United Nations /Austria Symposium on Integrated Space Technology Applications for Climate Change

Applications of the integrated remote sensing technologies to monitor the state of glaciers

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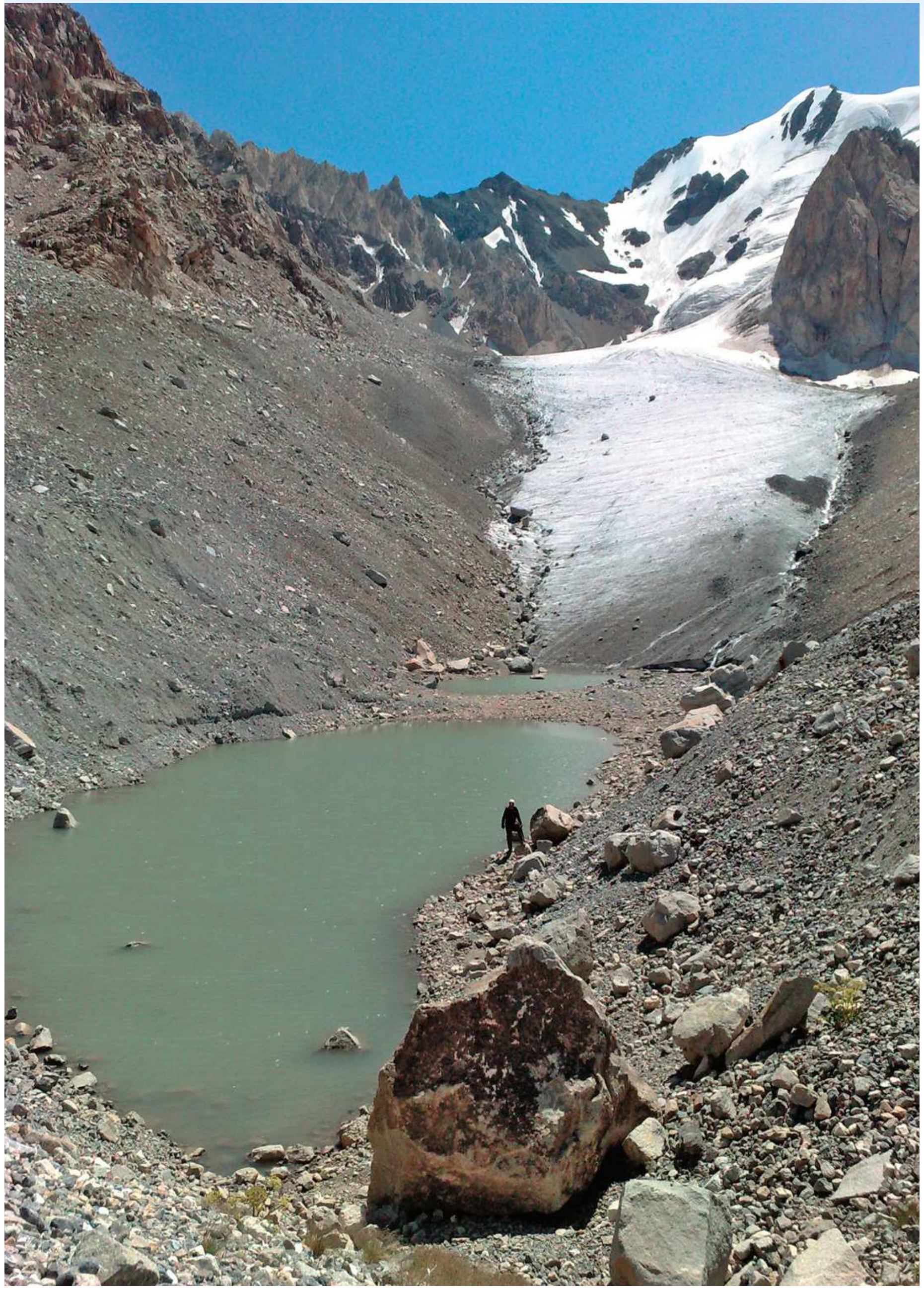
Introduction, Significance, Background



In conditions of arid climate and irrigated cropping of Uzbekistan, the **water resources** are of great importance for the country.

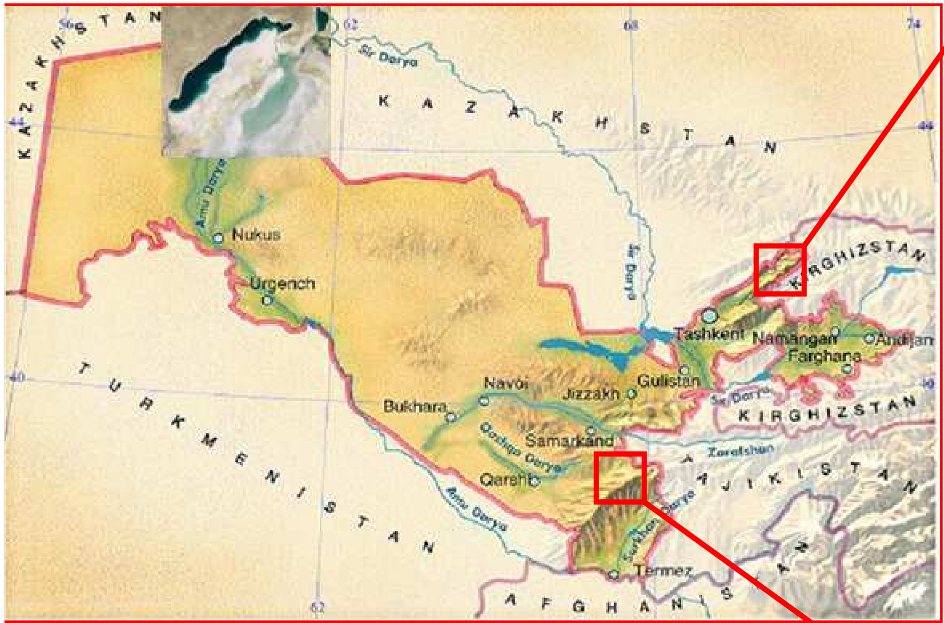
Mountain glaciers are the accumulator of a fresh water and play the role of a **regulator** of annual flow.

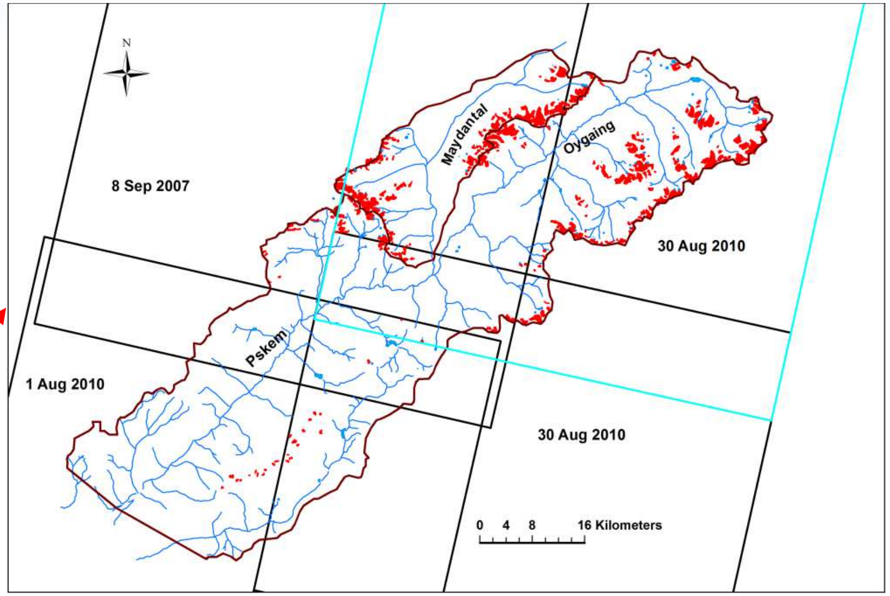
An assessment of the **state of glaciers** is also necessary to assess the **climate change** and the threat of **dangerous glacial phenomena**.

Because of the hard-to-reach mountain area, the synchronous **monitoring of all glaciers** is possible only by means of **remote sensing technologies**.

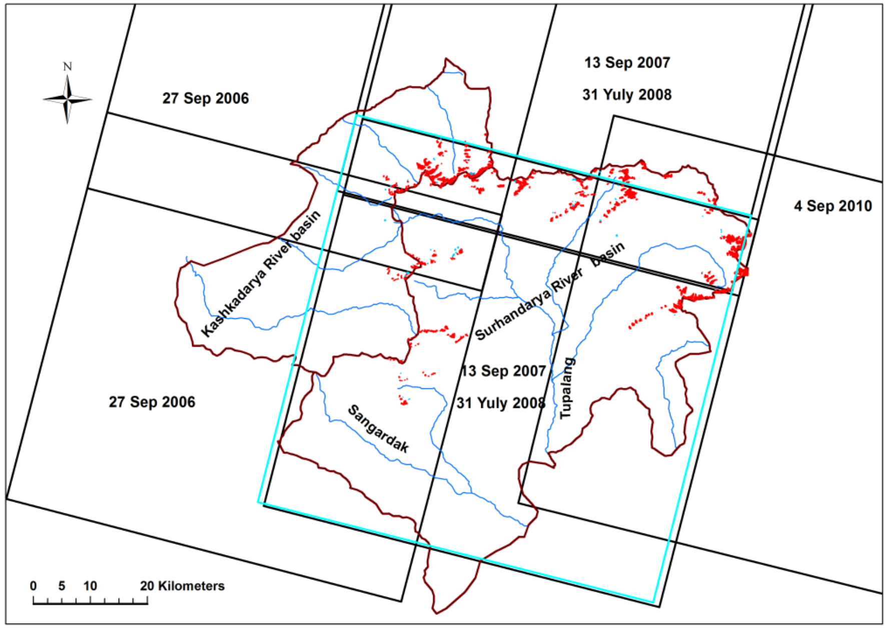
Study area

The Pskem River basin
(Western Tien-Shan mountain system)





Covering by ALOS/AVNIR-2 data



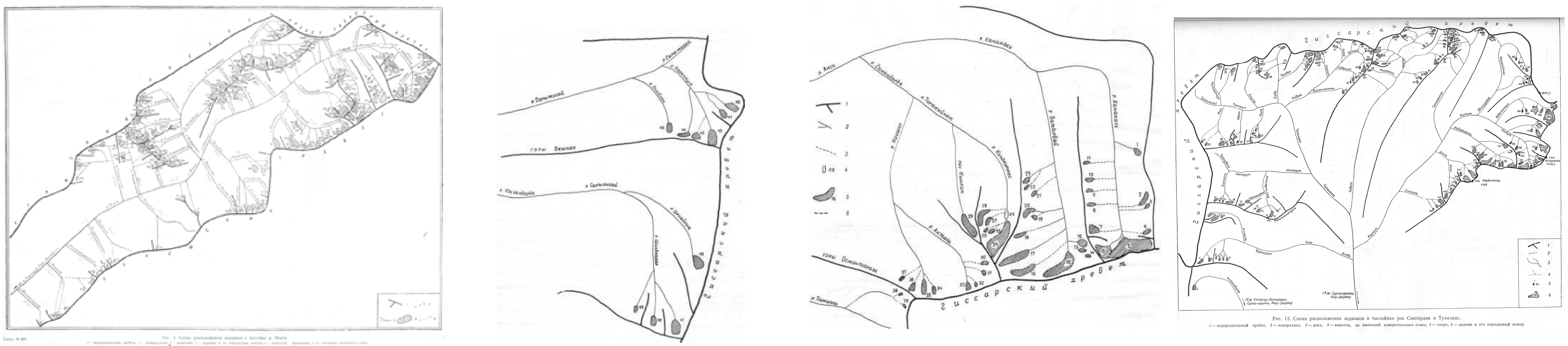
The Kashkadarya and Surhandarya River Basins (Hissar-Alay mountain system)

The elevation is up to 4630 m.
The climate is continental.

