The Glaciers of Central Asia: A Disappearing Resource

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Contributors: The report is based on extensive work performed by Bruno Chatenoux (UNEP/DEWA/GRID-Europe), with inputs from Valerii Kuzmichenok (Kyrgyzstan), Abdulkhamid Kayumov (Tajikistan), Aleksandr Merkushkin (Uzbekistan) and Igor Severskiy (Kazakhstan). Booklet compilation was done by Anna Kaplina (UNDP), edited by Alison McKelvey Clayson. Peer Reviewers: Laura Rio (UNEP), Michael Thurman (UNDP), Yegor Volovik (UNDP), Natalia Alexeeva (UNDP), Muratbek Koshoev (UNDP), Gleb Glazirin (Uzbekistan).

Contact: Yegor Volovik, yegor.volovik@undp.org

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Introduction

Future generations are not going to ask us what political party were you in. They are going to ask, what did you do about it, when you knew the glaciers were melting.

Martin Sheen, social and political activist

Back in the days when the mountains of Central Asia used to be a sacred place, everyone who passed the mountain route was captured by the view of graceful river-canyons, white mountain peaks and abundant glaciers…But today the picture is different. In the last 50 years, the glaciers of Central Asia are estimated to have shrunk by between 20 to 30%. Glaciers of Central Asia are disappearing at rather high rates.

Central Asia is one of the world's most vulnerable regions to climate change. An arid climate, combined with a history of environmental mismanagement and limited climate-related disaster risk mitigation strategies, have created a region that is increasingly vulnerable to the effects of rising temperatures, changing rainfall patterns, and increased aridity and frequency of extreme events.

Figure 1: Glaciers of Central Asia

Source: ZOÏ, 2009

Glaciers are highly important long-term reserves of fresh water in Central Asia. They supply water during the hottest period of the year, when it is needed for irrigation. Glaciers also provide critical water supply during drought years. For example, in Tajikistan, water from glaciers contributes 10-20% of the runoff in large rivers, and in particularly hot and dry years this figure can reach up to 70%.

Because they are highly sensitive to temperature increases, glaciers are among the first “victims” of climate change. Degradation of glaciers is likely to aggravate existing problems and pose additional risks to sustainable development, energy and food security in Central Asia. There is great concern that water shortages may prove to be the main impediment to the development of Central Asian countries both under current conditions (around 50 percent of water used for irrigation is lost to inefficient irrigation technologies) and in the future (increasingly due to decreasing availability of snowpack and glaciers). The increased water consumption requirements of a growing population is likely to put additional pressure on both food and energy supplies, and could aggravate tensions within the region and between Central Asia and neighboring countries. Currently observed changes in glaciers threaten the region in the short term with floods and with reduced water resources availability in the long term.

Better monitoring of the glaciers’ rate of degradation and their current status are essential steps to minimizing the negative effects of this degradation through better planning and management of water resources.

This booklet, prepared by the United Nations Development Programme (UNDP) Bratislava Regional Centre, Slovak Republic, is based on a review of the scientific literature undertaken by UNEP/DEWA/GRID-Europe and national consultants of Central Asia, with the support of the Government of Finland through Environment and Security Initiative (ENVSEC). It examines the current trends in scientific thinking and knowledge about glacier degradation in Central Asia; the possible reasons and repercussions thereof; the discrepancies or gaps in data and understanding; and some next steps for addressing these issues. A final section provides a list of web resources and institutions where reliable data, maps and other information materials may be found.

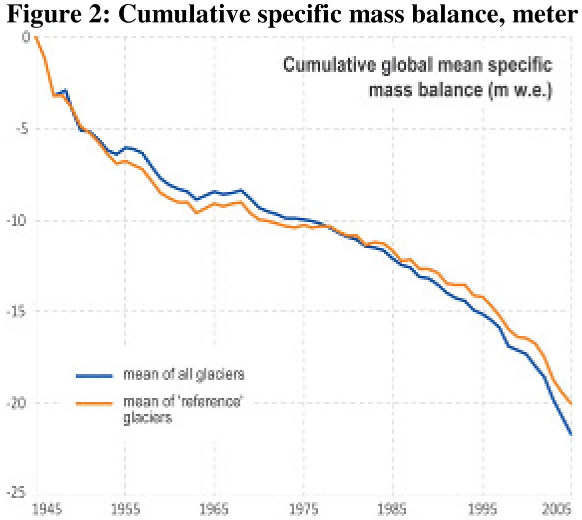
Chapter 1: What is Happening to the Glaciers

Glaciers are delicate and individual things, like humans. Instability is built into them.
Will Harrison, glaciologist

Glaciers are recognized as being among the best climate indicators, for the changes they undergo provide a signal: the advance or retreat of glacier tongues constitutes an indirect, delayed and filtered (but easily observed) signal of climate change, whereas the glacier mass balance is a more direct and not delayed signal of annual atmospheric conditions.

