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N. Isanov Kyrgyz State University of Construction, Transport and Architecture

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PROCEEDINGS OF THE SIXTH CENTRAL ASIA GIS CONFERENCE - GISCA'12

GEOINFORMATION FOR LAND AND RESOURCE MANAGEMENT

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Конференциясынын материалдар жыйнагы

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STUDYING THE OUTBURST OF THE MERZBACHER LAKE OF KYRGYZSTAN USING SATELLITE IMAGES AND FIELD DATA

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Abstract

The main objectives of this investigation is: find a relationship between temperature and the Merzbacher Lake outburst, lake development monitoring and estimation of the Inylchek Glacier movement and velocity. Initial data used in investigations was: Surface Temperature from MODIS 8 day Composite; field data; data from the Merzbacher1 automatic meteorology station; the dates of outburst of the Merzbacher Lake; aerial photo, topographic maps, satellite data: LANDSAT MSS, LANDSAT TM, LANDSAT ETM, ASTER, ALOS/AVNIR2, ALOS/PALSAR, ALOS/PRISM. This investigation was conducted within the framework of the project organized by Japan Aerospace Exploration Agency (JAXA) and Geoinformatics Center of the Asian Institute of Technology.

Introduction

The Inylchek Glacier is 60 km length, it formed by two glaciers - Northern and Southern Inylchek. Feature of this glacier is that earlier, both glaciers flow together and formed the Inylchek Glacier. Now the Northern Inylchek Glacier considerably degraded and has receded, as a result the Southern Inylchek Glacier has begun movement in it mouth, where the zone of its unloading in the form of constantly collapsing wall of ice in height to several tens meters was formed. This zone creates a barrier for a drain of thawed snow of Northern and Southern glaciers in the western direction on an extent more part of year, but basically during the winter period. These waters form the Merzbacher Lake, bounded with ice dam in a zone of unloading. Because of acceleration of movement of ice during the summer and autumn period and formations of cracks in a zone of unloading of the Southern Inylchek Glacier, occurs burst of water of the Merzbacher Lake on internal ice channels in a body of the of Inylchek Glacier with water flow up to 1000 m3/second, forming a catastrophic high water in the Inylchek River. This high water leads to destruction of bridges and other constructions on river bank in territory of Kyrgyzstan and can cause destruction of hydraulic engineering constructions in territory of China on the Aksu River which upper courses form the Inylchek and Sarydzhaz Rivers.

