**MODERN METHODS OF WATER FORECASTING
FOR PREVENTION OF NATURAL HAZARDS
IN TAJIKISTAN**

Jafar Niyazov,
Institute of water problems, hydropower and ecology,
National Academy of Sciences of Tajikistan

5th Tashkent Water Security Lectures. Integration of Scientific knowledge on water and land resources into policy dialogue on climate adaptation in Central Asia

Tajikistan global initiatives within the UN

1. Initiative of the President of the Republic of Tajikistan on the proclamation of 2003 as the International Year of Fresh water, proposed during the 54th session of the UN General Assembly (October 1, 1999). Based on this initiative during the 55th Session of the UN General Assembly the year 2003 was declared as the International Year of Fresh Water and the International Forum on fresh water was held in Dushanbe (29 August – 1 September 2003).

2. Initiative of the President of the Republic of Tajikistan on the proclamation of 2005-2015 International Decade for Action "Water for Life". In accordance with the Dushanbe Declaration on December 23, 2003 the UN General Assembly adopted a resolution and declared 2005-2015 the International Decade for Action "Water for Life".
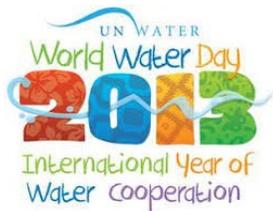
3. Declaration of the year 2013 as the International Year of Water Cooperation. In 2013 the international community recognized the UN General Assembly Resolution 67/204 on the International Year of Water Cooperation initiated by the Republic of Tajikistan. On February 11, 2013 the ceremony of announcing the International Year of Water Cooperation was held at UNESCO Headquarters in Paris, in which the Minister of Foreign Affairs of the Republic of Tajikistan took part and addressed the gathering.

4. Proposal of the President of the Republic of Tajikistan to announce 2018 - 2028 years International Decade for Action "Water for Sustainable Development". On December 21, 2016 the UN General Assembly adopted the relevant resolution and declared 2018-2028 the International Decade for Action "Water for Sustainable Development".

The establishment of the **Institute of Water Problems, Hydropower and Ecology of the National Academy of Sciences of Tajikistan** was preceded by a statement by the Founder of Peace and National Unity, Leader of the Nation and President of the Republic of Tajikistan, Emomali Rahmon, on 1 October 1999 at 54th of the United Nations General Assembly, which called for the proclamation of 2003 as the «International Year of Fresh Water». Resolution № 55/196 declared 2003 the «International Year of Fresh Water».

 The President of the Republic of Tajikistan, Emomali Rakhmon, in his address to the Academy of Sciences at a meeting with the country's intellectuals on 20th of March 2001, emphasized, in particular, the need to strengthen Tajikistan's scientific potential and to establish the Institute of Water Problems, on 3rd July 2002, the Government adopted Decree № 279 on the establishment of the Institute of Water Problems, Hydropower and Ecology of the Academy of Sciences.