Objectives and Data used

- **ALOS Satellite images (2006-2010)**
  - **AVNIR-2 -** Identification of the glaciers and mountain naturally dammed lakes; Assessment of their area and number;
  - **PALSAR -** Identification of the firn line (equilibrium line) on the glaciers;
- **LANDSAT** images (1977, 2000, 2002, 2011, 2013, 2015) - Comparative evaluation;
- **DEM** (SRTM, ASTER, TerraSAR-X/TanDEM-X) - Estimation of the glacier elevation change;
- **ICESat** altimetry data (2003-2009) - Co-registration of satellite elevation data sets; glacier surface lowering rate calculation;
- **Topographic maps** (1:200 000, 1:100 000 scale) – Vector data: boundary of study area, rivers;
- **Inventory of glaciers of the former USSR:**
  - 1957-1960
  - 1978-1980

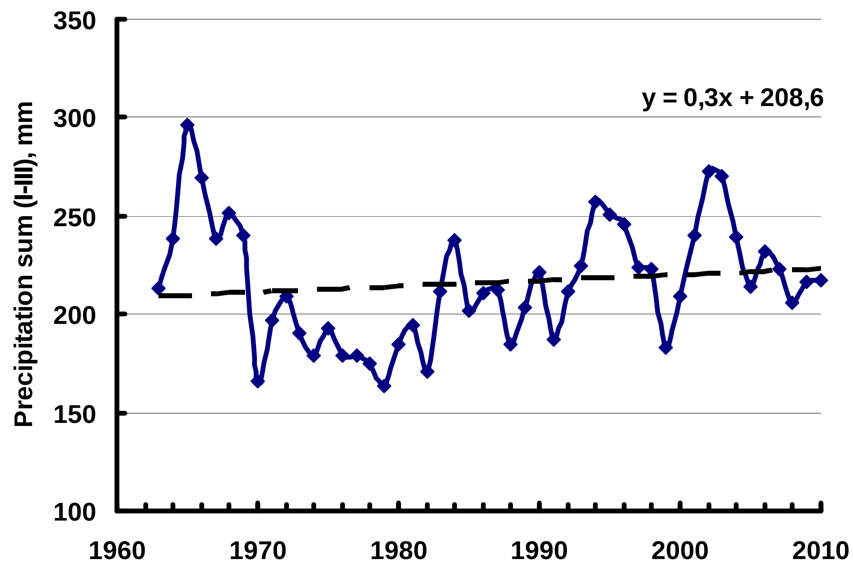
Scanned schemes of location the glaciers from the “Catalogue of Glaciers” for 1960s

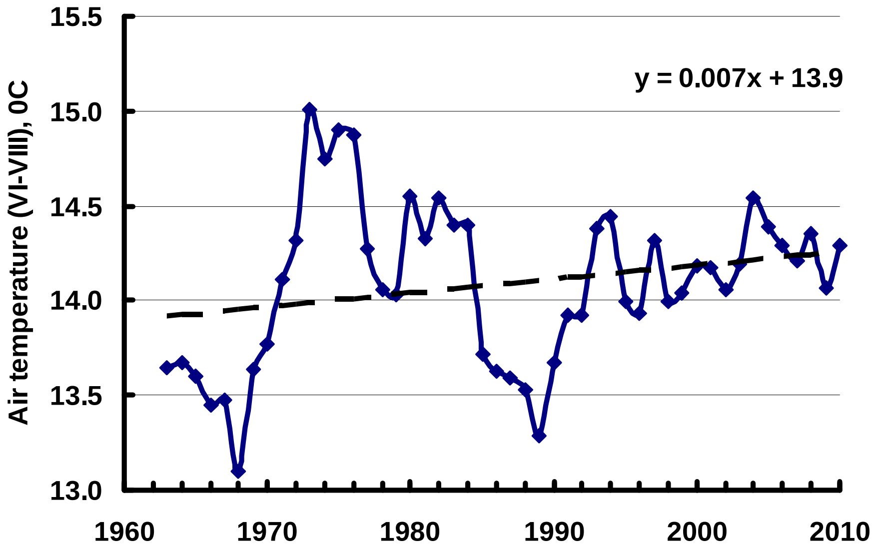


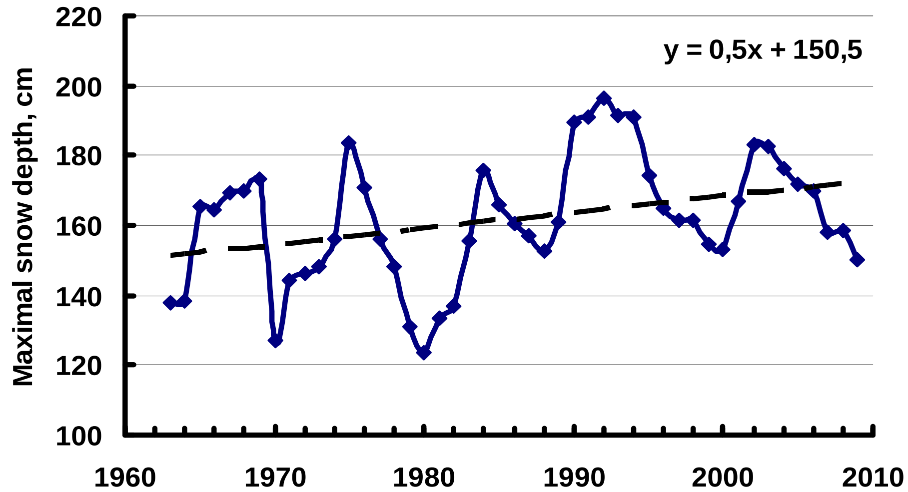
Climate conditions in the site of Oygaing MS (Z=2,15 km), in the Pskem River basin

The moving averages over the 5-years for:

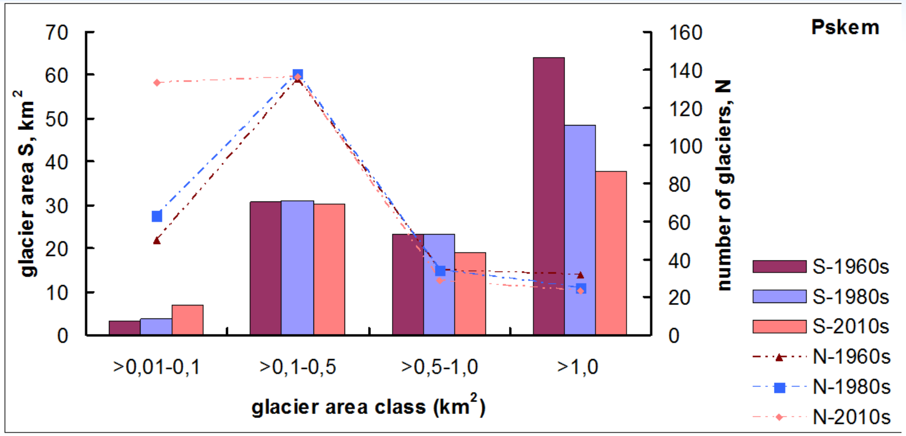
- **winter precipitation sum from January to March;**
- **average summer air temperature from June to August;**
- **maximal snow depth for the winter season.**

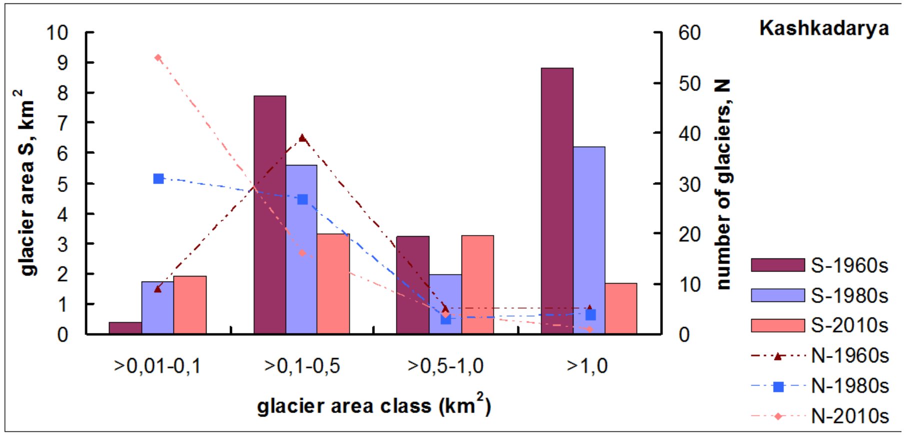


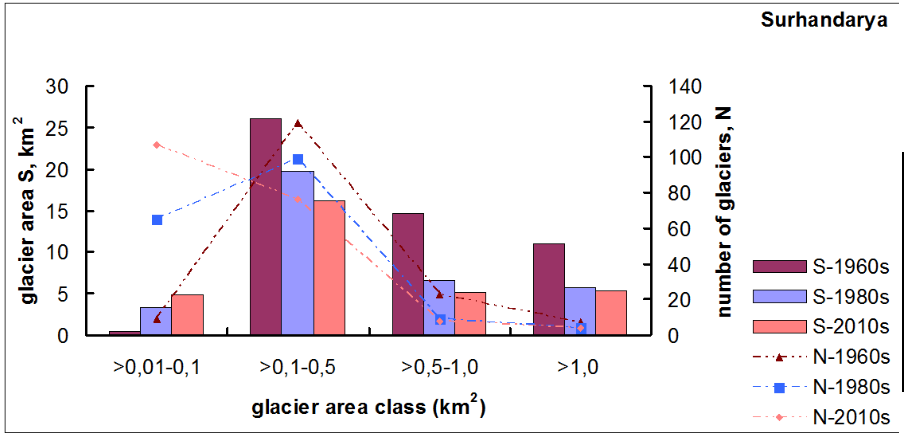




Area and number of glaciers in size classes for different periods







For the modern period:

Pskem (Oygaing+Maydantal) = 93,6 km^2 / 320
Kashkadarya = 10,3 km^2 / 75;
Surhandarya(Sangardak+Tupalang) = 31,5 km^2/202