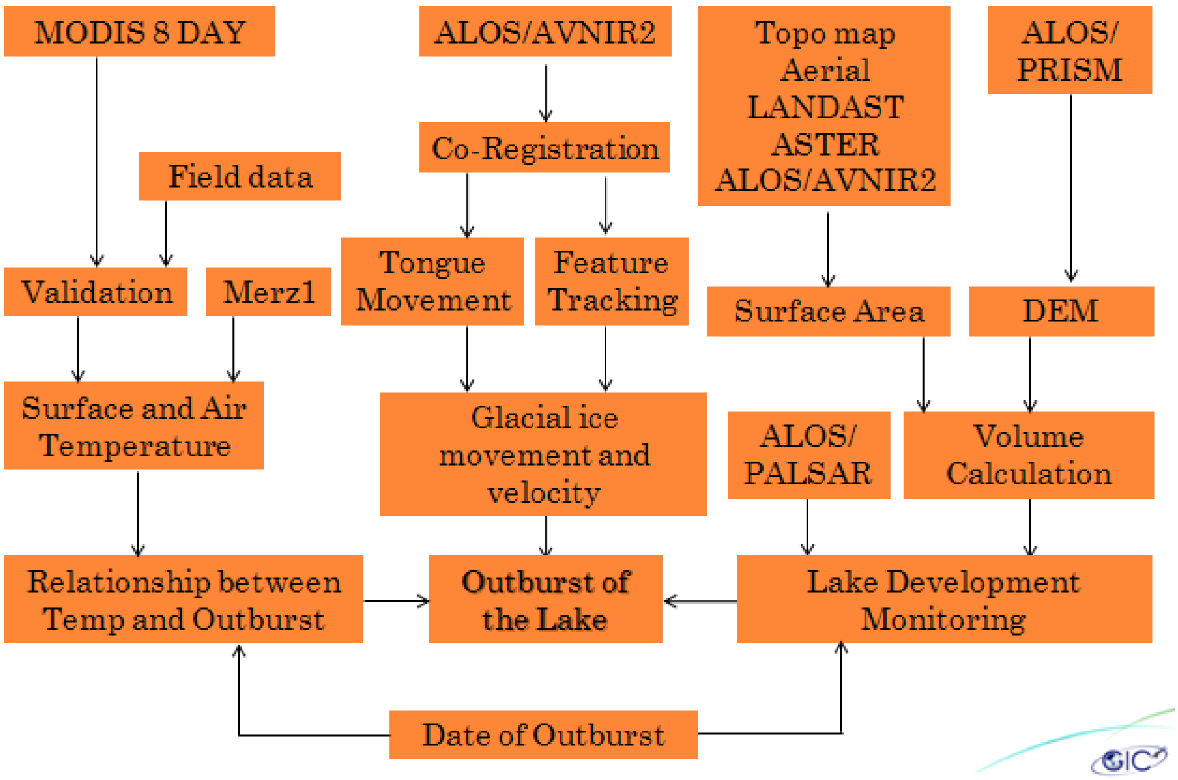
Problem Statement

There are not any forecasting models for outburst of the Merzbacher Lake now. Because the research area is located in a high-mountainous zone, it is difficult for research and consequently for its researching, remote methods have a great value.

Studying of the Inylchek Glacier is begun by the Central-Asian Institute of Applied Geosciences (CAIAG) together with German colleagues from the GeoForschungs Zentrum (GFZ) in Potsdam in 2004, in 2010 near the Merzbacher Lake the high-mountainous scientific station is constructed, where automatic meteorological stations, hydro-posts, seismic stations are established.During the same period measurements of the ice ablations, glacier sounding by an electromagnetic geo-radar, a method of electric sounding, gaugings geodetic GPS speeds of movement of a surface of icehave been made.

Now there is a necessity for the analysis of a development/change of the Merzbacher Lake on the basis of new satellite pictures and on this basis to specify a forecasting model of the lake outburst.

Methodology



Relationship between the temperature and the Lake Outburst

Initial data:

-Surface Temperature from MODIS 8 day Composite – MOD11A2.005 productover a period of 2000-2011;

-Field data for MODIS validation;

-Average daily data of the air temperature and accumulation of precipitation from the Merzbacher1 automatic meteorology station over a period of 2009-2010;

-The dates of outburst of the Merzbacher Lake over a period of 1902-2011.

The Surface Temperature from MODIS 8 day Composite on the inquire region was copied from the NASA FTP: ftp://e4ftl01u.ecs.nasa.gov/MOLT/ . Then, with the help of MODIS Re-projection Tool (MRT) software, this data was converted in the GeoTiff format with UTM, zone 43, WGS84 output projection. Further, with the help of ERDAS Imagine 8.4 software, was developed values of the 8 day CompositeSurface Temperature for two areas: lower – the Merzbacher Lake and upper – the Upper Lake. By this data, in Microsoft Excel software was developed the diagram of the surface temperature changes, and on this diagram the date of the Merzbacher Lake outburst was noted too (figure 1). This diagram show that the lake outburst occurs in the time of the temperature peaks, and always when the surface temperature upper than +10 ^{0}C, and more often when the temperature is about +15 ^{0}C.

In addition, one more uncertainty is obtain – too high absolute value of the minimal and maximal surface temperature. The probability of the temperature changes in the -20°C - +20 °C range is giving rise to doubt. To validate the MODIS data we decide the compare this data with the air temperature data from weather station located in this region. This approach provided good results.

Moreover, it is clear that if we remove the visible error measurements, we can receive more good results of validation.

One more investigation in this area was comparison data by air temperature and accumulation of the precipitation from the Merzbacher1 automatic meteorological station with outburst of the Merzbacher Lake. CAIAG and GFZ install this station on the Inylchek Glacier in 2009. The Merzbacher1 automatic meteorological station located on the right side of the Northern Inylchek Glacier between Upper and Lower Merzbacher Lakes. Unfortunately, the data from this station is limited by the period of: September, 2009 – August, 2010.