Structure of the Institute of Water Problems, Hydropower and Ecology of the National Academy of Science of Tajikistan
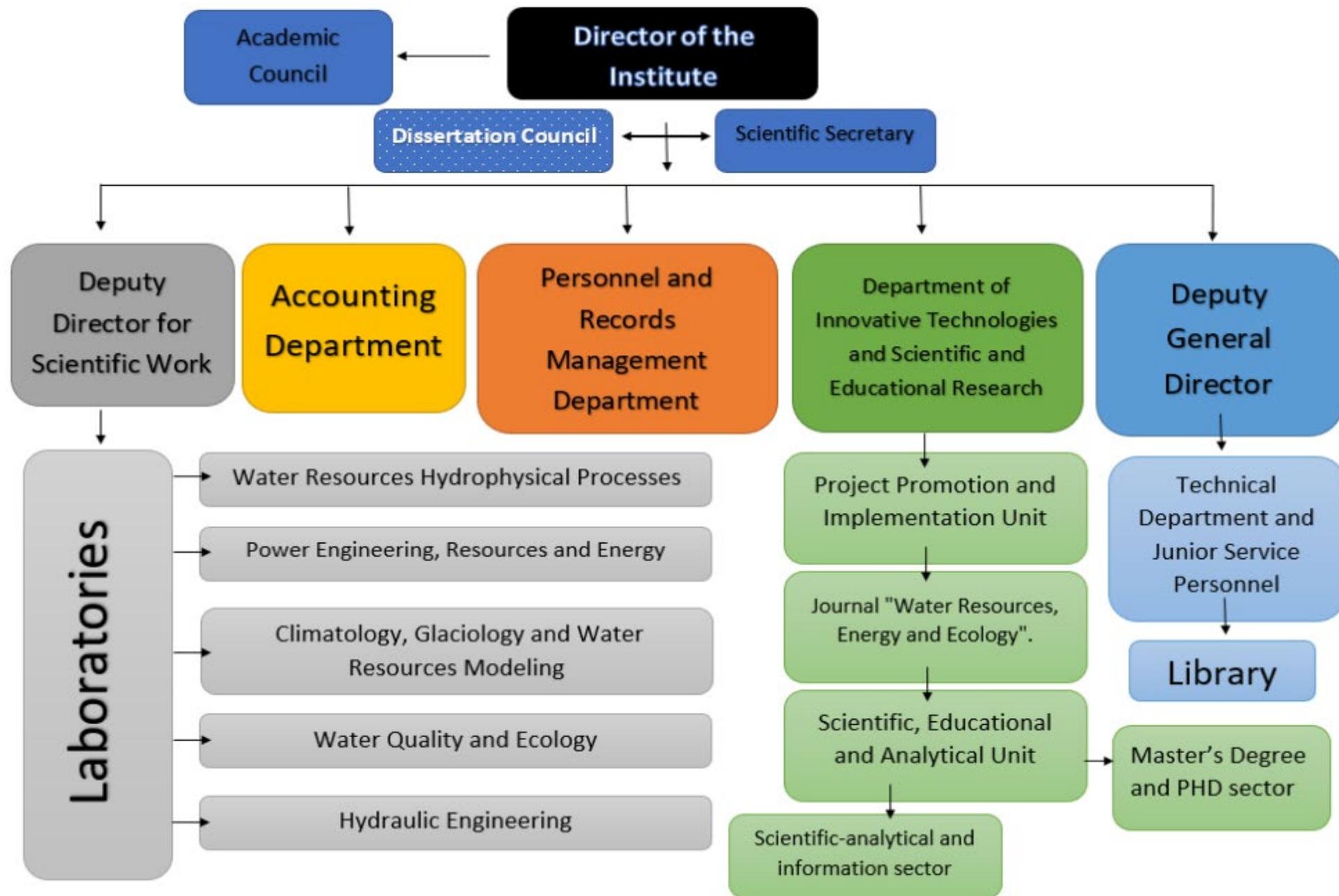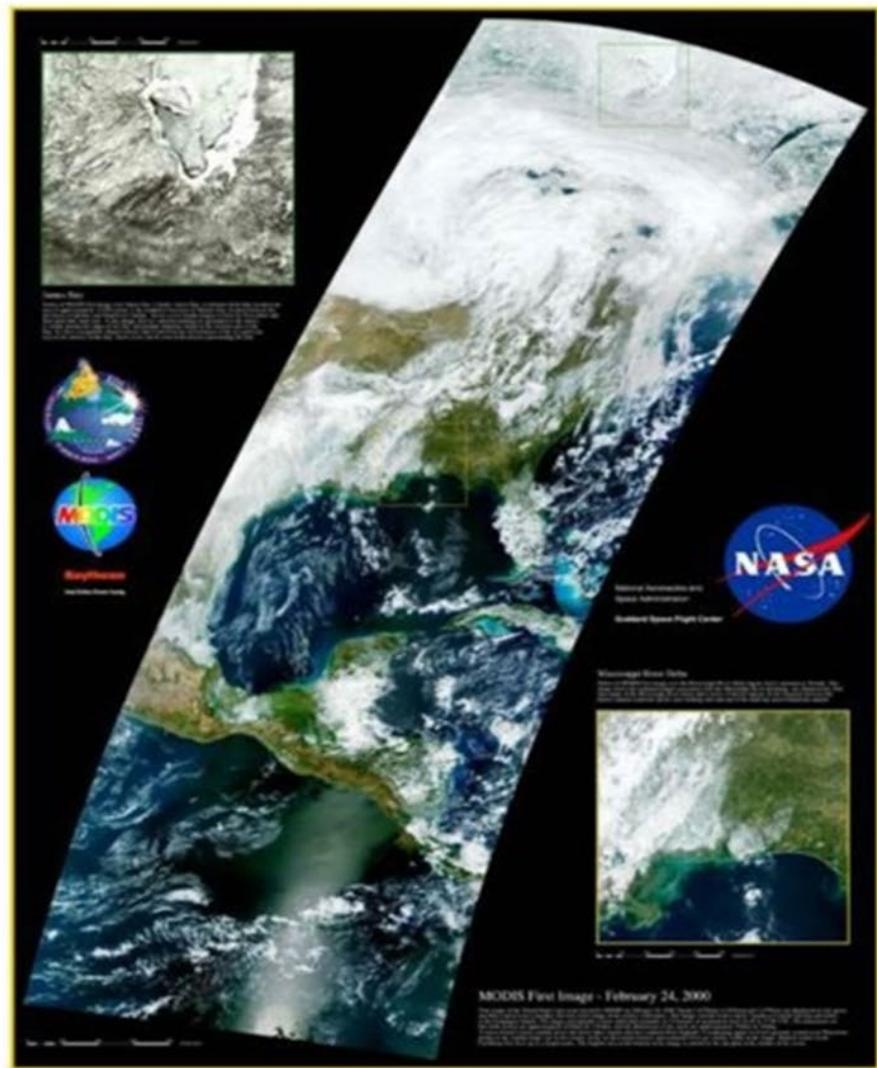
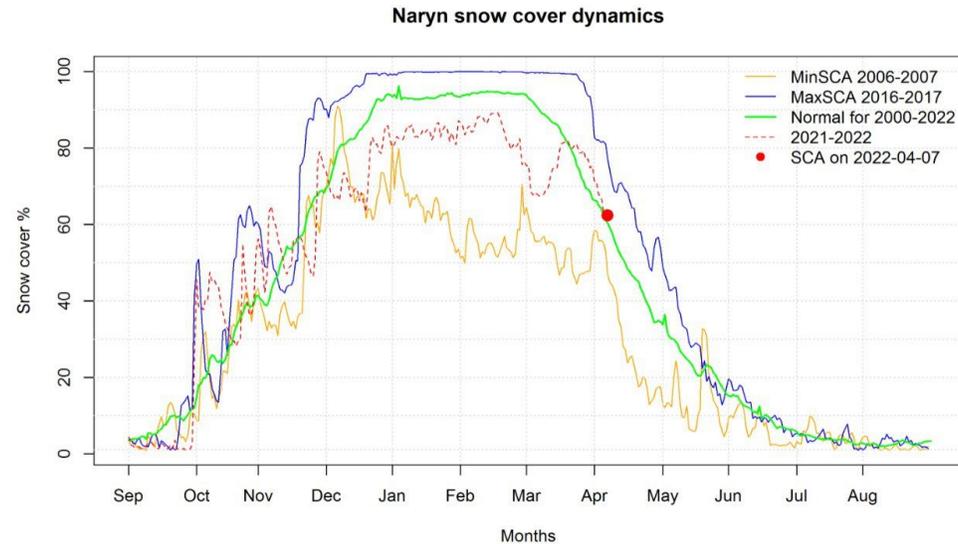**The most important research of the Institute includes:**

- Comparative analysis of the energy efficiency of large rivers in Tajikistan;
- Study the influence of climate change on water and energy resources;
- Development of methods for adapting of the hydropower to global climate change;
- Development of models and methods for forecasting of runoff for hydropower;
- Development of methods to optimize of hydropower plants with reservoirs;
- Development of methods to regulate water flow for hydropower engineering and irrigation;
- Analysis of international and national laws on sharing water and energy resources of transboundary rivers;
- Development of methods for economic assessment of water value in view of its joint use for hydropower engineering and irrigation.