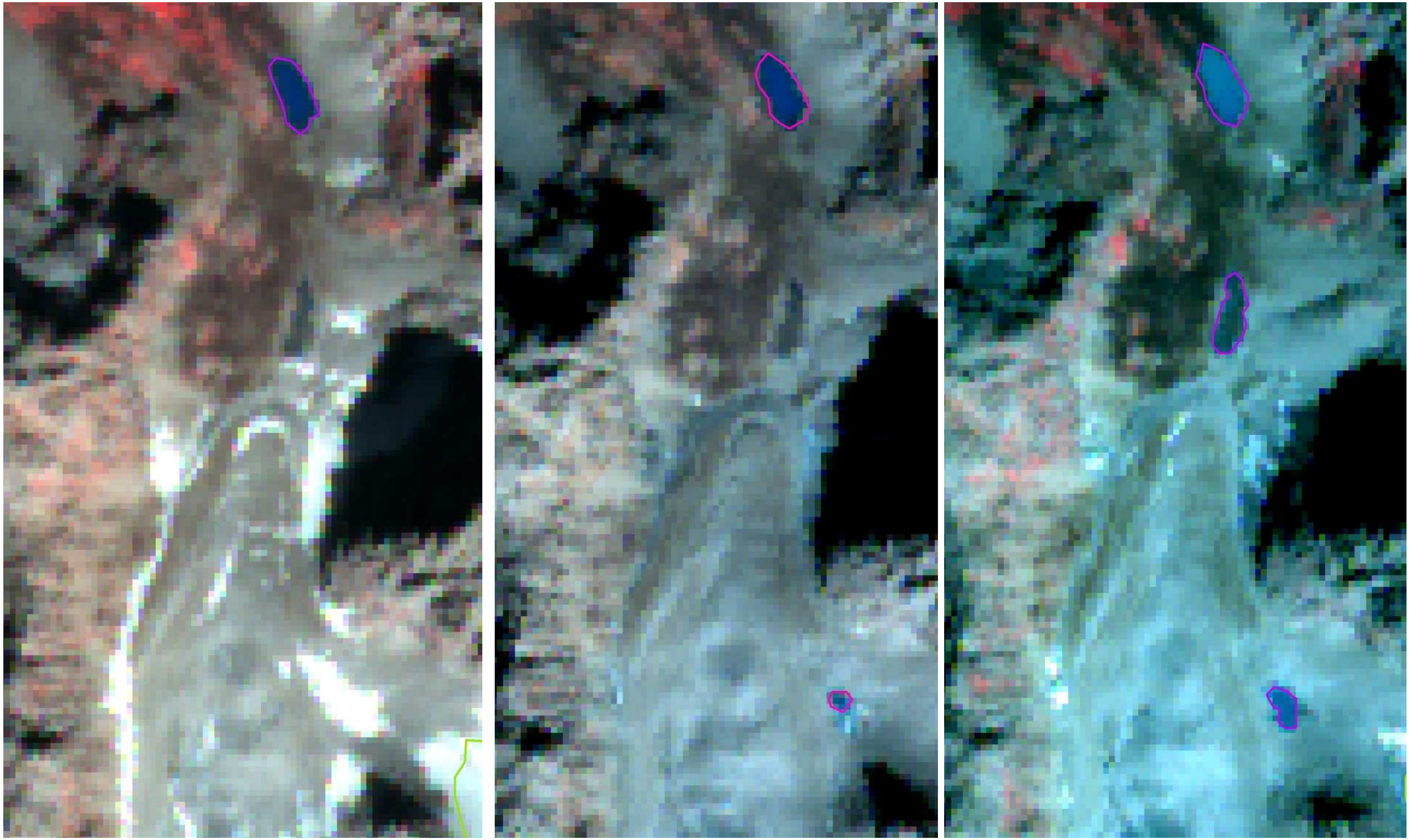
Change for 50 years: in area / in number
Pskem: - 23% / 28%
Kashkadarya: - 49% / 29%
Surhandarya: - 40% / 28%

River basin	**Rate of retreat,** % / year	
	1960-1980	1980-2010
Pskem	0,62	0,39
Kashkadarya	1,18	1,12
Surhandarya	1,61	0,36

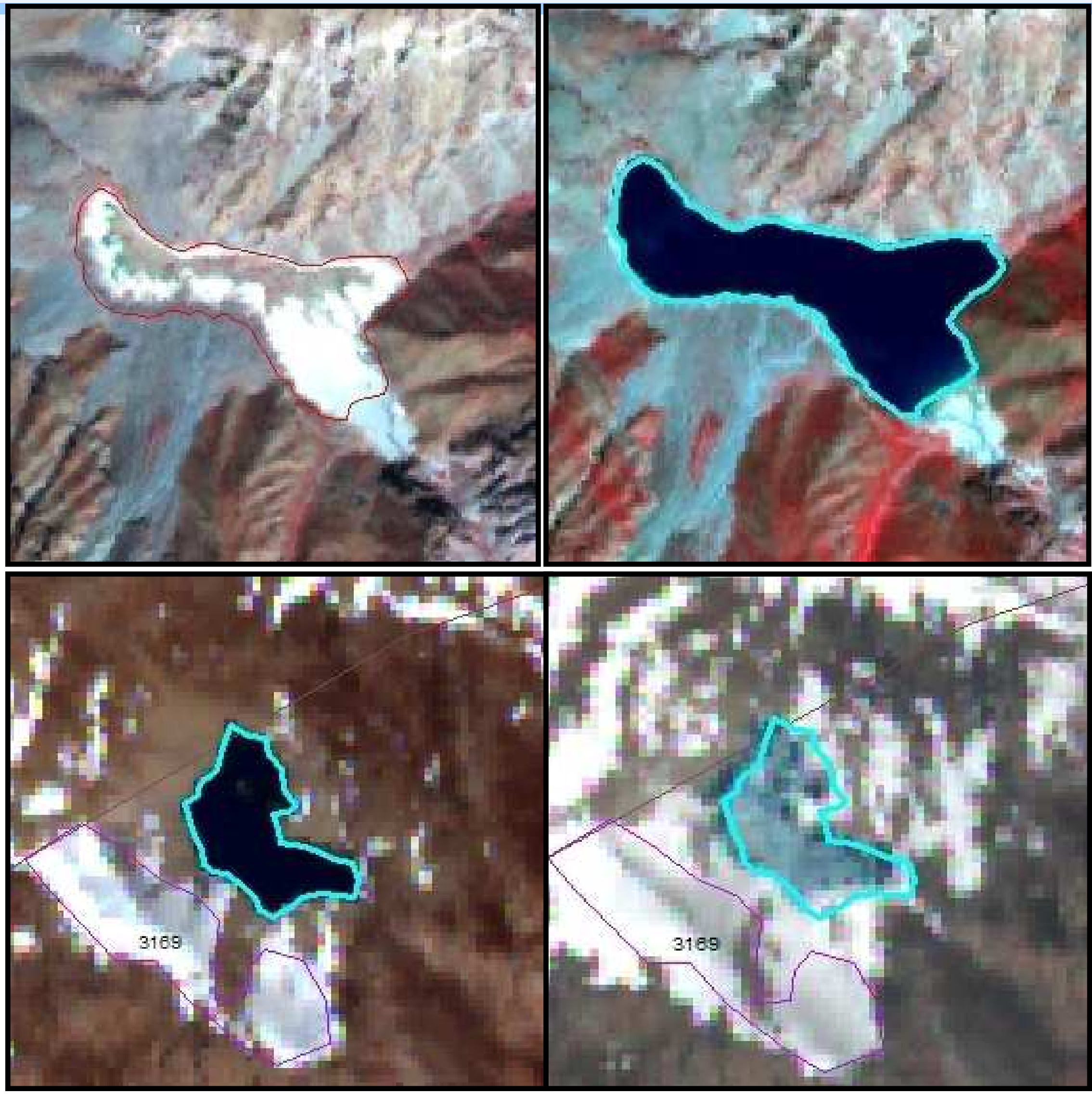
Comparison in climate conditions for Hissar- Alay and Western Tien-Shan mountains (1970-2010)

MS	Z, km	t daily	t min	t max	X an
Minchukur	2,12	8	6,3	9,2	655,6
Oygaing	2,15	2,7	0,9	4,7	726,6

Examples of the development and expansion of glacial lakes



Dynamics of some lakes

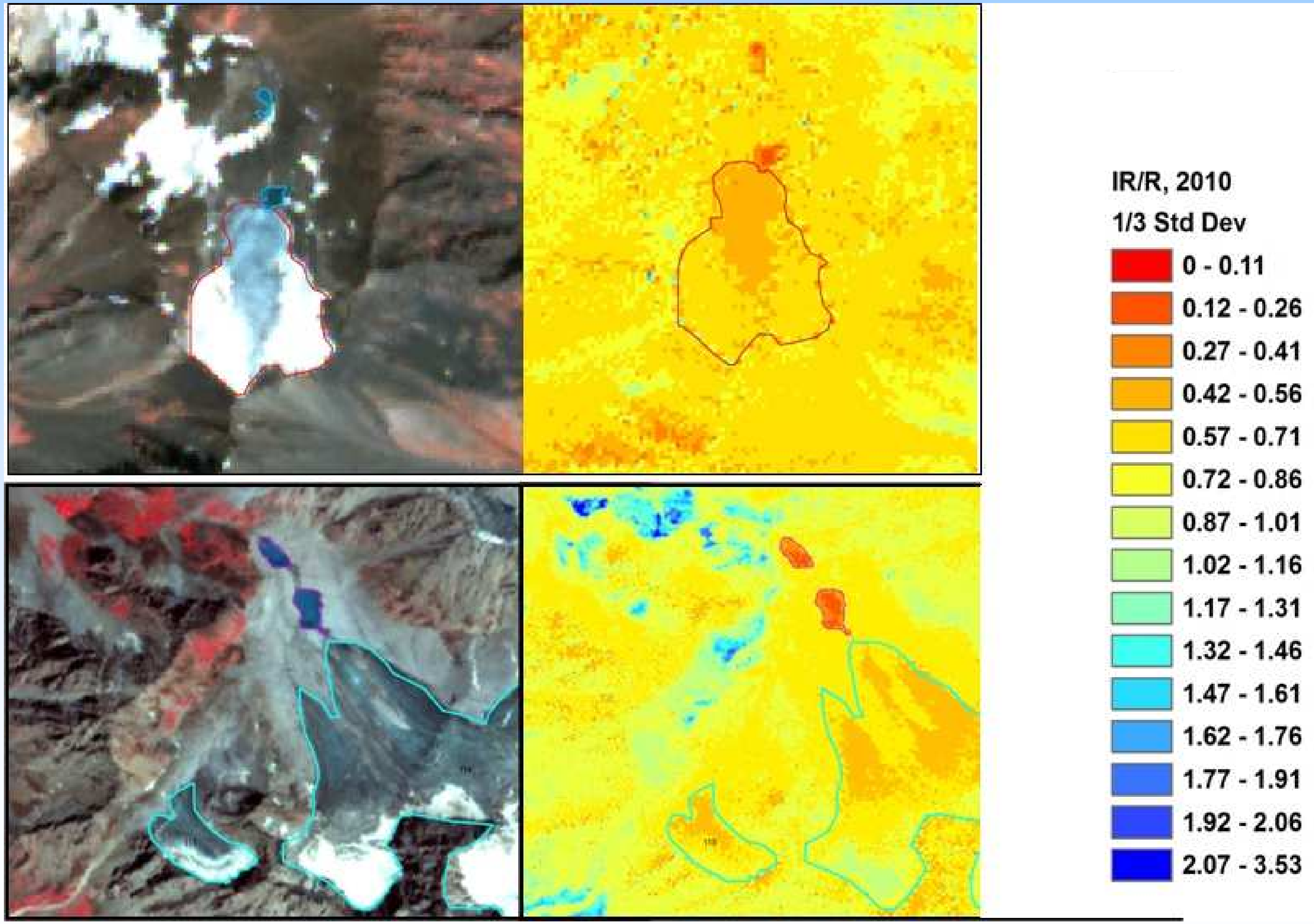


Rock-dammed lakes

Moraine-dammed lakes

08.09.2007 30.08.2010

The automatically identification of the mountain naturally dammed lakes using ALOS/AVNIR-2 data



