing multi-temporal terrestrial long range laser scanner data. Multi-temporal 3D point clouds were acquired by a long range terrestrial laser scanner, which offers a maximum range of 4 km when measuring on glacier ice. Velocity vectors are determined by applying 2D matching techniques to the point clouds interpolated to a regular grid.

The authors also proposes a solution to identify and eliminate errors in the measurements of angles that occur in the data.

However, it should be noted that the cost of the instrument and the technical effort is significantly higher. In addition, the beam divergence of 0.8 mrad poses limitations to the spatial resolution, and the scan rate (10 points per second at maximum range) limits the temporal resolution.

In [25] proposed the methodology and application results of the terrestrial laser scanner for the extraction of topographic data and surface motion at the Belvedere Glacier, in Italian Alps. The traditional measurements carried out using GPS and ablatometric stakes provide only punctual evaluations of the phenomena. In glacier monitoring an extensive approach could be preferred in order to obtain a complete description of the surveyed object. According to this statement, different terrestrial laser scanner campaigns have been planned at different

sites of the glacier surface Riegl LPM-321, in order to evaluate the most interesting geodynamical phenomena during their evolution.

To study used a laser scanner Optech ILRIS-3D ™. For each area under observation, two scan sessions have been executed with the aim of measuring changes in glacier features; during the third test on the central body of the glacier also measurements of some targets have been used in order to make a comparison with ablation stakes measurement accomplished with GPS, thus obtaining co-registered data.

Two methods were used in the work. That is, as control points used tie points and specific natural objects, such as boulders. The errors at the stage of data recording were 1-2 cm (tie points) and 20 cm (boulders). As a result, DEM have received each of the areas of observation. Comparison of the surface showed that the average displacement of more than 2 m with an average speed of 0.05 m / day. In addition, using traditional measurements determined the total value of the vertical displacement.

Analyzing this work we can conclude that the proposed "natural benchmark" approach has proved its applicability introducing a new method in the processing of data. However, it should be noted that this approach may be applied only to surfaces with stable characteristic of natural objects that do not change the location during the period of observation.

In [4, 5] proposed the use of technology ground laser scanning and digital photogrammetry measurements for monitoring the Antarctic ice island coast. It has investigations of Galindez and Winter glaciers were made. The field measurements were made with ground laser scanner Faro Focus 3D. From the experimental investigation was determinate optimal parameters. For further monitoring global coordinates of scanner stations and control points were measured with GNSS Leica GPS1200. The coordinates errors were not bigger than 3 cm.

Field measurements were processed with Faro Scene software, as a results the spatial models of glacier were received. The scanning was made during complicated meteorological conditions – snowing and raining. This precipitation were measured in the scans and were deleted using software filters and in manual mode. During the investigation we indicate that ice with different structure has different reflection characteristics. The permitted angles of laser beam falling must not exceed 45°. If angles are smaller the laser reflection is absent. Because of that the un scanned areas appears.

During laser scanning the ground photogrammetric digital measurements were made from basic points with digital camera EOS 450D 12 pixels and focus distance 18, 35, 55 mm. In normal and deviated causes.

The using of complex methodic allow us fulfil un scanned areas with digital photogrammetry data.

By the digital photogrammetric measurements made in 2005 and 2013 the changes of surface volume were detected and their kinematics characteristics [4].

The authors point out that the proposed flowsheet of determining the volume of glacier surface enable operational with the necessary precision to solve the problem without additional geodetic measurements. However, in some places on the glacier surface (cracks, caves) laser scanning data had occlusion. Also, a

comparative analysis of the accuracy of both methods in the work are not available.

In summary it should be noted that the contact methods are not technological and dangerous. Remote sensing techniques such as airborne laser scanning, radar and space imagine should be used to determine long-term changes in area of large areas. Aerial and terrestrial digital photogrammetry is satisfying. But the use of aerial in Antarctica is a technology problem and has a high cost. An alternative is the use of UAVs, but application of their technological scheme in polar regions not yet developed at this time.

Digital photogrammetry eliminates the negative aspects of these methods and makes it possible to determine the parameters of glaciers and the use of materials in various kinds glaciological works.

The use of laser scanner provides a complete description of the glacier surface in a short time. Point cloud is ready to process immediately and provides a geometric characteristics of the object. Although the use of TLS for such problems has not been sufficiently studied, but can improve the accuracy of quantification parameters of objects and it is a perspective method.

The use of a laser scanner, due to its high frequency data acquisition provides a full description of the glacier surface in a short time. Cloud points immediately ready for processing and provides a geometric characteristics of the object. Although the use of NLS for such problems has not been sufficiently studied, but can improve the accuracy of obtaining quantitative parameters of the objects of study, including ice surfaces and is quite promising.

The use of complex techniques of terrestrial laser scanning and digital photogrammetry will allow to define quantitative parameters of glaciers without additional geodetic measurements avoid occlusion and get control points for orientation of digital images.