MODIS Basics

▸ **Moderate Resolution Imaging Spectroradiometer Satellites:**
  ◦ Viewing the entire Earth's surface every 1 to 2 days
  ◦ Acquiring data in 36 spectral bands
  ◦ Multiple data products (Atmosphere, Land, Ocean etc.)
  ◦ Important for understanding global environment and earth system models

MODIS First Image - February 24, 2000
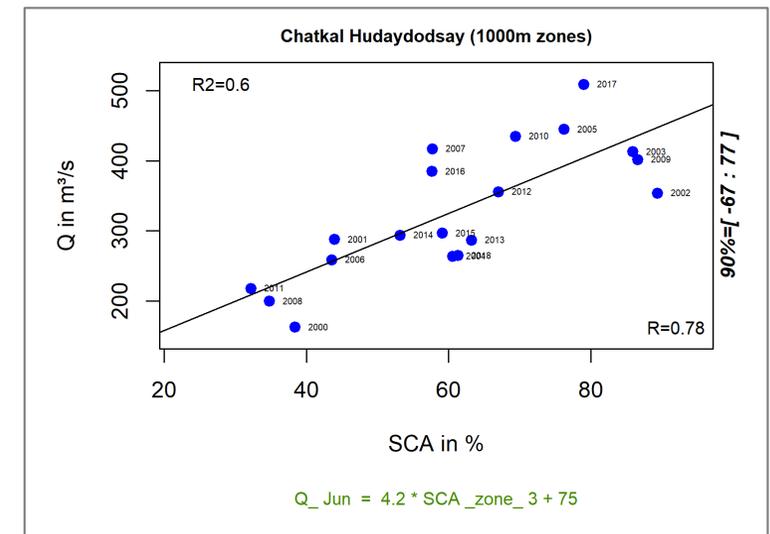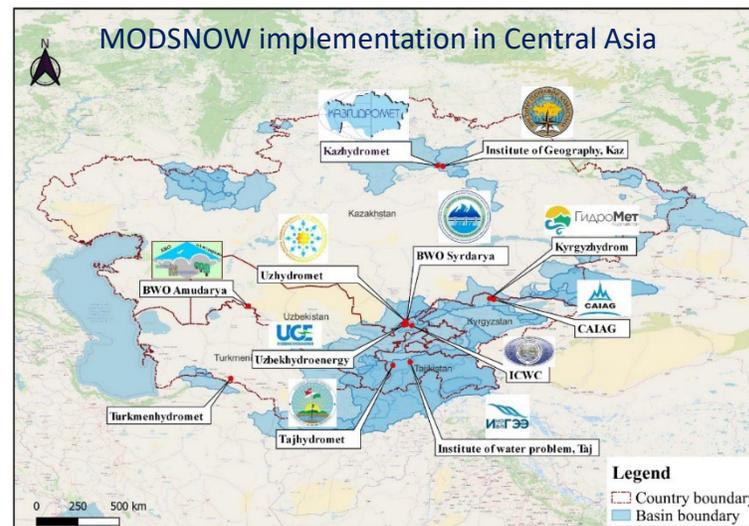
http://aqua.nasa.gov/doc/viz/media/aqua_orbit_sm.mpg

MODSNOW – operational water availability assessment model

Operational snow cover monitoring

Cloud removal with >94% accuracy

Comparative snow cover condition for >20 yrs

Zonal snow coverage statistics

Hydrological forecast for vegetation & monthly period

Gafurov et al., 2016

Naryn snow cover dynamics

Operational (daily) monitoring of snow cover for any predifined river basins

- Uses satellite snow cover data as an input

- Includes cloud cover elimination algorithm (Gafurov et al., 2009)

- Water availability prior to vegetation period and monthly scale based on remote sensing snow cover data (and other predictors)

MODSNOW implementation in Central Asia

Chatkal Hudaydodsay (1000m zones)