By this comparison we can see that outburst in 2010 was occur when the air temperature up to +10 °C, but same temperature was one month before outburst; the accumulation of precipitation in outburst up to 200 mm, but its disputable predictor for outburst forecast too (fig. 2).

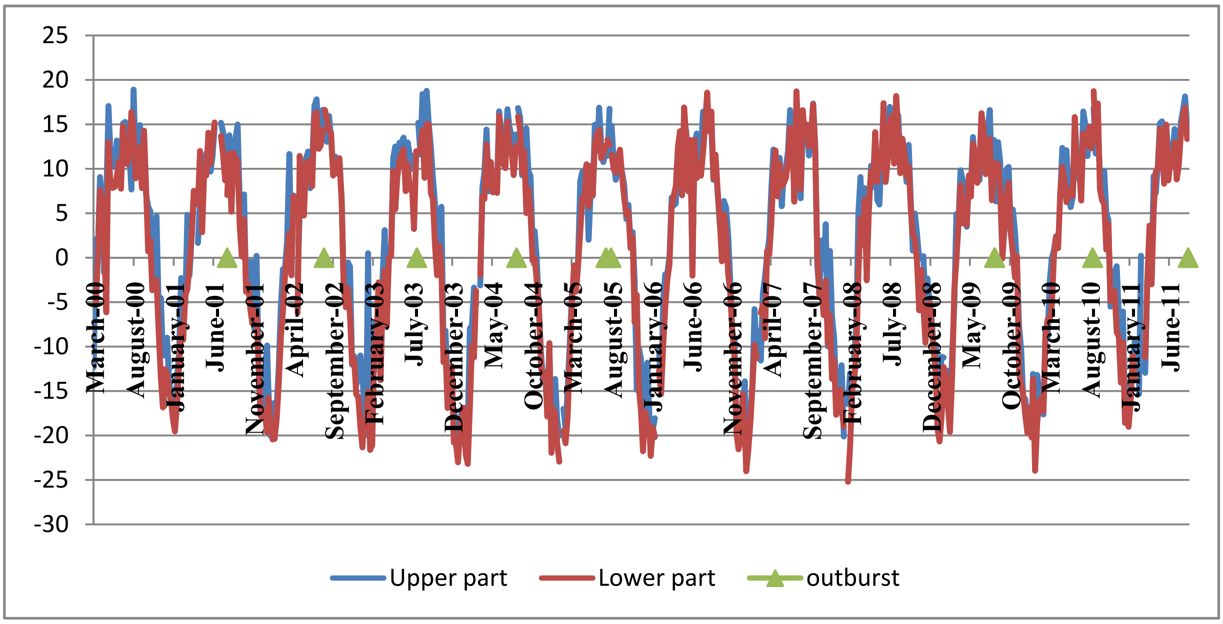


Figure 1.Surface Temperature from MODIS 8 day Composite for upper and lower parts of the Merzbacher Lake basin and the dates of the lake outburst.