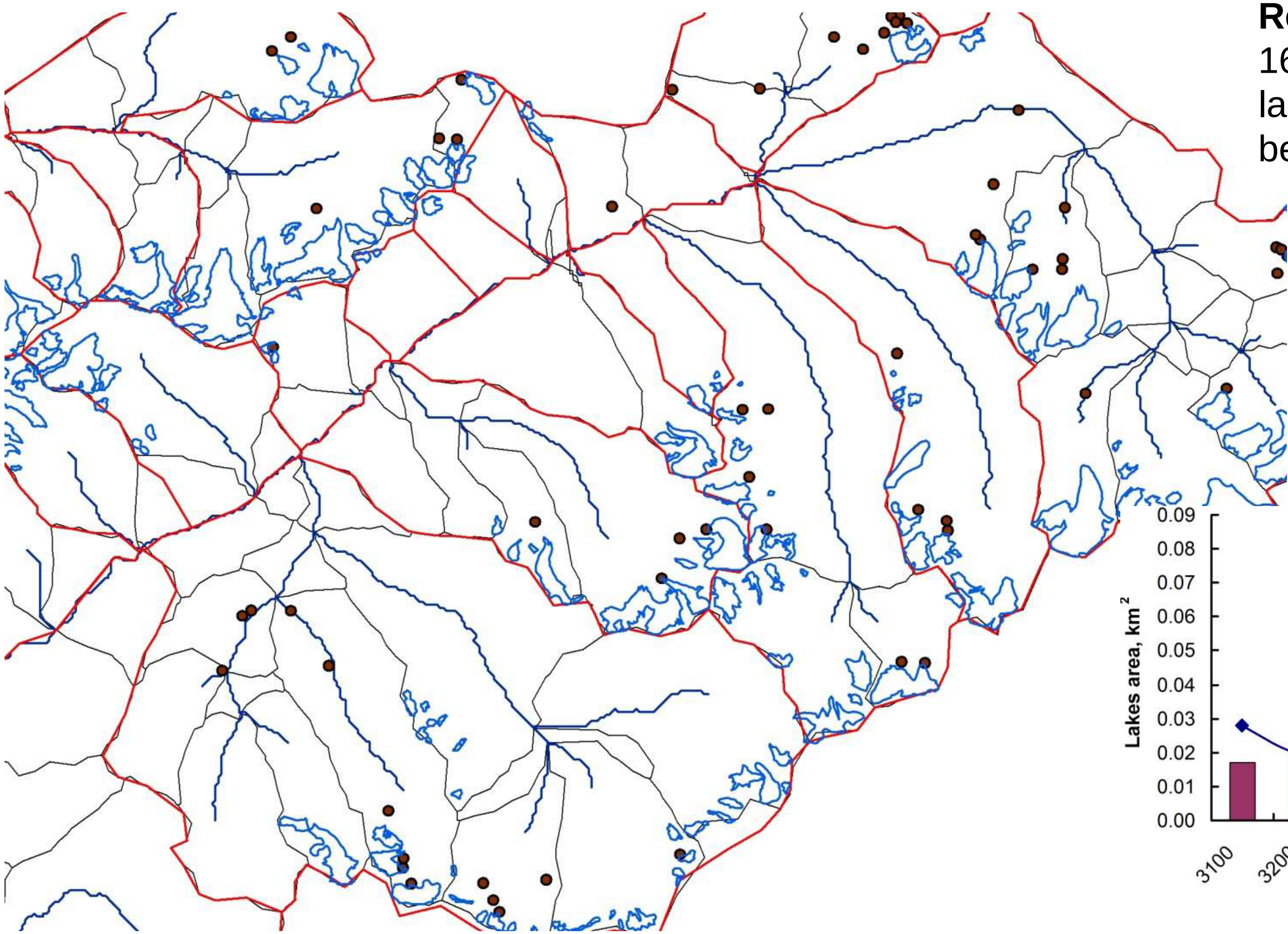
$\frac{N(glac)}{N(lakes)} = 0.17$ - for the Kashkadarya and Surhandarya River basins, 0.23 – for the Pskem.

The application of the probabilistic model of moraine-dammed lake formation due to glacier recession (G. Glazirin, 2009)

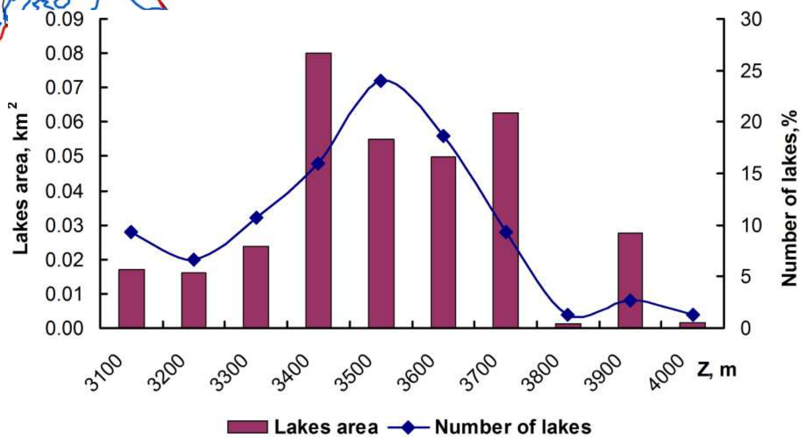
$$Plk = 9.063 \cdot Inab - 0.0478 \cdot \Delta Fm + 21.83 \cdot Inb - 4.199,$$
$$Pfr = 16.22 \cdot Inab - 0.1495 \cdot \Delta Fm + 31.49 \cdot Inb - 8.703.$$

If Plk > Pfr, then the presence of the lakes in this valley is possible

Inab – mean slope of ablation zone in the glaciers
Inb – mean slope of the valley
ΔFm – change in the glaciers area in the valley

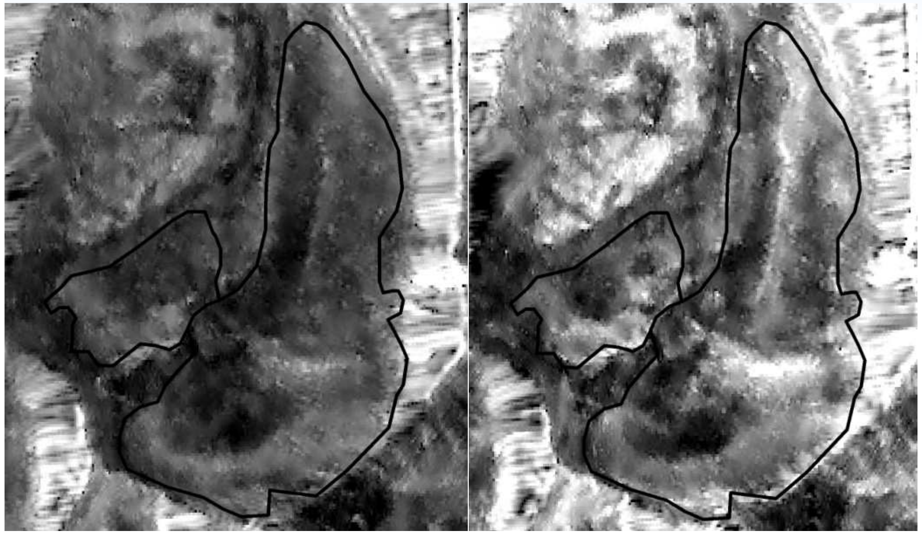


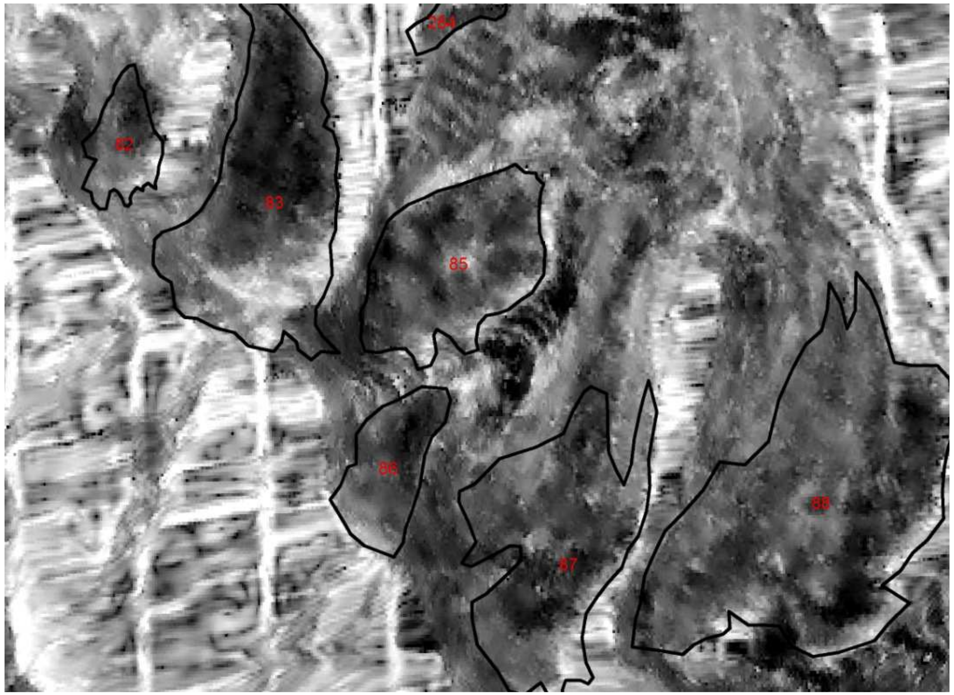
Results:
16% of the cases when there are no lakes in these images, but they can be occurred on other dates images



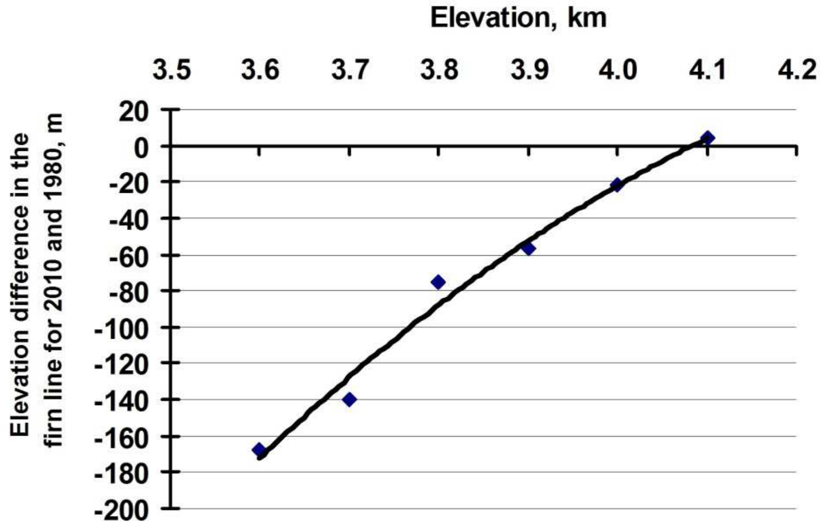
Identification of the firn line in the glaciers using ALOS/PALSAR data