In the 20th century, glaciers across the world were observed to be shrinking significantly at a rate that varies in time and space (Figure 2). In Central Asia, studies evaluate the average rate of area deglaciation at about 0.6 to 0.8 percent per year and at about 1 percent per year in volume, but these rates show high variation. It is anticipated that average annual temperature increases of less than 1.0 °C per century has reduced glacier surface in the mountains of Central Asia by more than one-third.

Figure 2: Cumulative specific mass balance, meter water equivalent



Source: UNEP/WGMS, 2008

Even if there is consensus in Central Asia about a general trend of glacier shrinking, the estimation of the degradation rate remains controversial. For example, the analysis of time series in the Tien Shan mountain range done by Aizen et al. (2006) shows that the degradation rate was three times faster during 1977-2003 than during 1943-1977. Kutuzov and Shahgedanova (2009) also recognize this period to have the most rapid rate of glacial retreat since the end of the little ice age. However, the inverse opinion reveals that after a sharp acceleration of mass losses in 1970-1978, the process stabilized and slowed down by 1990 (Kotlyakov and Severskiy, 2009).

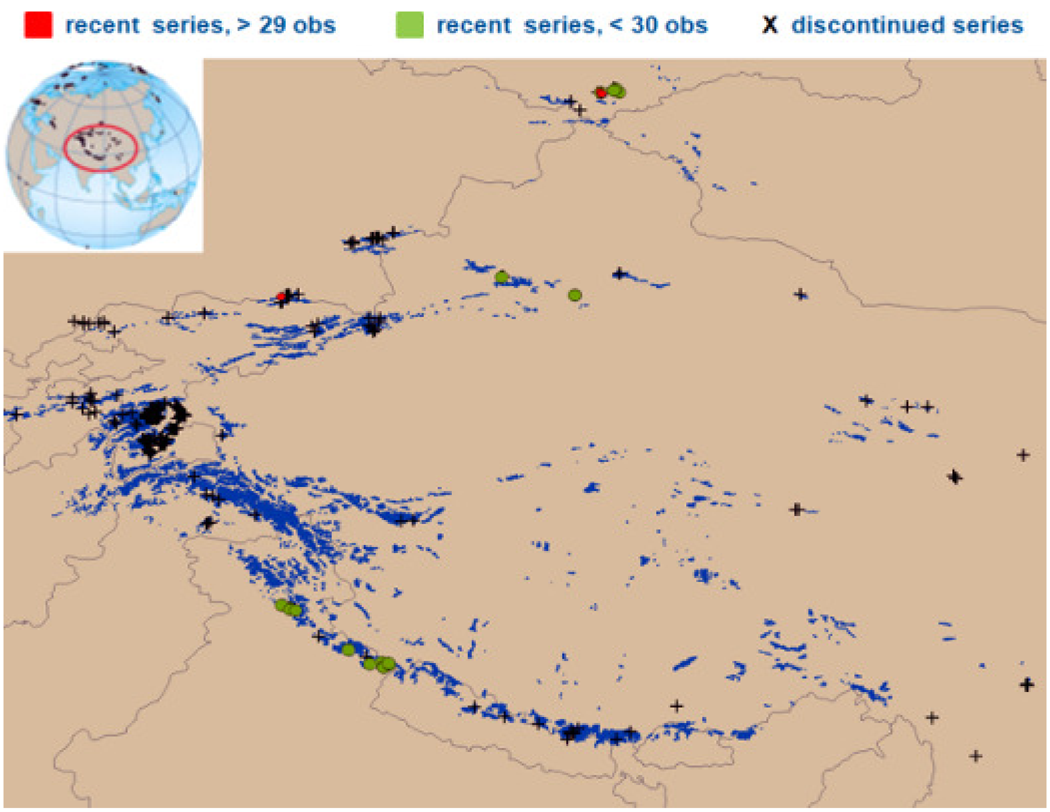
These and other contradictions stem from the lack of correct or up-to-date data on the glaciers of Central Asia.

