CO-014

RECONSTRUCTIONS OF MOUNTAIN GLACIERS IN LAST HOLOCENE (KASHKATASH, ULLUKAM AS EXAMPLES)

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INTRODUCTION

Many scientists from different fields of geography pay attention to researches of fluctuations of glaciers. Glaciers are one of the best indicators of climate changes. The response of mountain glaciers to climate change is crucial to the projection of sea level rise, the management of water resources, and the anticipation of natural hazards triggered by glacier retreat. Long data series are a key element in the glacier-climate linkage [Huss et al., 2010]. In Russia most of investigations of glaciers' fluctuations are based on instrumental measurements, therefore in most cases they consider glaciers' behavior only from the last half of XX century and, which is more important, they do not have any spatial reference of data.

We focused our study on the valley glaciers, situated on the Northern slope of the Central Caucasus. In this article we discuss Kashkatash glacier, which is located in Adylsu valley (Elbrus area), and Ullukam glacier, which lies on the southwestern slope of Elbrus.

APPROACH & METHODS

The process of reconstruction was conducted in two steps according to the methods of research. The first step included analysis of glaciers' fluctuations from the end of XIX century to nowadays. We used cartographic materials, aerial and satellite images, photographs and historical data. To compare different images, they should be in the same projection and without considerable distortions. In this research we applied projection UTM zone 38, ellipsoid WGS-84.

Satellite images do not usually require any processing. We got the images, which had already been edited (georectified and orthorectified). On the contrary the aerial photographs had to be analyzed before use. It is necessary to mention, that we assumed that satellite images with good resolution were the most accurate data. Therefore all other data were correlated with the remote sensing images (for Kashkatash glacier it was image from EROS, for Ullukam glacier it were images Cartosat and Geoeye (Google)). We used ERDAS Imagine 8.5 to make geometric correction. Firstly we identified control points on aerial photographs and satellite images (approximately 25 for a glacier forefield) to get coordinates, and secondly using digital elevation models (DEMs) we georectified and orthorectified images.

Distortions because of relief are significant in mountains, and at the same time accurate DEMs are difficult to obtain. Precision of global DEMs was not satisfying, so we digitized contours from topographic maps of scale 1:50 000 or even 1:25 000 if they were accessible to create DEMs. Unfortunately, there are many relief-related mistakes in mountain areas on the maps, therefore DEMs are not excellent, but can be used for our purposes.

None of the maps used in this research have UTM projection; therefore at first we transformed all the maps. Old maps (created at the turn of the XX century) sometimes do not have information about projection and grid, in such cases we tried to choose the most suitable ones and then corrected references of maps using control points (like mountain peaks, outflows of rivers etc). Scales of most of the old maps are not suitable for the research of fluctuations of an individual glacier, but sometimes they can help to indicate changes in its upper parts.

Ground photographs are another source of information. Modern photographs can be useful to identify features, if the latter are not obvious on remote sensing images. Also we have old photographs, made by researchers in the period from the end of XIX to the beginning of XX centuries, and during the field work in 2009 and 2010 we visited the same points, from which the images were made, to repeat the photographs. Overlaying and comparison of these photos as well as descriptions and remote sensing images of under study glacier allow indicating its approximate position 100 years ago. Repeated photographs are visual presentation of global changes of environment.

Different plans, which accompany articles, were used, if it was possible to lay them over satellite images. None of these plans have scale and coordinate grid, so if there were control points and lines of relief, we georectified and then carefully analyzed them.

On the second step we used proxy data to define positions of glaciers older then the end of XIX century (the first map for the Caucasus was created in 1887). During the field work in 2008, 2009 and 2010, we collected samples in the forefields of glaciers for dating surfaces. These samples included cores of pine (Pínus sylvéstris) and buried soils, which then were analyzed in the laboratories. We measured widths of tree-rings of pine's core and using cross-dating method we identified the year, when this tree had settled on the surface. Details of dendrochronological method are described in the articles of Shiyatov [e.g. Shiyatov et al., 2000]. These data gave us approximate minimum ages of surfaces. In Kashkatash valley we found the tree, which was damaged by the moraine. It was a real godsend, because having analyzed its tree-rings, we were able to define when the tree was damaged and as result we found out when the moraine was generated with the accuracy of one year. Unfortunately, only few glacier forefields are covered by trees; therefore we cannot use dendrochronological method for all glaciers.

Lichonometry is not as accurate as dendrochronology, but it can be applied almost for all surfaces near the glaciers on the Caucasus. It is based on the theory that diameter of lichen depends on its age. We used the world accepted methodology of measurements during field work (more detailed in works of Innes [Innes, 1985]) and then we compared received data to the regional curve of lichens' growth, which show dependence of diameter to age. Lichens also give us only approximate minimum age of surfaces.