HH-polarization **HV-polarization**

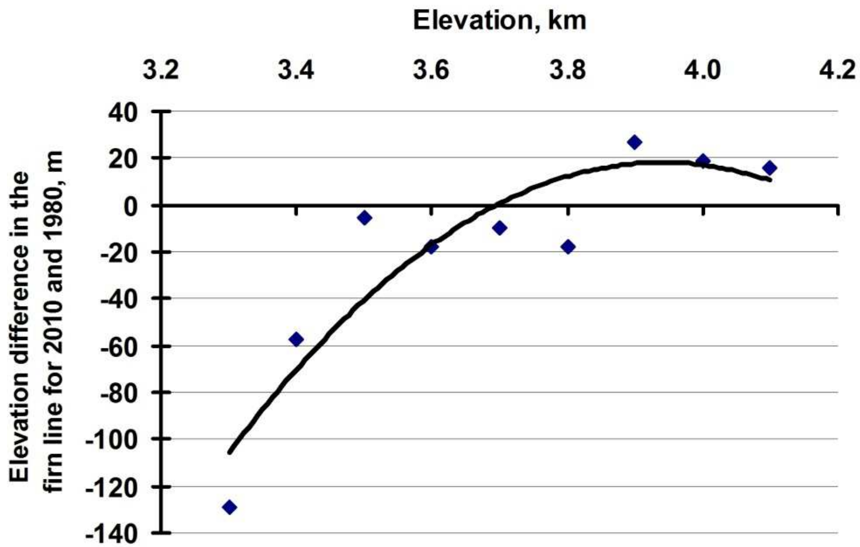




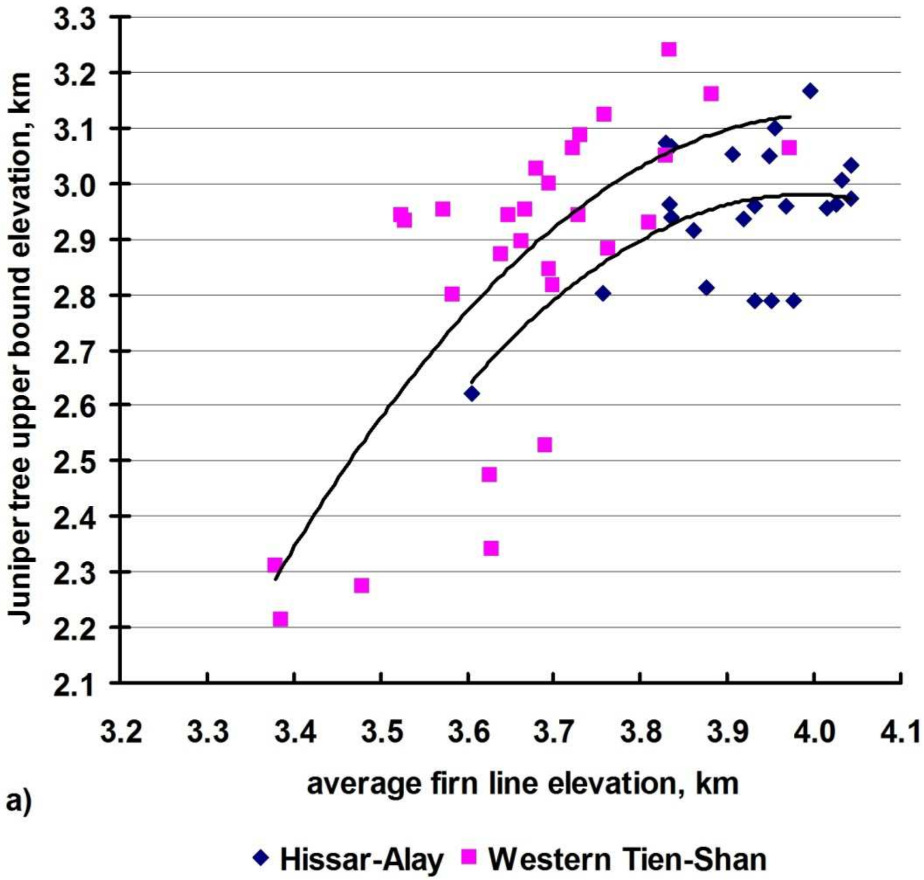
Surhandarya River basin

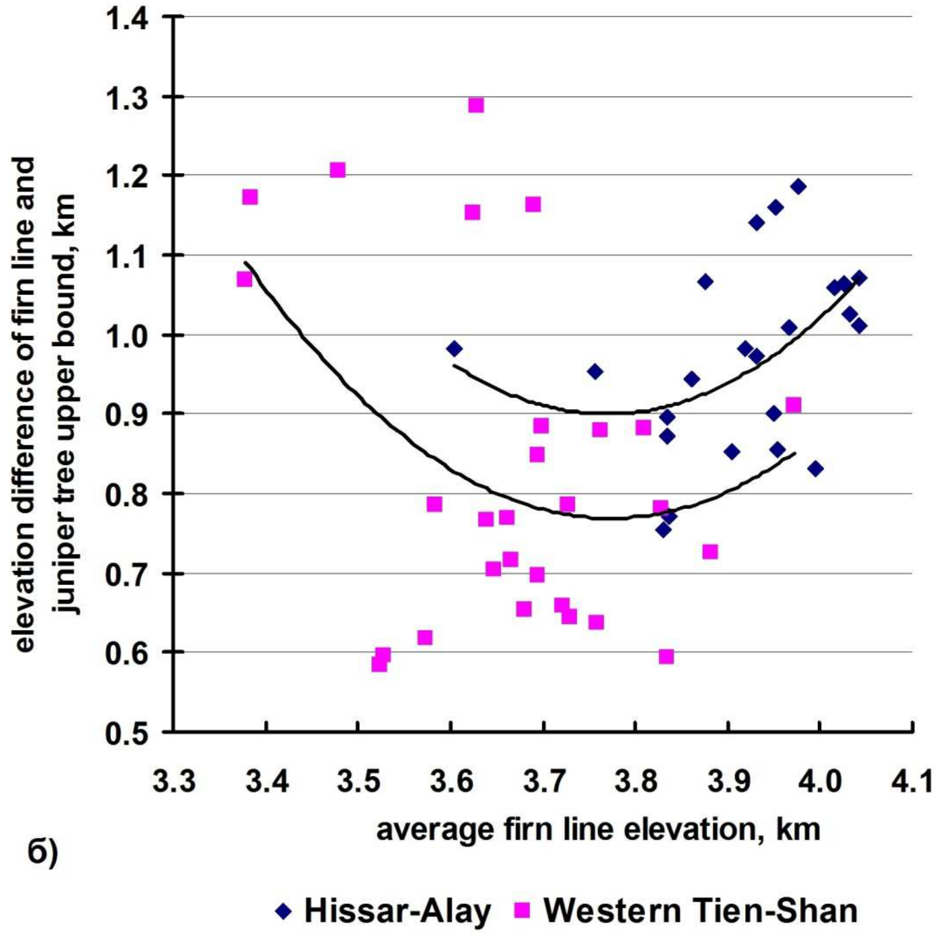


Pskem River basin

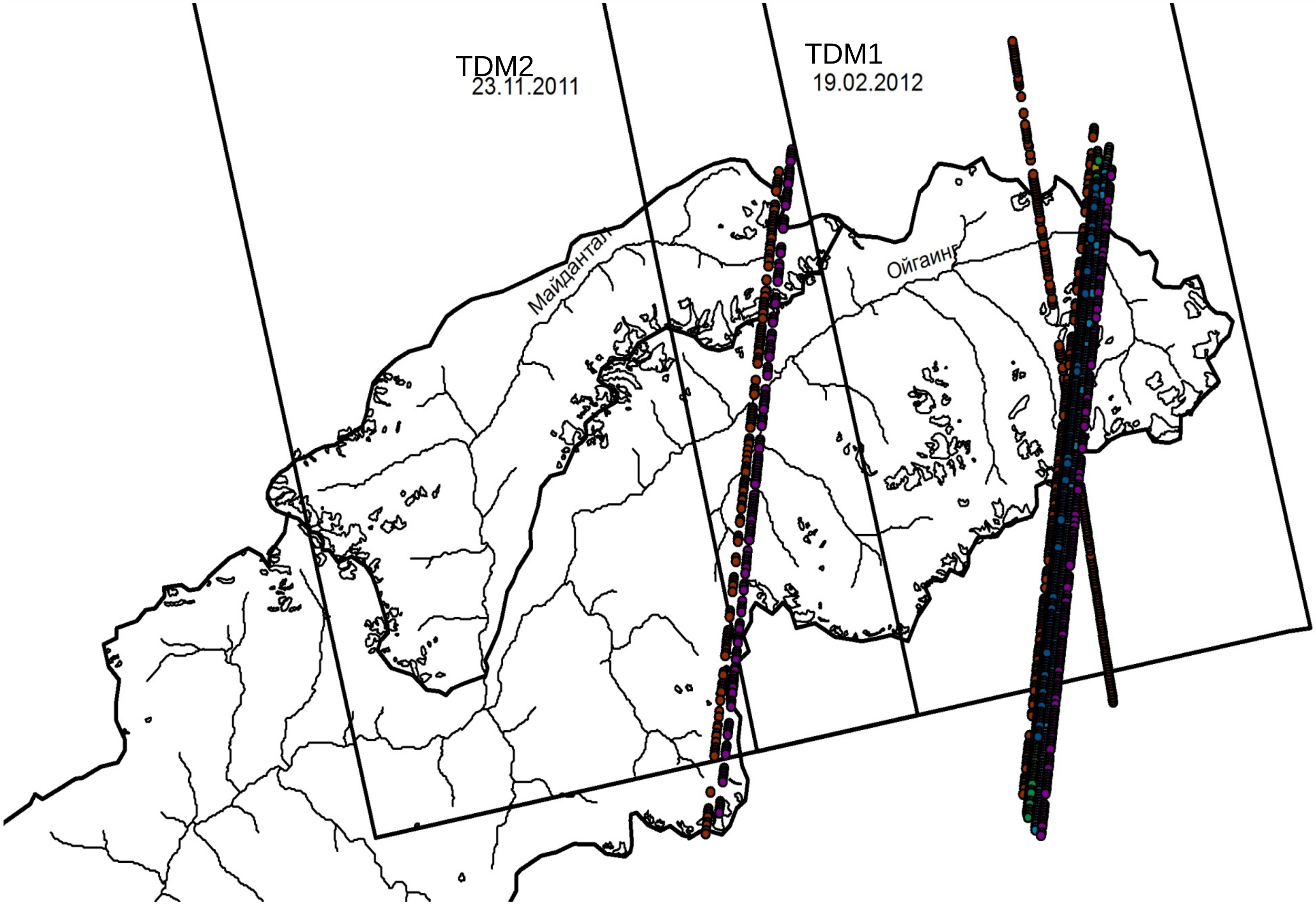


Relationships between the juniper tree upper bound elevation and the average firn line elevation