The lack of data, and the presence of incorrect data, makes accurate estimates on deglaciation extremely challenging. In effect, although many data were acquired in Central Asia during the Soviet Union period, the World Glacier Monitoring Service reports that unfortunately, 90 percent of the observation series were discontinued before 1991 and only about a dozen series have reported information in the 21st century. The distribution of mass balance series in space and time shows a similar pattern: just 6 out of 35 series consist of more than 15 years of observation. After the collapse of the Soviet Union and the related economic decline of the region, the national hydrometeorological services were unable to ensure continued monitoring activity at many high mountain stations and trained people were less readily available. Thus, the number of functioning stations decreased constantly until the mid 1990s, before some of the activities were re-activated through international efforts (Figure 3 and Tables 1, 2 and 3). It is therefore essential to remember that many data are disputed, controversial, or indeed unknown at the present time, although actions are being taken to improve the state of the knowledge base in Central Asia.

SOME GLACIERS AT RISK

- **The Fedchenko** – one of the largest glaciers of Central Asia situated in Tajikistan, which exceeds 70 km in length and 2 km in width, shrank by 1 km in length during the 20th century.
- **The Akshirak** massif (containing over 170 glaciers and covering the area of 300 km^2) in central Kyrgyzstan shrank by 4% from 1943 to 1977 and by over 20% from 1977 to 2001.
- **The Abramov** glacier located in the Alay range in southern Kyrgyzstan on the border with Tajikistan shrank by at least 500 m and lost 20% of its ice mass since the 1970s.

Figure 3: Glaciers: front variation observations in Central Asia



Source: WGMS (personal communication)

Table 1: Number of meteorological stations in Central Asia for the past 20 years (extracted from Glazirin 2009)

State	Number of meteorological stations		
	1985	1996	2004
Uzbekistan	91	75	78
Kyrgyzstan	95	62	31
Tajikistan	64	51	47
Turkmenistan	51	51	48

Table 2: Change in the ground and aerial snow measuring network in Central Asia (air observation marked in brackets, extracted from Glazirin 2009)

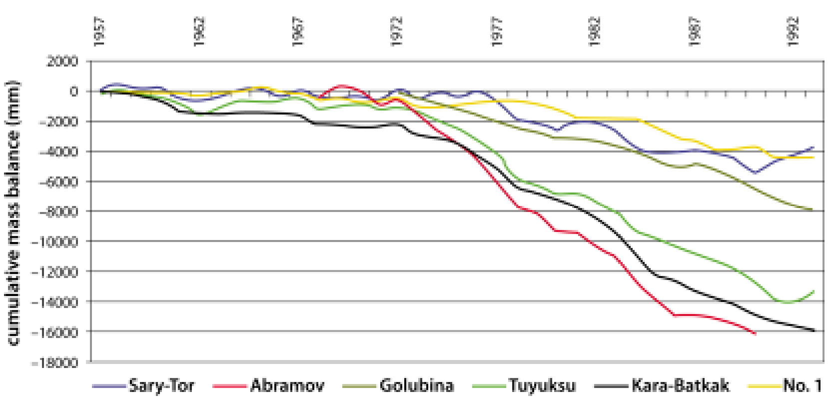
State	Quantity of snow measuring routes (basins with air supervision)		
	1985	1995	2004
Uzbekistan	18 (18)	2 (7)	2 (7)
Kyrgyzstan	15 (13)	0	0
Tajikistan	28 (12)	2 (0)	7 (3)

Table 3: Change of the hydrological monitoring network in Central Asia (extracted from Glazirin 2009)

State	Quantity of posts in years		
	1985	1996	2004
Uzbekistan	155	119	131
Kyrgyzstan	147	111	76
Tajikistan	139	85	81
Turkmenistan	38	23	32

Based on the extensive literature review conducted for the UNDP report "Central Asia Glaciers' Study - Current state of knowledge and recommendations", the average degradation rate in Central Asia varied between 30 and 35 percent in the last century and between 20 and 30 percent in the last 50 years; however, these values have not been constant through time, as illustrated in Figure 4, which also shows a rather abrupt worsening of glacier conditions in the Central Asia region during and since the mid-1970s.

Figure 4: Cumulative mass balances of several well-studied Central Asian glaciers



Source: Kuzmichenok 2009

One issue under debate concerns the eventual disappearance of the glaciers of Central Asia. While some scientists suggest that by 2050, about 32 percent of glacier volume will have disappeared in the region, others estimate that a compensation process involving underground ice (permafrost, rock glaciers) will preclude the glaciers' disappearance.

Key points:

- Glaciers across the world have been shrinking significantly at a rate that varies in time and space.
- Despite a general trend of glacier retreat in Central Asia, the estimates of retreat rate vary significantly.
- Averaged degradation rates have varied between 30 and 35 percent in the last century and between 20 and 30 percent in the last 50 years.
- Regional differences make consistent understanding of the glacier situation in Central Asia challenging.
- Data monitoring gaps are significant in the region, which leads to differing estimates and levels of concern.
- Compensation mechanism and its potential impact on water resources should be studied.