These two methods, described above, allow us to date surfaces no older than 1000 years. Older surfaces can be dated if they contain buried soils (analysis of isotope C14).

Each of the samples has coordinates, gotten by GPS-receivers. The accuracy of GPS is 15 meters, but in mountain conditions it sometimes does not work well. Steep slopes of valleys close the sky and GPS-receiver cannot observe enough satellites. Therefore some of the samples cannot be considered because of big errors in their coordinates.

Having prepared the data, we digitized the borders of the glaciers' snouts for different years and moraines. Usually it is better to use earlier images for identification of moraines, because the latter are covered by more sparse vegetation and less destroyed. On the final map the borders of glaciers can be drawn on a remote sensing image or a common geographic base. Then we made some calculations, such as changes of glaciers' lengths and areas, changes of altitudes of glaciers' tongues, mean velocities of fluctuations.

RESULTS AND DISCUSSION

We created the reconstructions of Kashkatash glacier for 20 years from XVII century to nowadays (fig. 1). It is one of the most detailed reconstructions for the Caucasus. Another reconstruction made by us is for Ullukam glacier. It consists of 10 positions of glacier snout over the past 130 years and a level, below which the glacier had not climbed down in last 4000 years (according to dating of buried soil).

Analyzing these two reconstructions, it is clearly visible, that:

- there was Little Ice Age on the Caucasus, which is marked by moraines,
- since the middle of XX century glaciers have retreated,
- apart from retreats there were some advances, the biggest one was from the end of 60s to the middle of 80s of XX century.