$R2=0.6$

$R=0.78$

$Q\_Jun = 4.2 * SCA\_zone\_3 + 75$

Automatic generation of hydrological forecast models for the operational assessment of water resources
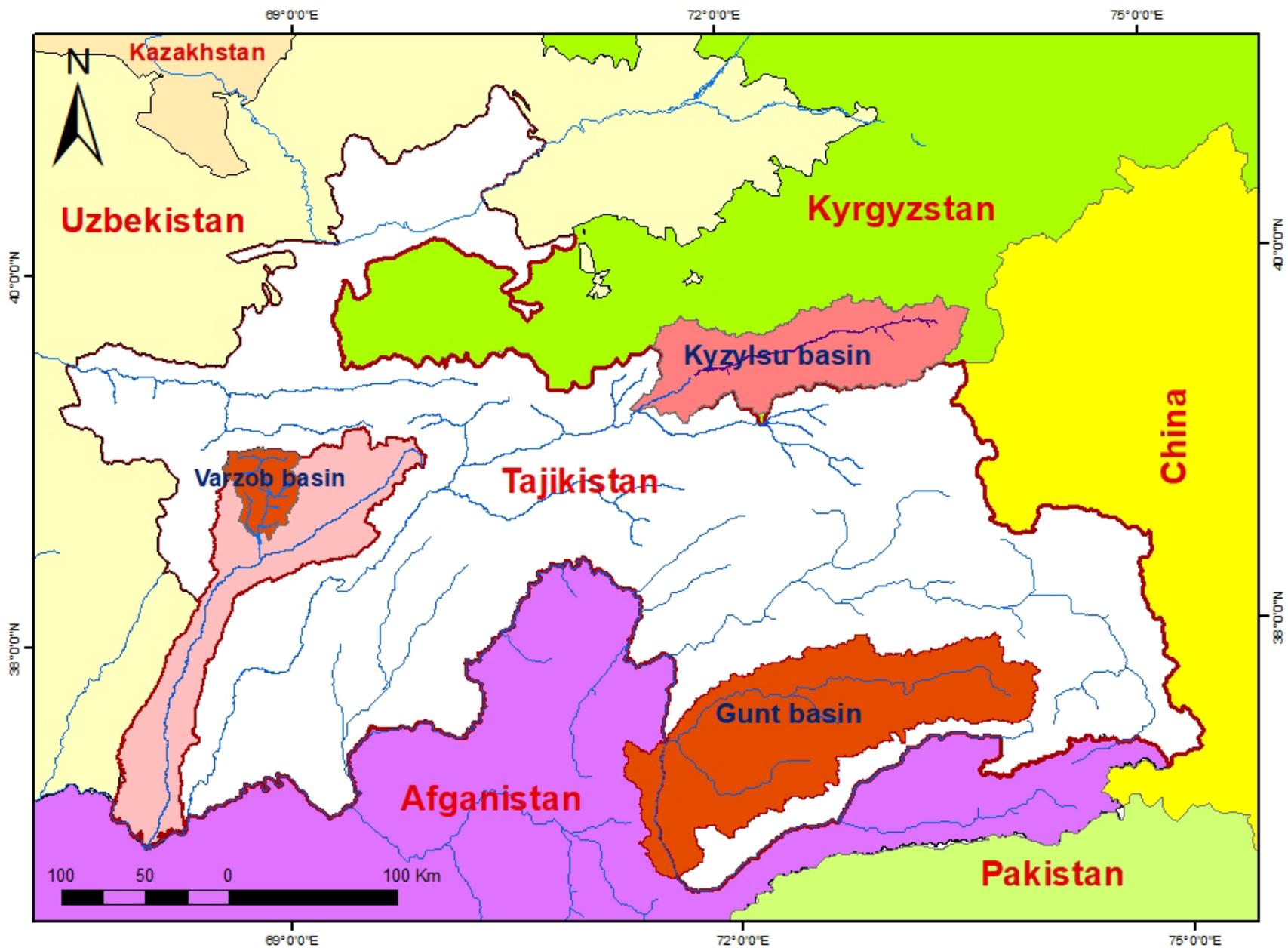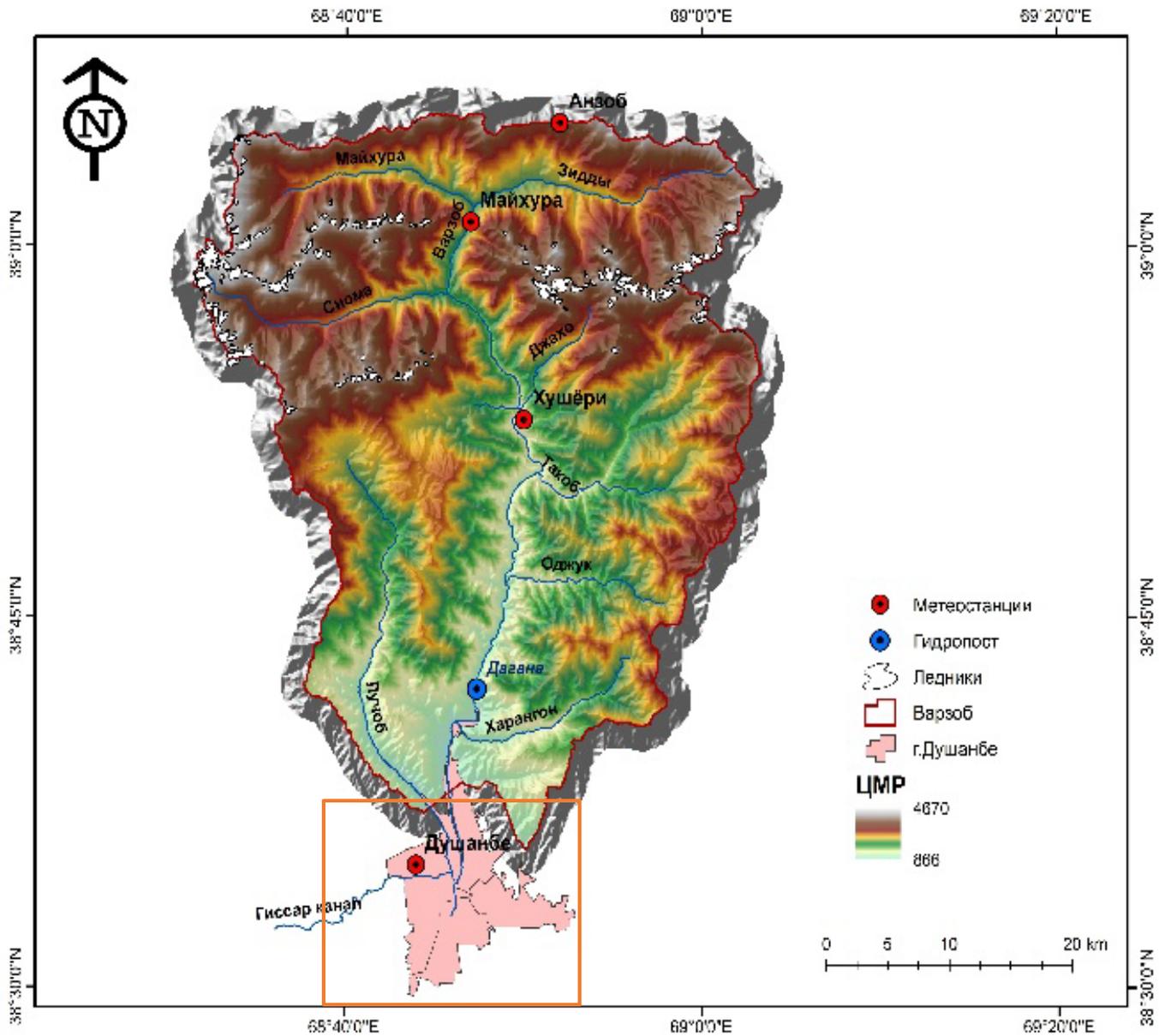
Varzob is a river in the southwest of Tajikistan, the right tributary of the Kafirnigan River. Length - 71 km, pool - 1740 km². In the lower reaches, the average water flow is 45.9 m³/s, max. 61.3 m³/s, min. 31.5 m³/s. Varzob is a snow-glacial type of river. The high water is from the end of February to the beginning of October, and the maximum runoff is observed in June. The city of Dushanbe is located in the south of the basin.

We used the snow cover data of MODIS images processed in the MODSNOW-Tool program and calculated the snow cover area for high-altitude zones with an interval of 500 meters. For each altitude zone, the snow coverage was calculated per day as a percentage of the river basin area (SCA, snow cover area).