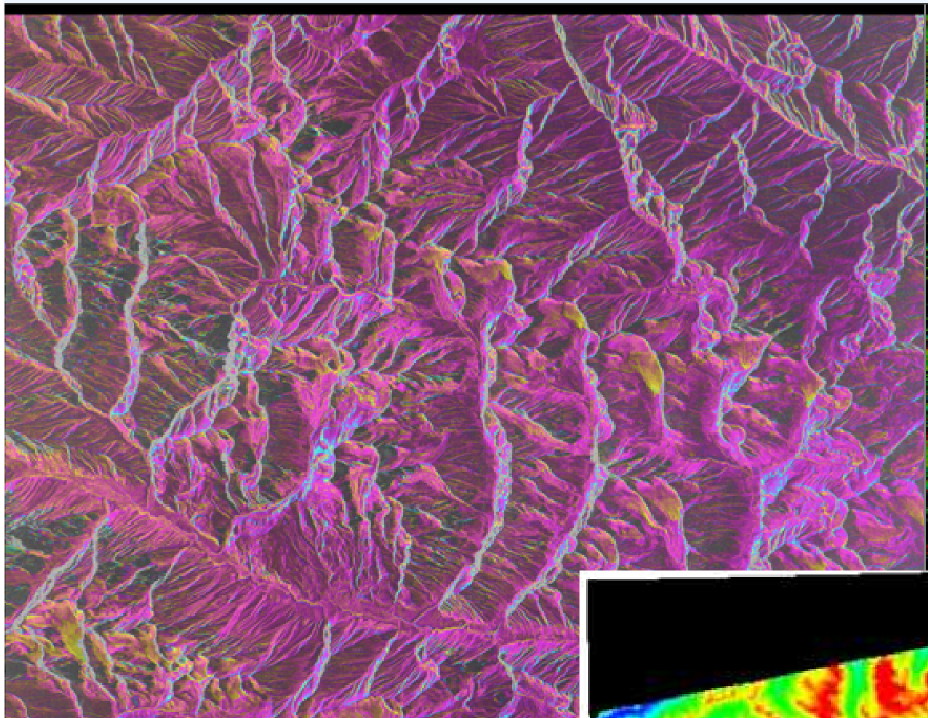


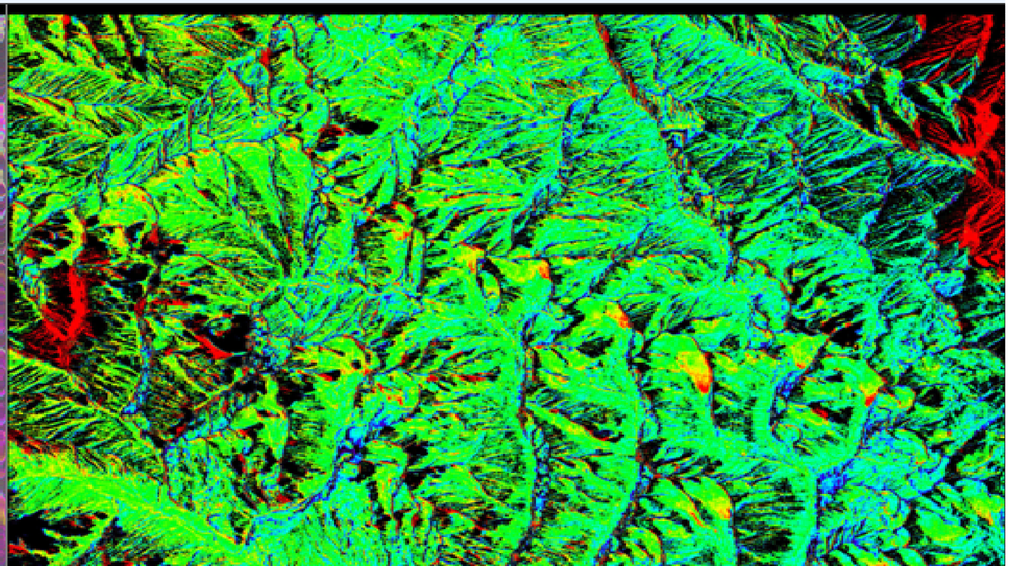


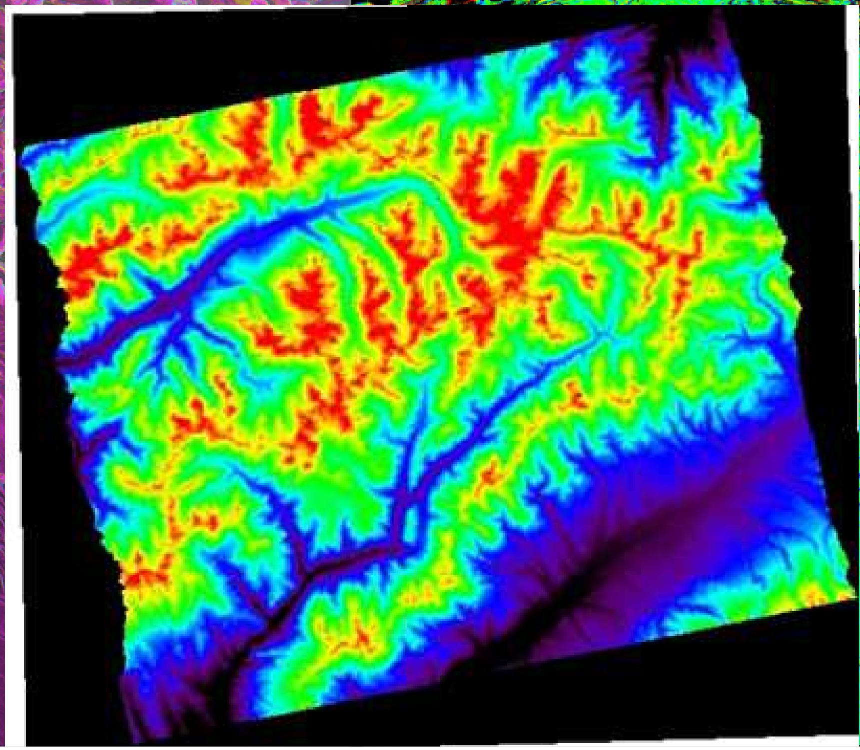
Covering of the Pskem River basin by ICESat profiles (2003-2009) and TerraSAR-X / TanDEM-X data

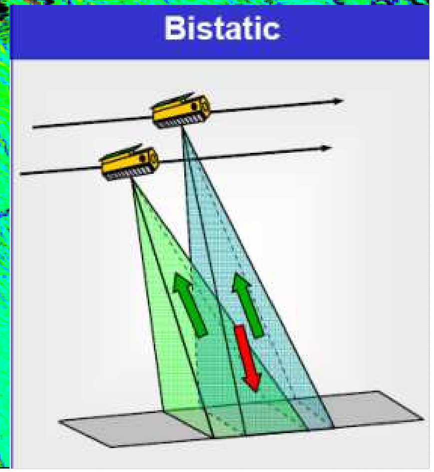


Generation of the Digital Elevation Model from TerraSAR-X / TanDEM-X interferometric radar data





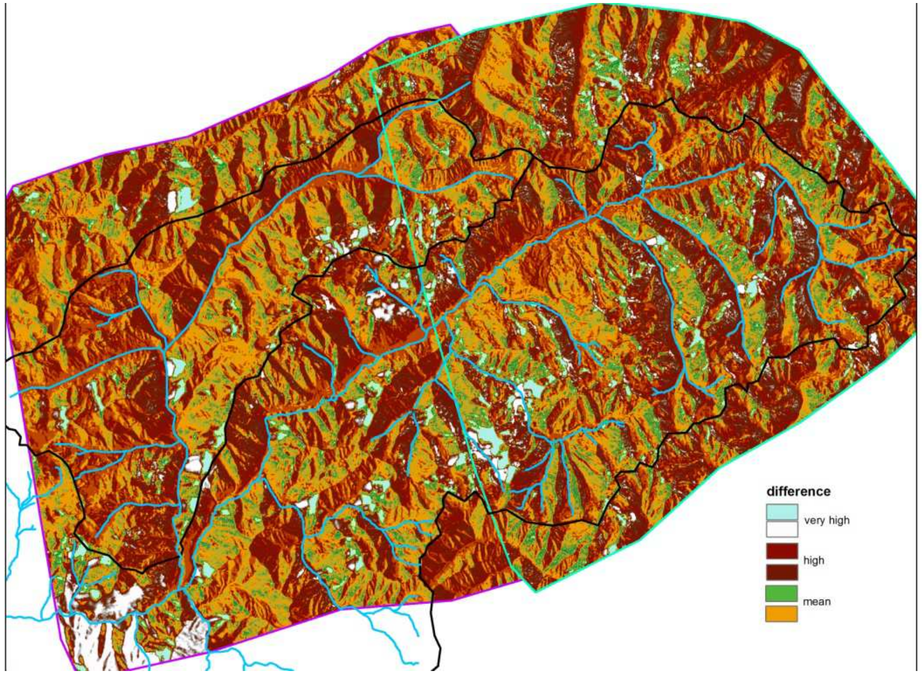


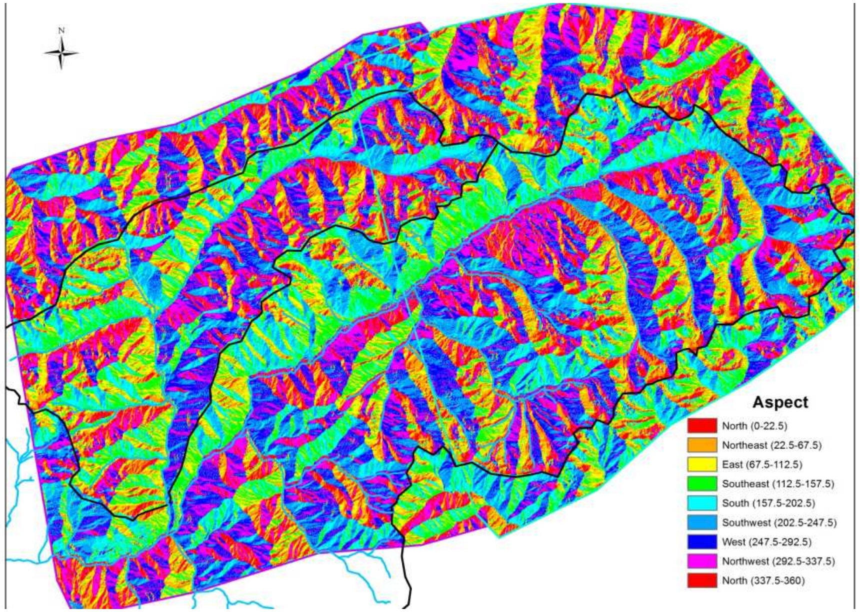


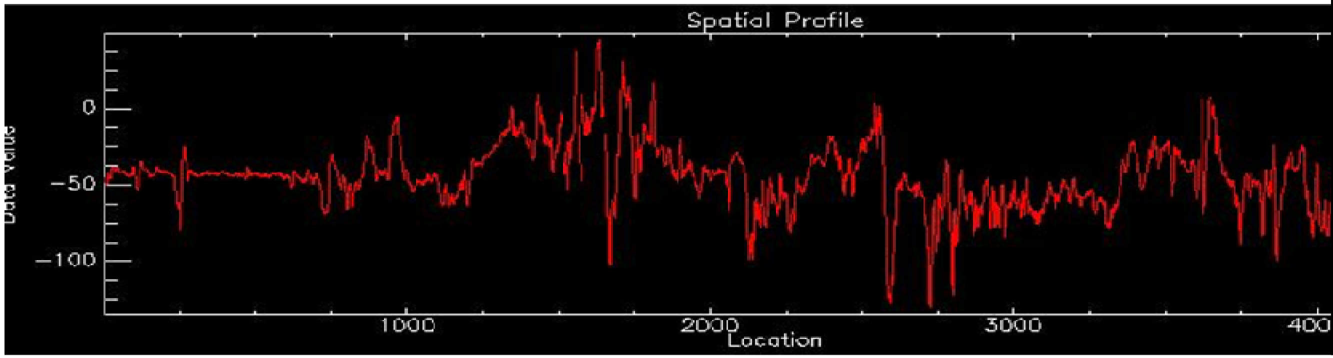
The process flow chart

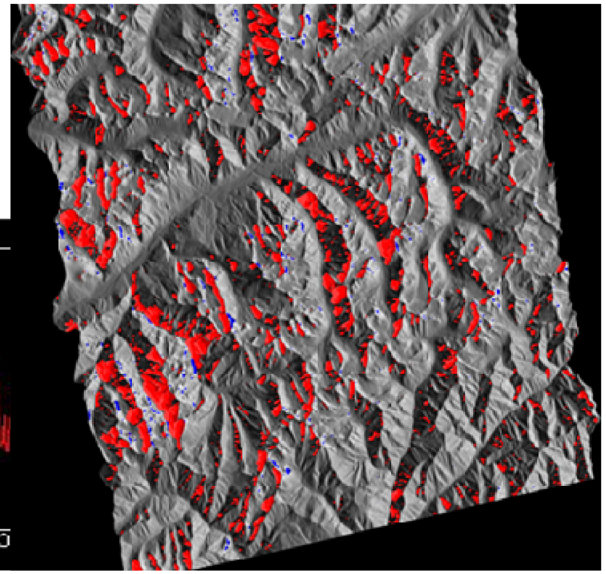
- CoSSC Data
- Interferogram Generation
- Interferogram
- Flattening
- Adaptive Filtering
- Coherence Generation
- Phase Unwrapping
- Phase to Height Conversion
- Geocoding