After reviewing the literature was proposed general flowchart of methods and ways to study glaciers (Fig.2).

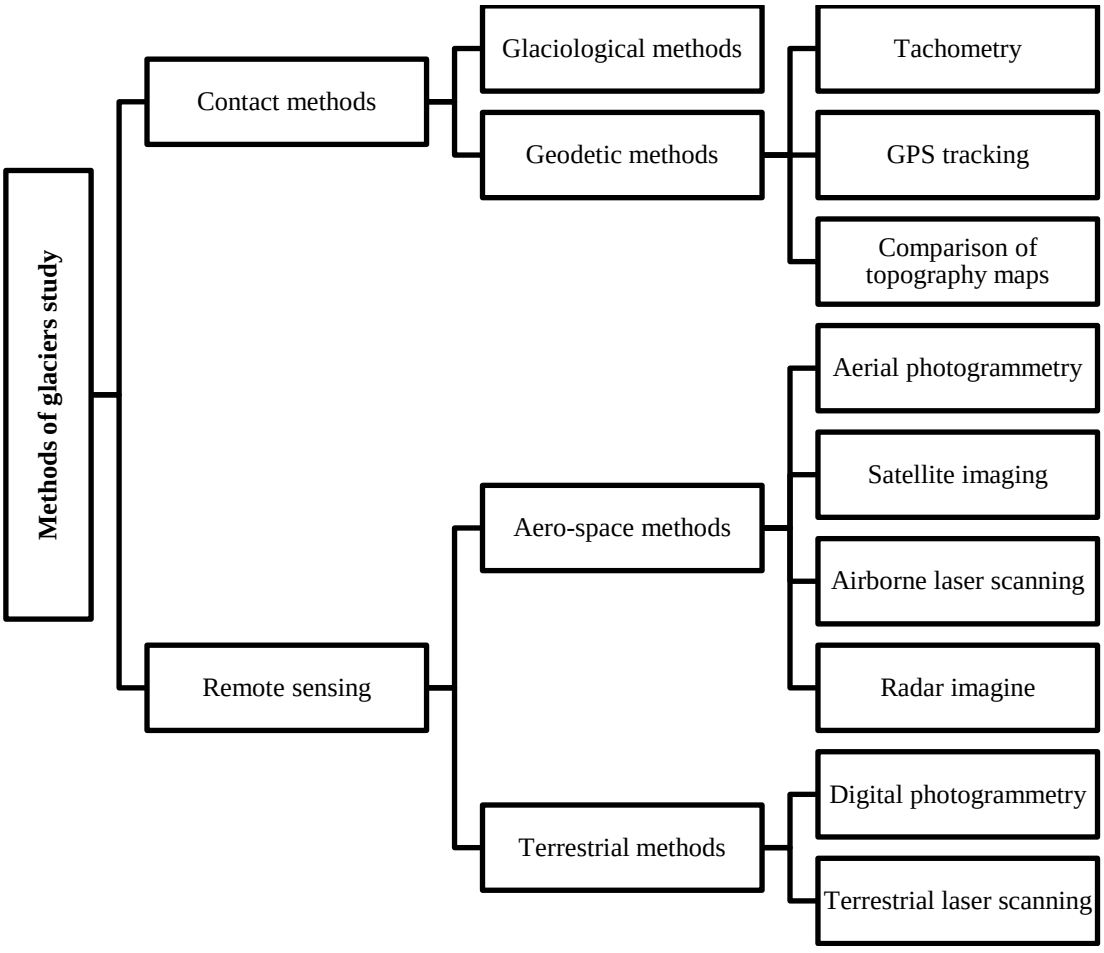

Figure 2. Flowchart of methods and to study glaciers

Conclusions

1. After reviewing the literature, it should be noted that the chosen topics is an actual today because glaciers are indicators of the climate change on the planet.

2. There are many methods for monitoring glaciers, which are widely discussed in current publications at this time.

3. Contact methods are not technological, but in the most types of work it is dangerous.

4. Remote sensing techniques such as airborne laser scanning, radar and space imagine should be used to determine long-term changes in area of large areas.

5. Aerial photogrammetry is satisfying. But the use of aerial in Antarctica is a technology problem and has a high cost.

6. The use of laser scanner provides a complete description of the glacier surface in a short time. Although the use of TLS for such problems has not been sufficiently studied, but can improve the accuracy of quantification parameters of objects and it is a perspective method.

7. Suggested methods for combining TLS and digital photogrammetry for monitoring changes in of glacial surface.

8. Planned to develop the complex methodology for ground-based laser scanning and digital photogrammetry for the study of quantitative parameters of glaciers in the future.

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Analysis of the modern methods of research quantitative parameters of the glaciers

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In article are presents an analysis of modern technology investigation of glaciers surface. Accented on changing the quantitative parameters of glaciers that is connected with climate change on Earth. Corresponding conclusions about application of the existing methods to investigate the changes of glaciers.