Calculation of Snow Cover Area (SCA), for high-altitude zones after 200 m

River Varzob, Hydropost Dagana
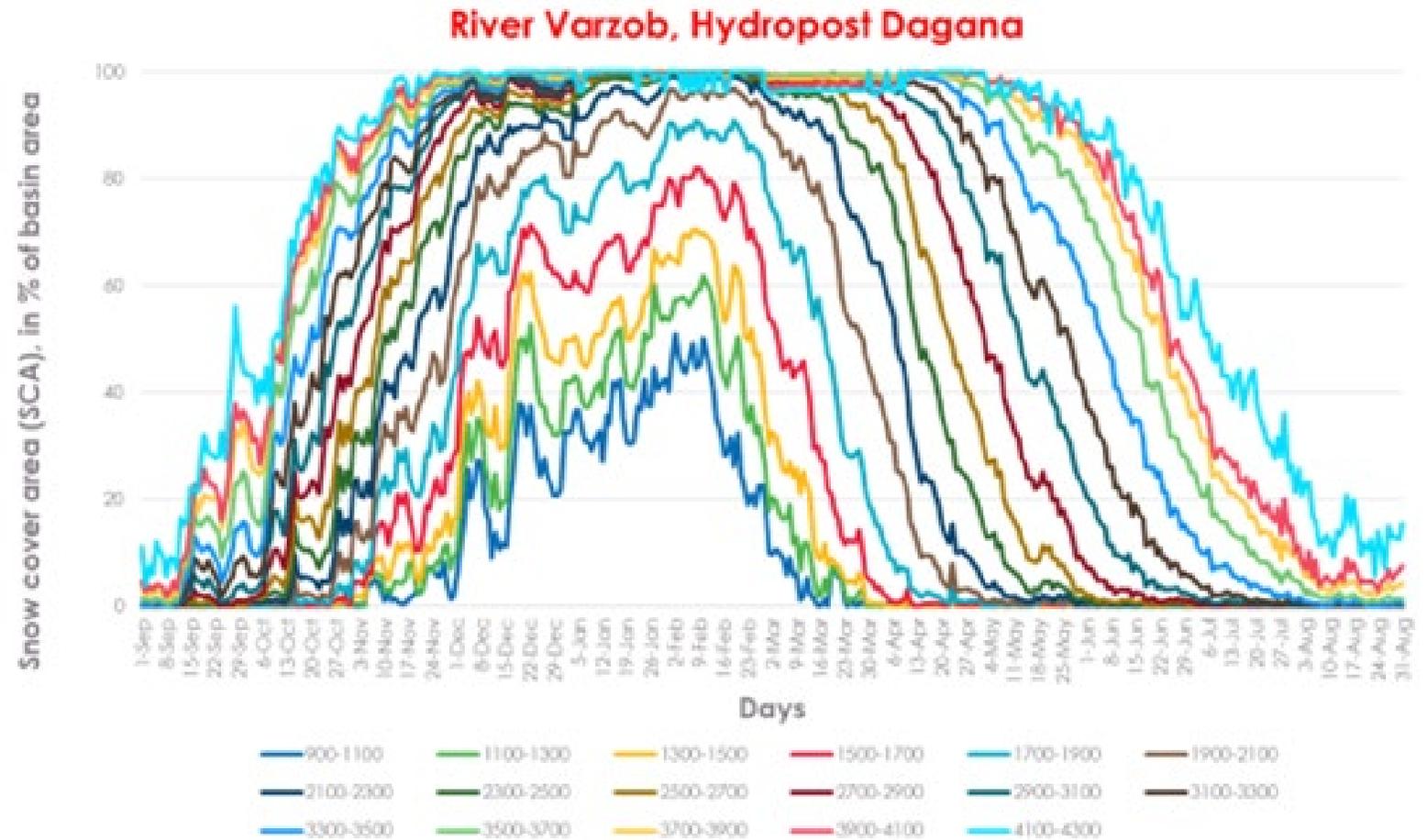
Correlation coefficient (R) of **average decade (ten-day)** water discharges and SCI index for high-altitude zones on the Varzob River

	700-900	900-1100	1100-1300	1300-1500	1500-1700	1700-1900	1900-2100	2100-2300	2300-2500	2500-2700	2700-2900	2900-3100	3100-3300	3300-3500	3500-3700	3700-3900
1 dec.May	-0.24	-0.03	-0.02	-0.04	-0.01	-0.03	-0.07	-0.17	-0.25	-0.28	-0.20	-0.14	-0.12	-0.08	0.03	0.04
2 dec.May	-0.27	-0.08	-0.06	-0.07	0.00	0.04	0.08	0.03	0.00	-0.01	0.09	0.13	0.15	0.17	0.21	0.19
3 dec.May	0.48	0.50	0.51	0.55	0.56	0.51	0.43	0.35	0.34	0.38	0.45	0.51	0.55	0.64	0.61	0.53
1 dec.June	0.47	0.46	0.53	0.60	0.61	0.61	0.59	0.60	0.66	0.71	0.75	0.77	0.76	0.71	0.52	0.35
2 dec.June	0.27	0.36	0.45	0.52	0.57	0.59	0.59	0.58	0.62	0.62	0.65	0.65	0.59	0.50	0.34	0.14
3 dec.June	0.63	0.54	0.58	0.69	0.82	0.86	0.85	0.83	0.73	0.66	0.60	0.58	0.57	0.57	0.43	0.32
1 dec.July	0.47	0.47	0.50	0.54	0.60	0.62	0.66	0.69	0.69	0.66	0.60	0.58	0.55	0.52	0.43	0.26
2 dec.July	0.52	0.48	0.52	0.55	0.61	0.63	0.67	0.72	0.70	0.66	0.61	0.62	0.63	0.64	0.64	0.56
3 dec.July	0.32	0.20	0.25	0.35	0.42	0.46	0.51	0.62	0.70	0.78	0.79	0.81	0.83	0.81	0.77	0.60
1 dec. August	0.61	0.48	0.52	0.63	0.75	0.81	0.83	0.86	0.80	0.76	0.71	0.70	0.72	0.76	0.75	0.69
2 dec. August	0.51	0.38	0.41	0.50	0.64	0.71	0.75	0.80	0.72	0.67	0.60	0.58	0.59	0.60	0.61	0.62
3 dec. August	0.49	0.40	0.42	0.46	0.53	0.56	0.61	0.65	0.58	0.54	0.48	0.48	0.50	0.53	0.62	0.70
1 dec.September	0.66	0.59	0.56	0.56	0.58	0.54	0.54	0.55	0.49	0.45	0.36	0.34	0.34	0.34	0.42	0.49
2 dec.September	0.52	0.40	0.37	0.39	0.42	0.40	0.41	0.44	0.37	0.35	0.27	0.26	0.28	0.30	0.41	0.54
3 dec.September	0.00	-0.11	-0.19	-0.21	-0.25	-0.28	-0.27	-0.22	-0.19	-0.12	-0.13	-0.15	-0.14	-0.16	-0.10	-0.01

Using the linear dependence of the SCI index and **the average decades (ten-day)** water discharge on the Varzob River, equations were obtained for predicting runoff river for decades. The best results were in the months of seasonal snowmelt. The reliability of forecasts taking into account the permissible forecast error, it amounted to 78-100% (Varzob River).