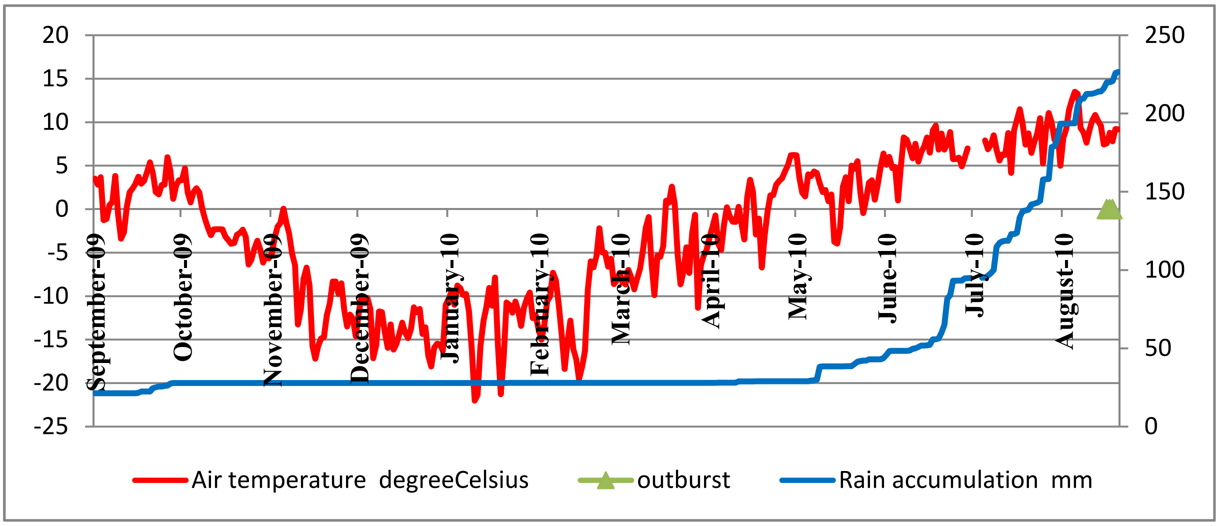


Figure 2. The data by the air temperature and accumulation of the precipitation by the automatic meteorological station and outburst date of the Merzbacher Lake in 2010.

Lake development monitoring

Area calculation

All data which used for calculation of the lake area was co-registered and the area of the lakes was calculated in GIS software. The results of calculation summarized in the table 1.

Table 1.The area of the Upper and Lower Lakes for the various periods of time

Source	Date	Area (Km²)		Source	Date	Area (Km²)	
		Upper Lake	*Lower Lake*			*Upper Lake*	*Lower Lake*
Aerial Photo	18.08.1943		3,253	*ALOS/AVNIR2*	23.08.2006		0,327
Landsat MSS	30.08.1975	2,323		*ALOS/AVNIR2*	08.10.2006		0,353
Landsat MSS	16.10.1976	2,295		*ALOS/AVNIR2*	24.09.2007		0,361
TOPO Map	1981	1,898	2,72	*ALOS/AVNIR2*	11.10.2007		0,391
Aerial Photo	20.07.1981	2,437		*ALOS/AVNIR2*	13.07.2008	3,05	0,493
Aerial Photo	29.07.1990	3,016	3,079	*ALOS/AVNIR2*	29.03.2009		0,349
Landsat TM	10.09.1990	3,777		*ALOS/AVNIR2*	15.04.2009		0,355
Landsat ETM	13.09.2000	0,289		*ALOS/AVNIR2*	16.10.2009		0,363
Aster	08.07.2002	0,347	2,241	*ALOS/AVNIR2*	14.02.2010		0,41
Aster	05.10.2002	0,346	0,63	*ALOS/AVNIR2*	02.07.2010	2,797	0,413
Aster	25.06.2003	0,336	1,906	*ALOS/AVNIR2*	19.10.2010		0,212
				ALOS/AVNIR2	21.04.2011		0,327

Volume calculation

First step in the calculation of the water volume in the Merzbacher Lake was DEM generation. This process was making in LPS 2011 module of the ERDAS IMAGINE 2011 software. We are used ALOS/PRISM data by the 2006 for this purpose. In this process we follow after "DEM generation from ALOS PRISM_ERDAS_LPSl.doc". This instruction was taking from lecture material in first phase of the JAXA Mini-Project. So, by the ERDAS IMAGINE 2011 software we extract the set of DEMs for visualizations and calculations processes.

For next calculation of the water volume we choice output type of DEM as 3D Shape file. This file was open in Global Mapper 8.02 software and then was converted to ASCII *.xyz format. And from this file in Global Mapper software was generated the contours of the relief. We check result data with the cartographic and literature data and fined good coincides with it.

Next step was the area calculation for the different levels of the water in the MapInfo Professional 7.8 software.

And then in the Microsoft Excel software we calculate the volume of the lakes for the different level of the water. The volume of the deeper layer (or first from the bottom) we calculate by truncated paraboloid equation:

$$\delta W_{0-1} = 2/3\ \omega_1\ \Delta Z_{0-1},$$

all another layers – by truncated pyramid equation:

$$\delta W_{1-2} = (\omega_1 + \omega_2)/2\Delta Z_{1-2};\ \ \delta W_{2-3} = (\omega_2 + \omega_3)/2\Delta Z_{2-3};\ \ldots$$

After processing of the volume calculation we develop the Bathymetric graphic and Volume curves of the Merzbacher Lakes.