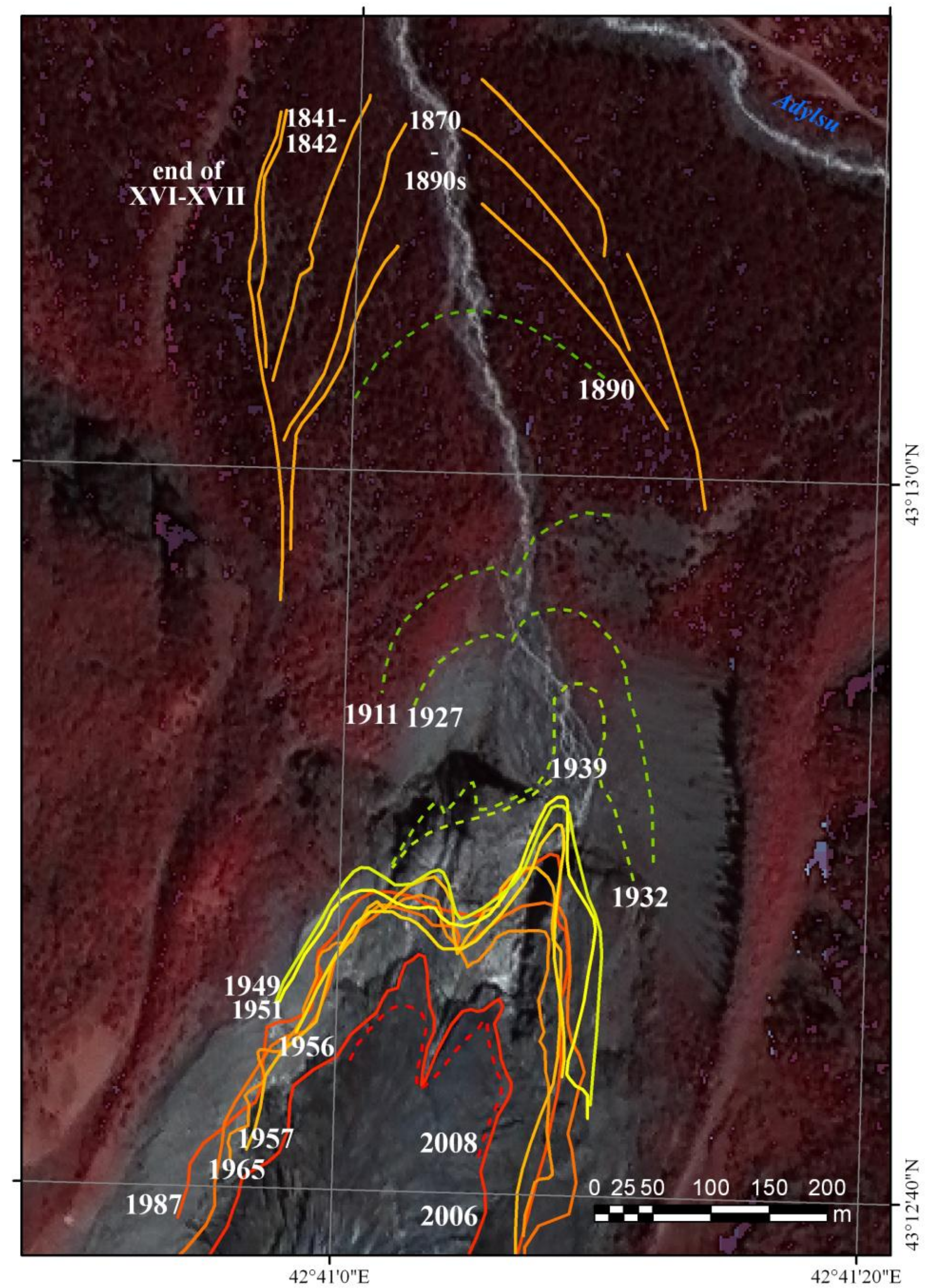

Fig. 1 Map of fluctuations of Kashkatash glacier

The distinctive characteristic of these reconstructions is that all positions of glacier have spatial reference. It is more useful than tables with measured changes of length or area, because maps are more visual and more detailed (it is not rare that a snout of glacier separates into two parts and they fluctuate with different velocity). Of course, we add the tables with changes of length or area to the maps, but borders of glacier as a GIS layer are more accurate.

Modern satellite sensors are very accurate and spatial resolution of images Geoeye (for example) is less than 1 m. But in our research we used different data and as a result the information, derived from them, has different precision. For the modern satellite images spatial errors are no more than 3 meters, for the images CORONA they are 15 meters, for the aerial photographs – 6 meters, for the old maps – no more than 10 meters. These values were calculated by comparison of several (some 15) control points on the different images, therefore the values show us not only spatial resolution, but also errors of georeferencing and orthorectification. We think that these distortions are in tolerable values. The accuracy of lichenometry and dendrochronology is described above.

The main results of this research are well correlated with data already existed for Caucasian glaciers. Fluctuations of observed glacier are similar to fluctuations of Bolshoy Azau glacier [Natural processes in Kabardino-Balkaria, 2004], which is the most visited and the most explored one on the Caucasus. The type of changes of mean velocities of fluctuations, which we observed, is identical to that, which was received by Zolotarev [Seinova, 2001]. We compared our glaciers with Alpine ones as it is accepted and also found out similarities of the glaciers' behaviors [Zumbuhl et al., 2008].

Besides these reconstructions we also made the interactive unit, which visually shows changes of the glaciers. We used repeated photographs and, putting modern photographs over the old ones, we created some short movies. Users can choose changes of what glacier they want to watch and they also have possibility to stop or to restart the movies. It was made with Macromedia Flash Professional 8 and we think it is one of the ways of science popularization.

CONCLUSION AND FUTURE PLANS

Using cartographic materials and proxy data we created the reconstruction of two mountain glaciers. The reconstruction of Kashkatash glacier covers 450 years and the reconstruction of Ullukam glacier includes positions for last 150 year and approximate position for 4000 years ago. The analysis of results shows that the glaciers have periods of retreats and periods of advances as well (the last advance was in 1980s). Comparison of fluctuations of several glaciers allow to distinguish local reasons of glaciers' fluctuations from global. Fluctuations of observed glacier correlate well with fluctuations of other glaciers not only on the Caucasus, but in the other mountain chains as well, for example the Alps. It confirms that the reasons of oscillations have continental or even global nature. Created reconstructions can be used in modeling and making forecasts.

The next investigations in this discipline are necessary. Quantity of observed glaciers should be increased to be able to make more detailed conclusions about factors which provoke glaciers' fluctuations and to analyze glacier behavior more correctly. Also there is an idea of calculating volume changes from changes of glacier area and calculating area changes directly from repeated photographs.

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REFERENCES

Huss, M., R. Hock, A. Bauder, and M. Funk (2010), 100-year mass changes in the Swiss Alps linked to the Atlantic Multidecadal Oscillation, Geophysical research letters, 37, L10501, doi:10.1029/2010GL042616.

Innes, J. L. (1985), "Lichenometry.", Progress in Physical Geography, 9(2), 187–254.

Natural processes in Kabardino-Balkaria (2004), Russian Academy of Sciences, Moscow. (in Russian)

Seinova, I.B., E.A. Zolotarev (2001), Glaciers and debris flows in Prielbrusie (Evolution of glaciations and debris flow activity), “Scientific world”, Moscow. (in Russian)

Shiyatov, S.G., V.S. Mazepa, R.M. Hangemirov, V.M. Goryachev (2000), Results and perspectives of using dendrochronologycal method for dating of archeological, historical and ethnographic monuments in YANAO, Scientific bulletin. Archeology and ethnography, 3, Salehard, 49-56. (in Russian)

Zumbühl, H.J., D. Steiner, S.U Nussbaumer (2008), 19th century glacier representations and fluctuations in the central and western European Alps: An interdisciplinary approach, Global and Planetary Change, 60, 42–57.