| Decade	Elevation zone	Equation	Correlation coefficient (R)	The reliability of forecasts for period 2010-2018, in %
2 decade of April	2100-2300	55.01* SCI + 42.024	0.58	78
3 decade of May	1500-1700	33.548*SCI + 88.811	0.56	100
1 decade of June	2700-2900	91.565*SCI + 39.746	0.75	100
2 decade of June	2700-2900	66.534*SCI + 61.154	0.65	100
3 decade of June	2100-2300	67.259*SCI + 54.519	0.60	100
1 decade of July	2100-2300	52.334*SCI + 61.532	0.69	100
2 decade of July	2100-2300	49.125*SCI + 47.773	0.72	100
3 decade of July	2700-2900	70.668*SCI + 13.595	0.79	89
3 decade of July	2900-3100	78.462*SCI + 7.5133	0.81	89
1 decade of August	2100-2300	46.3*SCI + 21.451	0.86	89
2 decade of August	2100-2300	32.015*SCI + 22.25	0.80	100
3 decade of August	2100-2300	19.599*SCI + 22.007	0.65	100
1 decade of September	2100-2300	15.439*SCI + 17.844	0.55	100
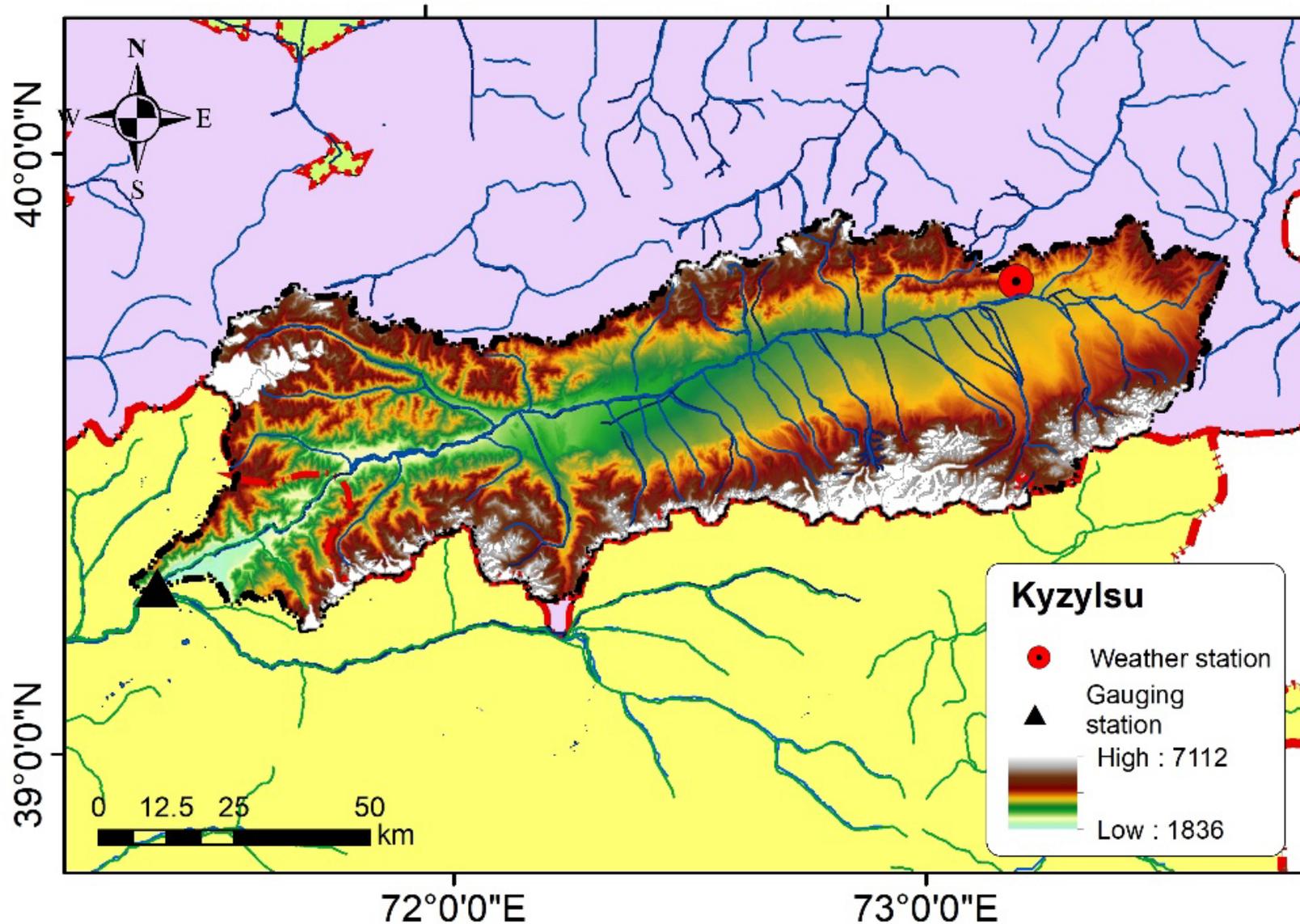
The Kyzylsu River (the main source of the Vakhsh River) is of transboundary importance in the water allocation of the Central Asian states. The Vakhsh River originates in the territory of Kyrgyzstan, where its area is 7,900 km2 (20.2% of the total basin area), and then enters the territory of Tajikistan and here has an area of 31,200 km2 (79.8% of the total basin area). The Vakhsh River is of great hydropower and irrigation importance for the whole of Central Asia since its flow is one-fourth of the annual flow of the Amudarya River.

Methodology.