Next step was the calculation of the area-volume dependency. This dependency has the practical application, if you can recognize the area of the Upper or Lower Lake from air or satellite imagine, you can calculate the volume of this lakes too. And through this dependency we calculate the volumes of the lakes on different periods of time (table 2).

One more activity in the frame of this work was the effort to DEM generation by the ALOS/PRISM data on 2010. The process for DEM extraction was the same with the first one. But in this case we faced with the unrecognized problem. Output DEM after pre-processing was the 300 m upper then the real relief. After all parameter requalification, generation the different DEMs (with control points and without it, in different formats etc.) the problem is remain.

After visual estimation of the forward, nadir and backward images we decide to remove forward image from the set to DEM generation, because a lot of space on this image is dark. Resulted DEM (by the two imagine) was on 40 m bellower the 2006 DEM. But the quality of this DEM was not perfect and we decide that this DEM can`t be used for forward processing.

Table 2. The area and volume of the Upper and Lower Lakes for the various periods of time

Source	**Date**	**Area (km^2)**		**Volume (km^3)**	
		Upper Lake	*Lower Lake*	*Upper Lake*	*Lower Lake*
Arieal Photo	18.08.1943		3,253		0,0667
Landsat MSS	30.08.1975	2,323		0,0350	
Landsat MSS	16.10.1976	2,295		0,0350	
TOPO Map	1981	1,898	2,72	0,0270	0,0546
Arieal Photo	20.07.1981	2,437		0,0377	
Arieal Photo	29.07.1990	3,016	3,079	0,0541	0,0607
Landsat TM	10.09.1990	3,777		0,0705	
Landsat ETM	13.09.2000	0,289		0,0019	
Aster	08.07.2002	0,347	2,241	0,0023	0,0415
Aster	05.10.2002	0,346	0,63	0,0023	0,0078
Aster	25.06.2003	0,336	1,906	0,0023	0,0336
ALOS/AVNIR2	23.08.2006		0,327		0,0031
ALOS/AVNIR2	08.10.2006		0,353		0,0035
ALOS/AVNIR2	24.09.2007		0,361		0,0039
ALOS/AVNIR2	11.10.2007		0,391		0,0043
ALOS/AVNIR2	13.07.2008	3,05	0,493	0,0541	0,0056
ALOS/AVNIR2	29.03.2009		0,349		0,0031
ALOS/AVNIR2	15.04.2009		0,355		0,0035
ALOS/AVNIR2	16.10.2009		0,363		0,0039
ALOS/AVNIR2	14.02.2010		0,41		0,0043
ALOS/AVNIR2	02.07.2010	2,797	0,413	0,0487	0,0043
ALOS/AVNIR2	19.10.2010		0,212		0,0017
ALOS/AVNIR2	21.04.2011		0,327		0,0031

Lake development monitoring

Nearest imaging to the outburst date is the aerial photograph 29.07.1990 (7 days before outburst) the area of the Upper and Lower Lake on this time was about 3 km^2 each (3,016 km^2 and 0,054 km^3 Upper and 3,079 km^2 and 0,061 km^3 Lower). But on the Landsat TM 10.09.1990 imaging (36 days before outburst) area of the Upper Lake is increased (3,777 km^2 and 0,071 km^3 respectively), and the Lower Lake is fully drained. So, it means that it was occur of the Lower Lake outburst only. In any case, we can suggest that the critical area of the Lower Lake before outburst is about 3 km^2 and 0,06 km^3 respectively. And as we can see, the Upper Lake is full, so for that lake the critical area and volume is about 3,8 km^2 and 0,07 km^3 respectively.

On the 18.08.1943 aerial photograph the Lower Lake increased to critical area - 3,253 km^2 and 0,067 km^3 respectively too, but the outburst by the literature data was occurs only in September 22 (35 days after). It can be occurring because of next situation: interglacial passages plugging and lower water accumulation in the lake because of the weather conditions.