Analysis of the DEMs differencing (TanDEM-X и SRTM) and Aspect

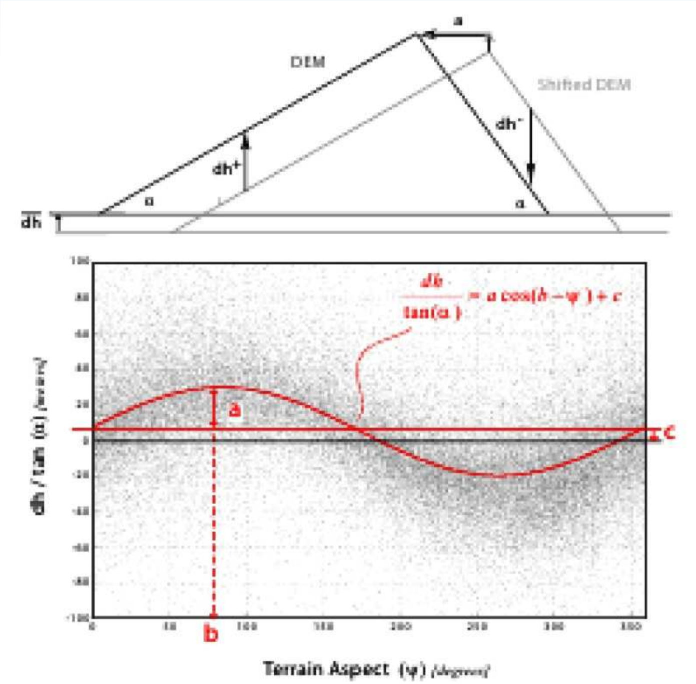


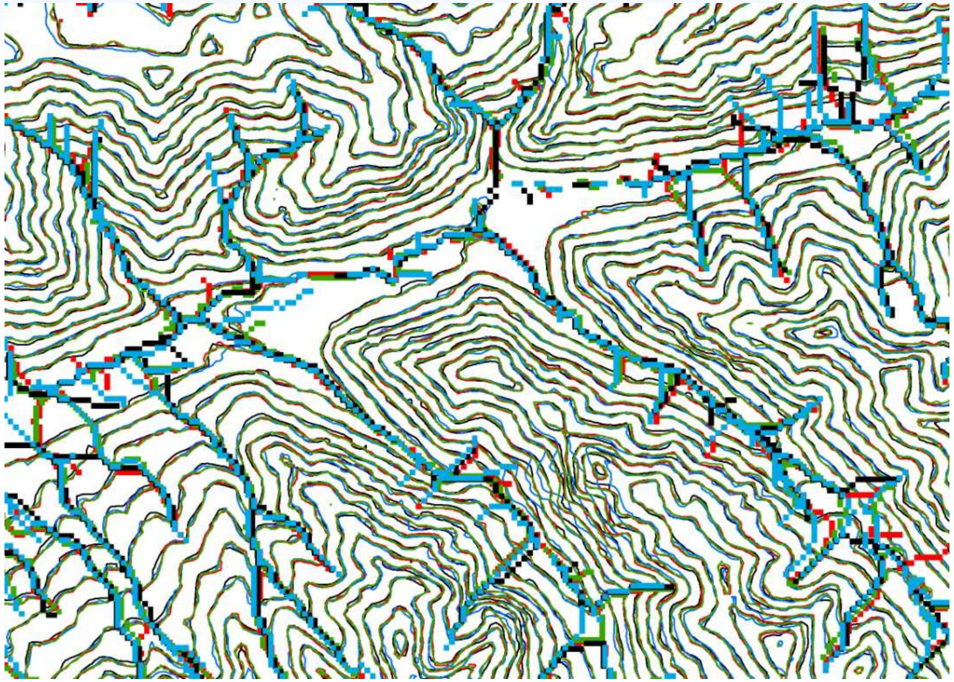






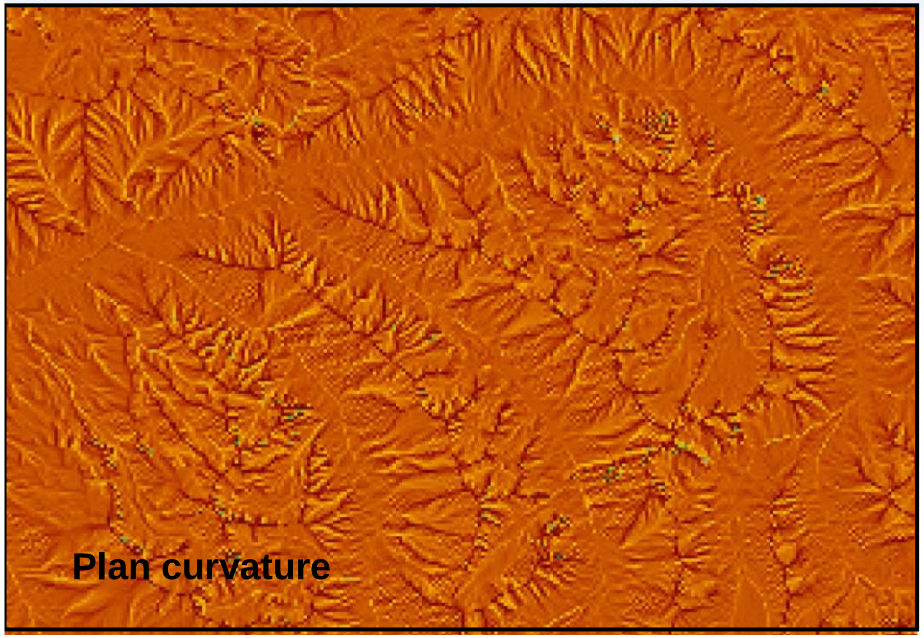
Calculation of a shift vector of the DEMs (res. =70 m) with respect to the ICESat measurements (C. Nuth and A. Kǻǻb method, 2011)

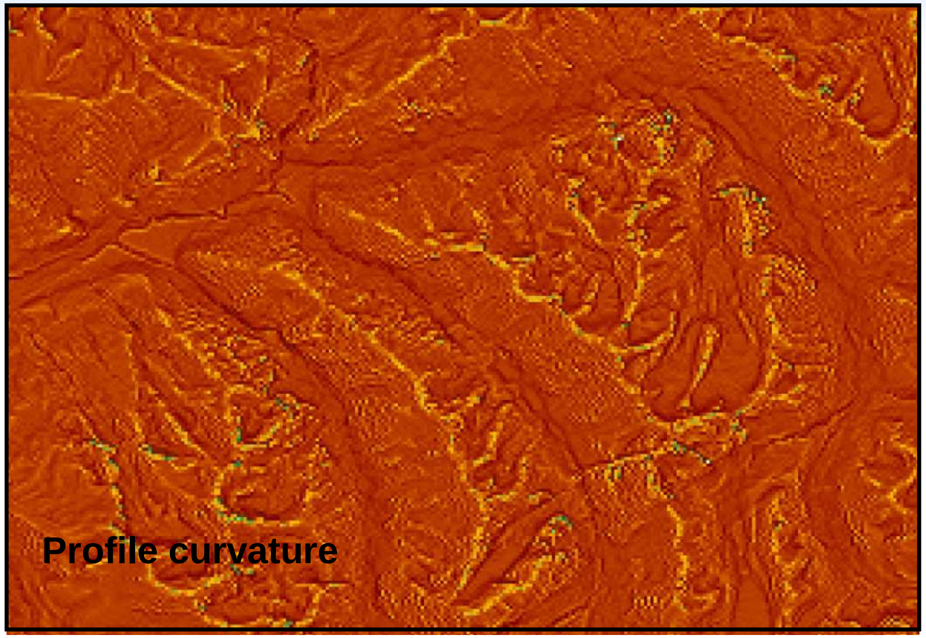


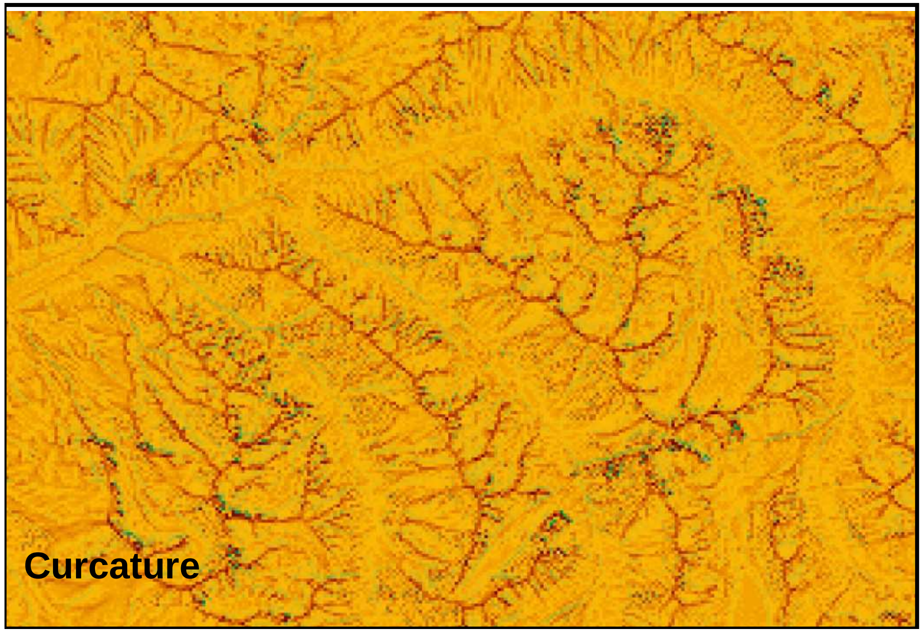


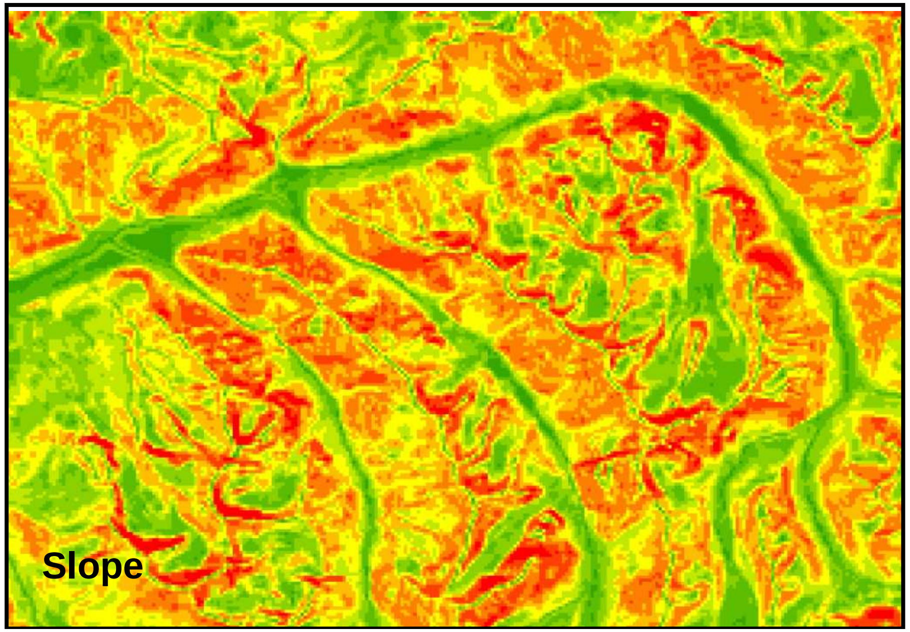
DEM	SRTM	ASTER	TDM1	TDM2
Horizontal Shift, m	85	67	-48	-41
Azimuth of the Shift, deg.	3	2	0.5	0.7
Improvement in std, %	45	39	32	24
Improvement in std after second iteration, %	0.1	0.2	2.0	5.1
ΔZ (DEM-ICESat), m	-0.4±19.7	0.8 ±18.4	5.6 ±16.5	3.8 ±20.7
RMSE, m	19.7	18.4	17.5	21.0