The genetic vertical dissection of the hydrograph on the runoff component with MODIS images

Hydrograph (m3) Kyzylsu, SCA and Temperature Sary-Tash 2011
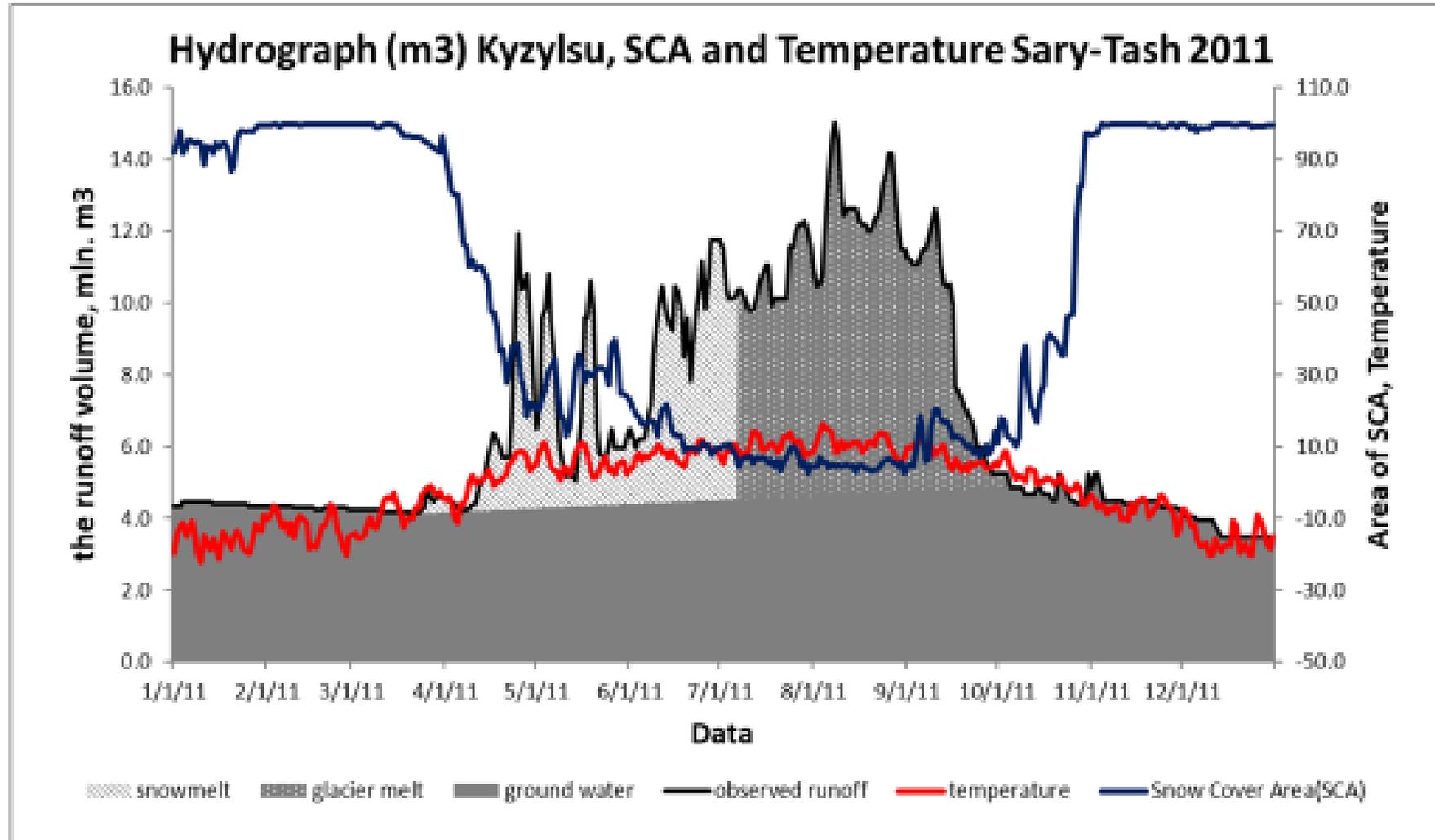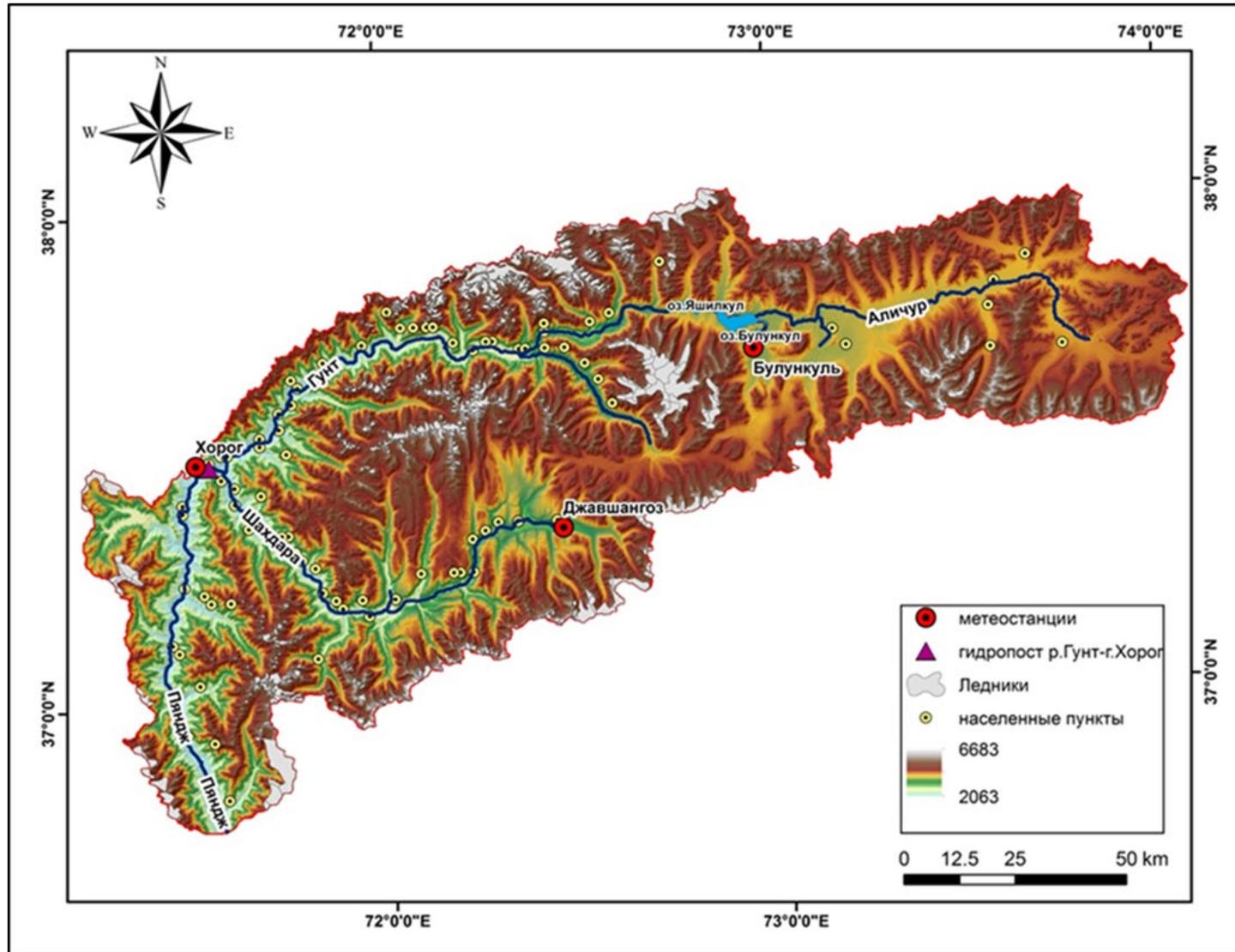
The length of the Gunt River is 296 km, the basin area is 14.9 thousand sq km, the average basin height is 4170 m above sea level, and the area of glaciation occupies about 4% of the total basin area. The river basin extends in the range of heights from 2063 to 6683 m above sea level.
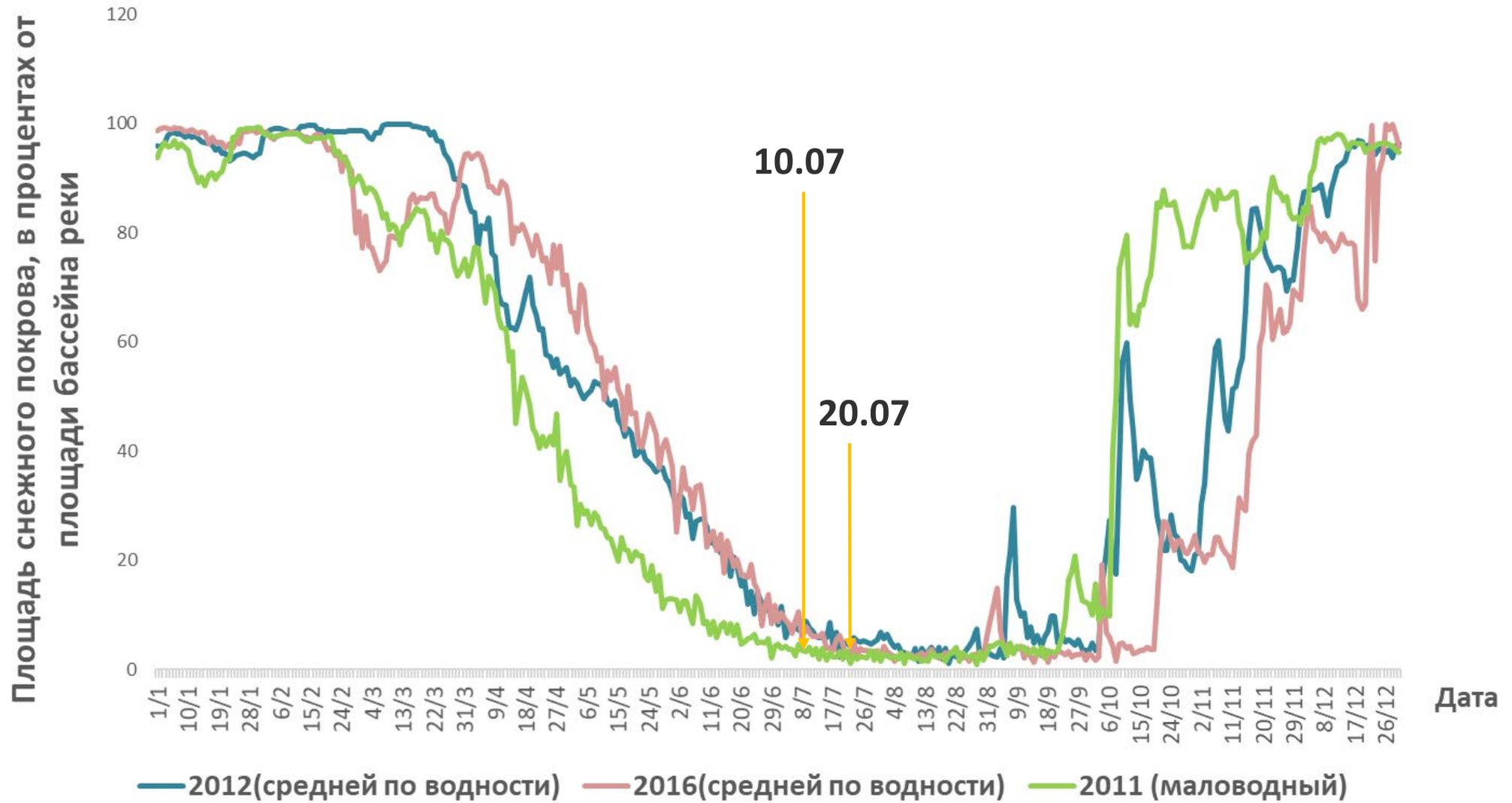
Daily variation of snow cover according to MODIS imagery data for 2011 dry year, 2012, 2016 average water years for the Gunt River basin.