Fact that the outbursts can occurs two times in year is confirmed such faster water accumulation in the lake. By the aerial photograph 20.07.1981 data, the Upper Lake is not reached to maximum area (2,437 km^2 and 0,038 km^3 respectively) after 8.07.1981 outburst (12 days after), and the Lower Lake is empty. But by the literature data, the next outburst date was occur in 8.08.1981 (19 days after). That fact one more indicates fast regeneration of these lakes in certain conditions.

In other case the conditions for the lakes regeneration not favorable: low air temperature, opened interglacial canals and so on. In this case the lakes regeneration can go on long time. We can see it by ASTER 2002 and 2003 imagines. On the 08.07.2002 image the Lower Lake has a half of critical area (2,241 km^2 and 0,042 km^3 respectively), the outburst occur only 23 days after. On the 5.10.2002 image the areas of the Upper and Lower Lakes is insignificant (0,346 km^2 and 0,002 km^3; 0,63 km^2 and 0,008 km^3 respectively), but this image was produced 65 days after outburst.

Unfortunately we recognize the weather limitation for same imagines. And one additional task in the frame of this study was the recognizing of the backscattering changes by the ALOS/PALSAR imagines. The objective of this task was examined possibility to detect the outburst date by the microwaves imagines (without weather or night limitation). This task was successfully implemented with pair of ALOS/PALSAR imagines. We recognize the approximately date of two outbursts: June 12 – July 28 2006 (fig. 3) and July 11 – July 28 2008.

Glacier ice movements and velocity

Co-registration

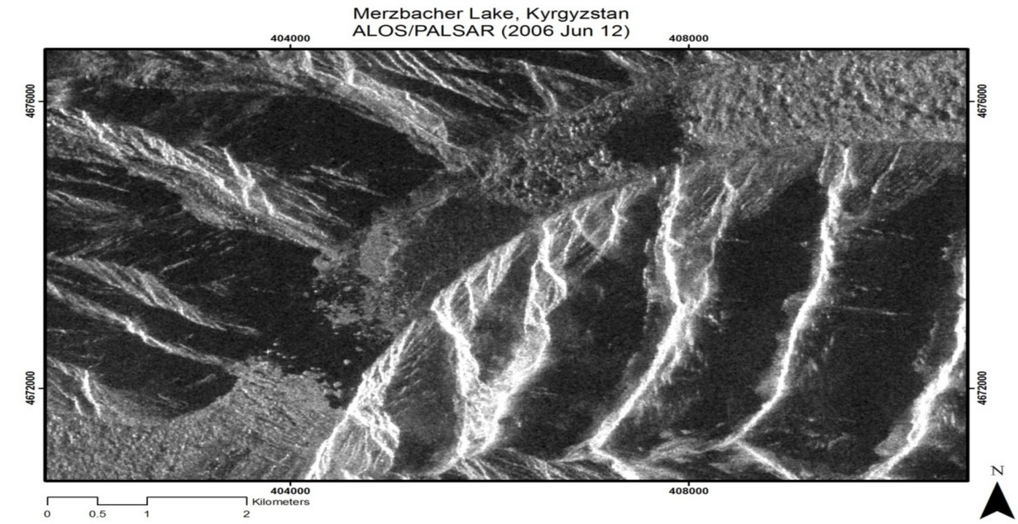
The initial data for this process was the satellite imagines from the optical sensors. For this purpose we choose the good quality imagines on 2006, 2008 and 2010.

First we co-registered this imagines. For that purpose we used 4 registration points on the corners of imagine and 1 in the middle.

Co-registration errors for each point not exceeding 2 pixels, for 10 m resolution of the imagines it`s mean 20 m on the ground for ALOS/AVNIR2.

Feature tracking

For detection of the Northern and Southern Inylchek movement by the feature tracking method we used the ALOS/AVNIR2 imagines on the August 23rd 2006, August 28th 2008 and August 17th 2010.