Surface indexes derived from TDM1







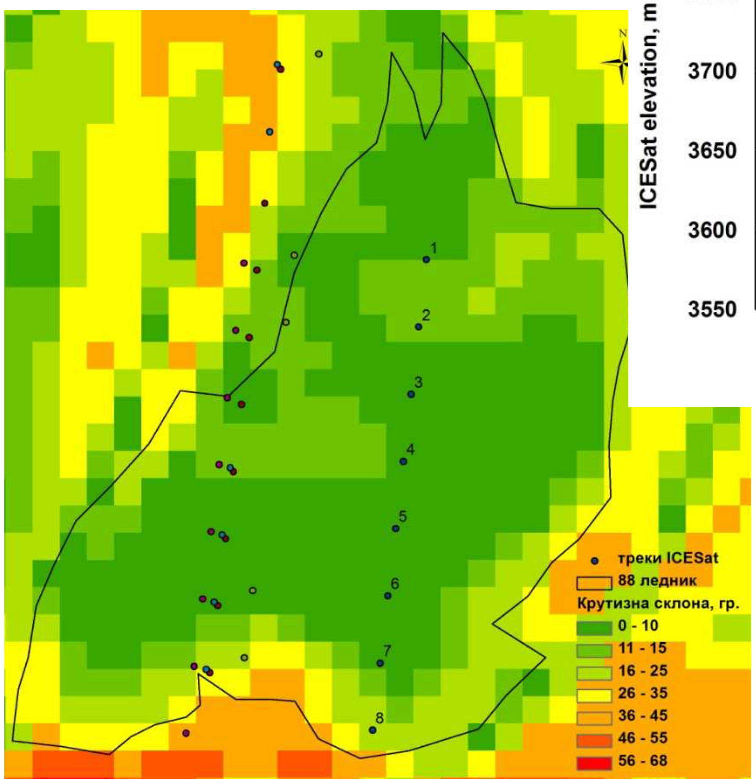


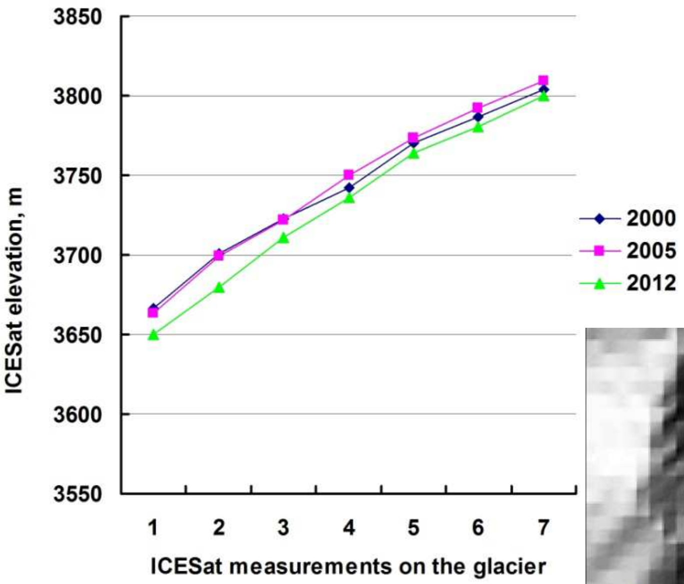
Assessment of glacier surface elevation change

1) Difference in the ICESat tracks measurements; the lowering rate = -1,0 ±0,7 m/a.
2) ICESat - DEM elevation differences; the average lowering rate is -1,3 ±0,7 m/a.
3) DEM differencing: TDM1 (2012) - SRTM (2000); the average lowering rate is -1,3± 0,6 m/a.

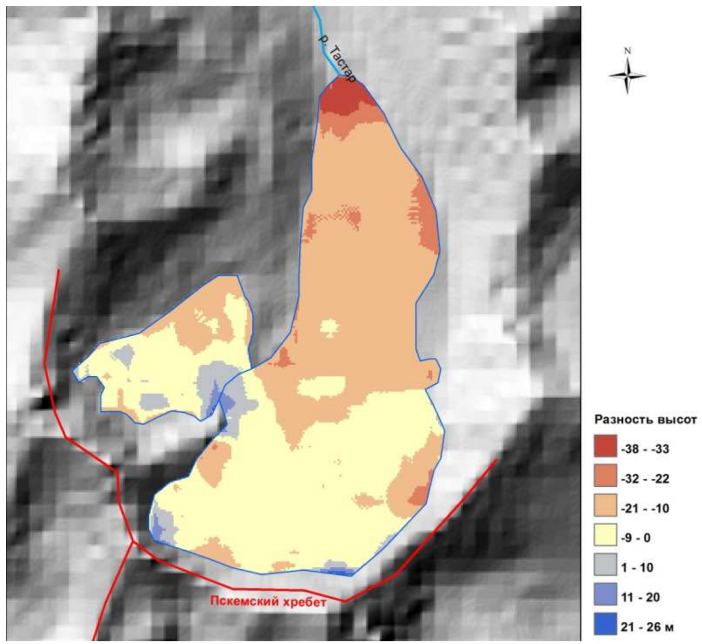
This rate changes from -0,3 to -1,7 m/a along the track in toward to the glacier terminus.

Note: we consider the surfaces with slope less than 15^0 and summer ICESat tracks.



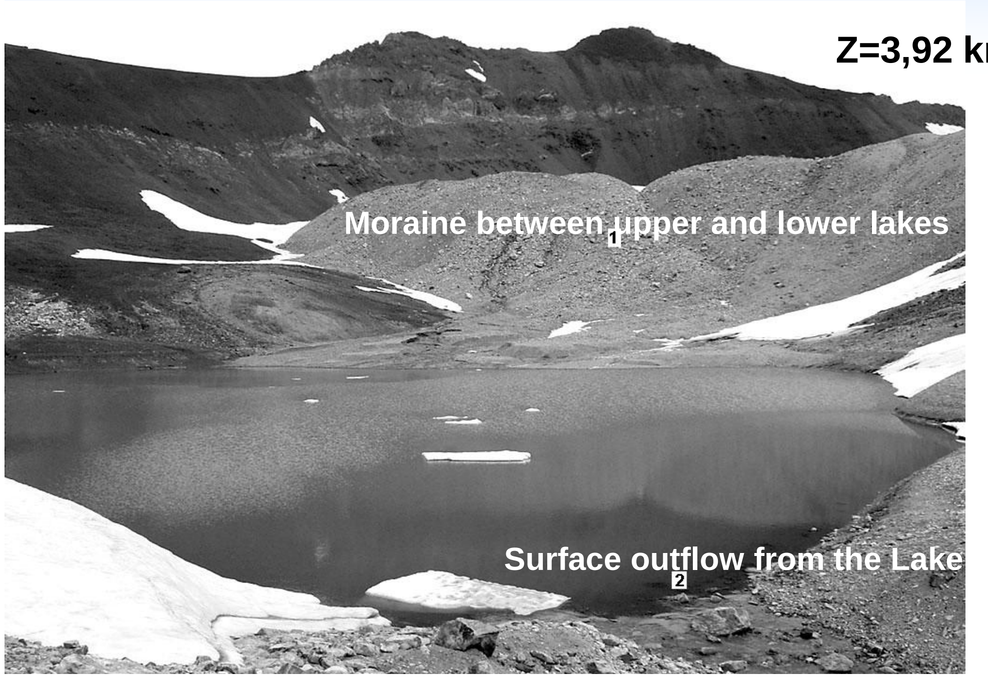


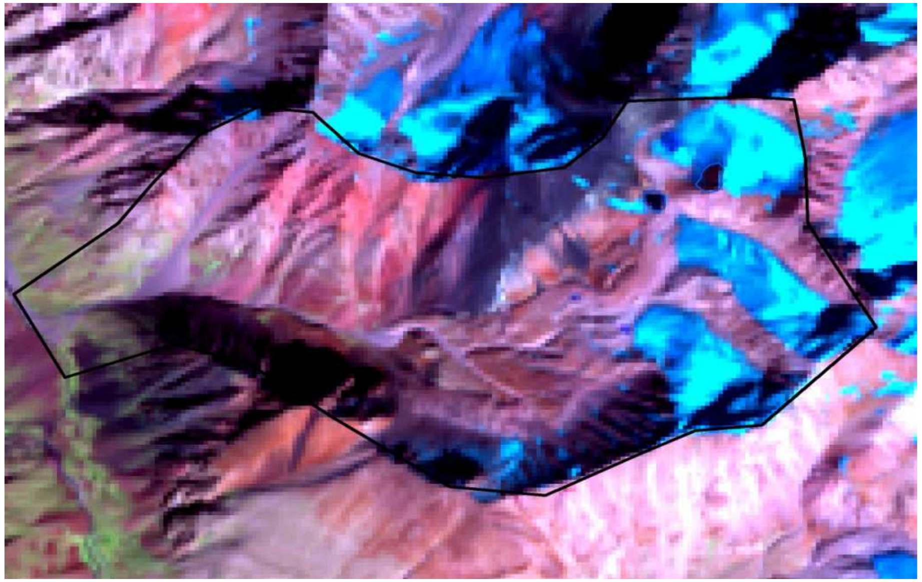
DEMs difference, m



Examples of debris flow dynamics simulation in case of outburst of the glacial Ozerniy Lake using the TanDEM-X DEM and RAMMS modelling system (SLF)

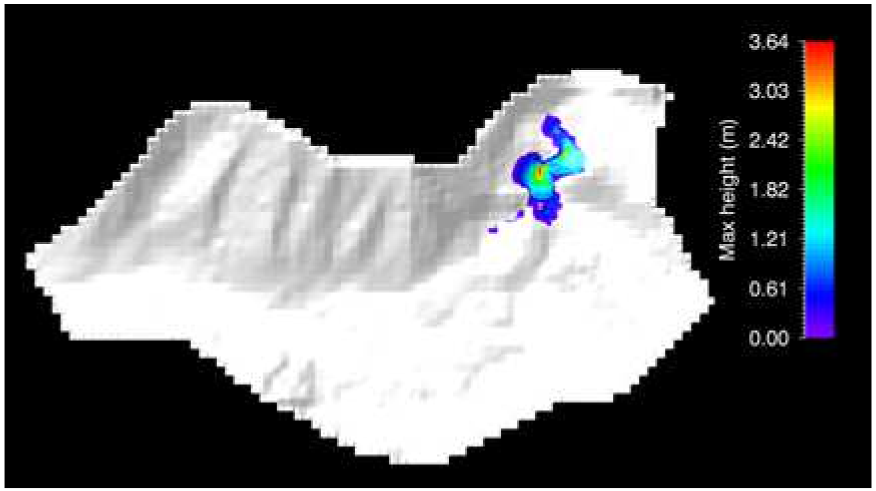
Z=3,92 km, Area=13300 m², Volume = 42200 m³, max h = 6,1 m

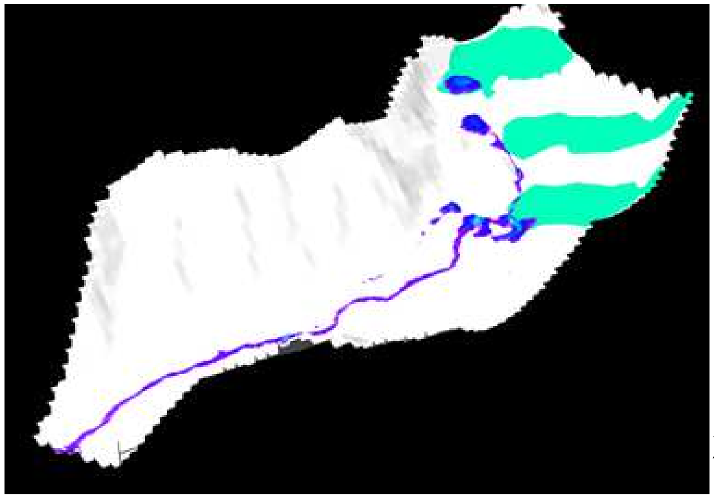




Landsat, 3.09.2013

Mu (): 0.200, Xi (м/с²): 200, max flow velocity: 9 m/s, max height: 3 m, max pressure: 163 kPa





Friction coefficients:
Mu (): 0.050
Xi (м/с²): 500

Conclusions

- The use of **multi-temporal remote sensing** data integrated from **various sources** enable a better temporal characterization of glaciers and mountain naturally-dammed lakes and a higher level of inventory completeness.
- **Future work** will focus on updating of glaciers' area and elevation, surface lowering assessment for other glaciers in the study area, calculation of their mass balance change and analysis of regional climate change.


Thank you very much for your kind attention!