Years	the volume of runoff of the main river alienation					
	ground runoff		Melted snow runoff		Melted glacial runoff	
	million m3	%	million m3	%	million m3	%
r. Gunt - Khorog						
2011 dry year	1220	55	359 (23.04-10.07)	16	645 (11.07-20.10)	29
2012 average water year	1649	51	961 (26.05-22.07)	30	596 (23.07-06.10)	17
2016 average water year	1471	47	1148 (08.05-20.07)	36	530 (21.07-11.10)	17

Conclusion

1. One of the main advantages of the proposed method is a qualitative and reliable forecast of the high-altitude rivers runoff using MODIS satellite images processed in the MODSNOW program, which is important for the rivers runoff forecasting with mid and high-mountain basins and the basins, where ground-based observations of snow cover are not currently being conducted.

2. MODIS satellite images processed in the MODSNOW-Tool program can be used to assess the water content of rivers in the formation zone of the river runoff during vegetation and flood periods and during flood months.

3. An analysis of the correlation coefficients of the Snow Cover Index (SCI) calculated for high-altitude zones in 500 m with average months water discharge showed the close relation for months, where melt snow and glacial runoff plays a decisive role in the river flow formation (June-September).

4. The analysis made it possible to draw up equations for forecasting runoff river for months.

5. The proposed equations for the dependence of the average monthly water discharge for a flood period with a snow cover index (SCI) can be used to reliably forecast river water content in order to prevent dangerous hydrological phenomena such as floods and hydrological droughts.

Thank you for your attention!