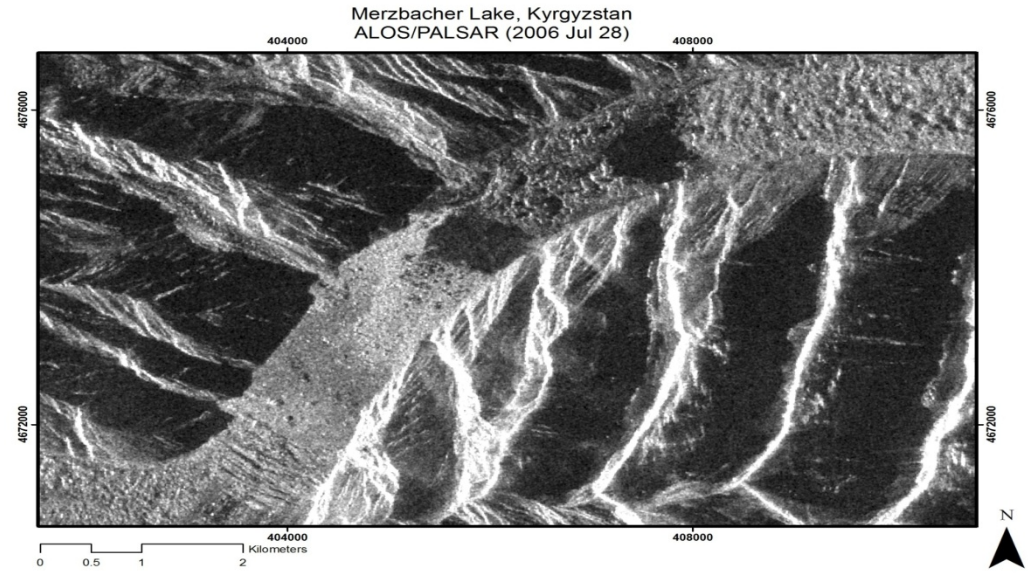


Figure 3. ALOS/PALSAR imagines before and after outburst

Then we are choosing number of features on the glaciers surface and noted it with point marker on each imagines. After that we connect these points with the arrow and thus can detect the length of the feature movement.

Similarly we detect the number of features and detect the glacier movement in different areas from 2006 to 2010, and calculate the velocity (fig. 4).

As we can see, the highest velocity for period of 2006-2010 obtained in the upper part of the Southern Inylchek glacier (about 0.30 m/d). Near the turn of the glacier, the velocity is decreased up to 0.21 m/d. After the glacier turned the velocity is very small (0.09 m/d) and on the glacier tongue it is inessential (in the range of the error of measurements).

We check that results with the previous study (Mayer, C. et. all, "Post-drainage ice dam…", 2008) and detect good conformity with that results.

The Northern Inylchek glacier is quite stable. The velocity on the explored part is inessential (in the range of the error of measurements) too.

Figure 4. Velocity of the glaciers surface

Conclusion and recommendations:

1. The comparison of the Surface Temperature from MODIS 8 day Composite with the Merzbacher Lake outburst is show that the lake outburst always occurs with temperature high than +10 ^{o}C, and more frequently when the surface temperature about 15 ^{o}C.
2. The validation of the MODIS data by the weather station provided good results.
3. For detection of the lake outburst with surface temperature, we need to take the water temperature data directly from the Merzbacher Lake. In the purpose of this, CAIAG has planned the installation of the water temperature sensors on the Merzbacher Lake in 2012.
4. ALOS/PRISM data provide to be a good source for the DEM generation in this study.
5. Developed bathymetric, volume and area-volume dependency curves have the practical application for father investigations.
6. The critical area of the Lower Lake before outburst is about 3 km^2 and0,06 km^3 respectively. And the critical area of the Upper Lake before outburst is about 3,8 km^2 and 0,07 km^3 respectively.
7. There is a very faster regeneration of the lakes by certain condition.
8. This is a dependence of the water accumulation in the lakes on the weather conditions and conditions of the passing canals.
9. The date of the lake outburst can be clearly detected by the microwaves imagines.
10. The highest velocity for period of 2006-2010 obtained in the upper part of the Southern Inylchek glacier was about 0.30 m/d. Near the turn of the glacier, the velocity is decreased up to 0.21 m/d. After the glacier turned the velocity is very less (0.09 m/d).

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