Chapter 2: Why the Glaciers are Vanishing

When we try to pick out anything by itself, we find it hitched to everything else in the Universe.
John Muir, 19th century American naturalist and explorer of the High Sierras

There are a number of different factors affecting glacier degradation, and the process of glacier degradation is itself both complex and indirect, involving multiple interactions, contributing factors and feedback loops that can give rise to unexpected consequences. Among the main contributors to this complex process are changes in temperature and precipitation.

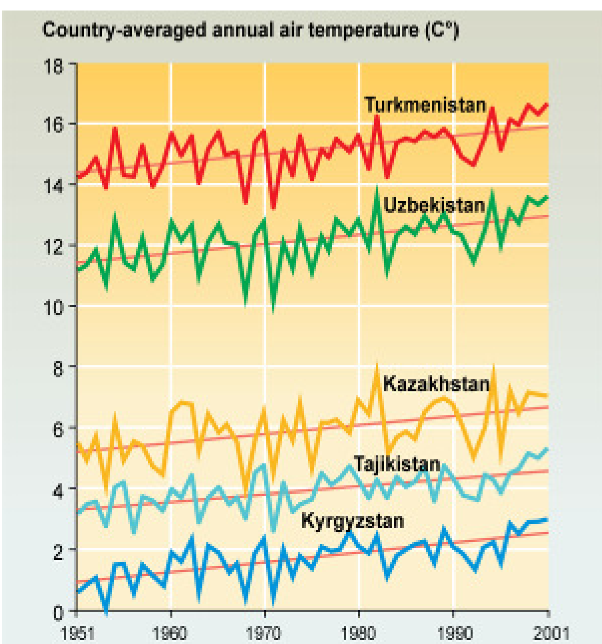
TEMPERATURE TRENDS

There is a strong consensus that the temperature has been rising throughout Central Asia (Figure 5), mainly due to greater increases during winter. The rates are not homogeneous, however, and vary geographically. The increase in mountainous areas has been lower than in the plains, and, in some cases, even cooling appeared.

When analyzing country average annual air temperature, it appears that the increase rate over the period varies between countries:

- Uzbekistan (1950-2005): 0.29 °C/decade
- Kazakhstan (1936-2005): 0.31 °C/decade
- Turkmenistan (1961-1995): 0.18 °C/decade
- Tajikistan (1940-2005): 0.10 °C/decade
- Kyrgyzstan (1883-2005): 0.08 °C/decade

Figure 5: Surface temperature trends

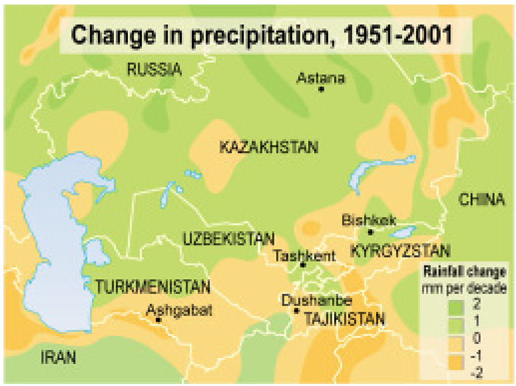


Source: ZOÏ, 2009

PRECIPITATION TRENDS

In terms of *precipitation*, no clear tendency emerges from an analysis of the literature. Most authors tend to define the situation as stable, but some mention significant increases or decreases at specific locations (Figure 6). The snowfall pattern is more or less similar.

Figure 6: Change in surface precipitations, 1951-2001



Source: ZOÏ, 2009

Once glaciers begin to lose their snow and ice, glacier degradation (Table 4) is commonly accompanied by increasing debris cover on many glacier termini and the formation of glacier lakes that have the potential to threaten downstream areas with outburst floods. Heavy debris cover acts as an insulator of the glacier ice, which becomes decoupled from climate changes. Inversely, snow cover, in particular in the ablation area, increases the albedo and consequently decreases the ablation. A diminution of snow cover would therefore accelerate the ablation rate.

Table 4: Area decrease in recent scientific literature (Fgl in km^2)

Basin/Region	Year	F_{gl}	Year	F_{gl}	Retreat of glacier, km²	Rate of retreat, %/yr	Duration of period, years
West Tien Shan	1957	170.8	1980	146.8	24.0	0.61	23
Vanch	1957	344.8	1980	291.6	53.2	0.67	23
Gunt	1957	534.1	1980	441.1	94.0	0.76	23
Matcha	1957	506.0	1980	437.9	68.1	0.58	23
W. Kzyl Su	1966	527.3	1980	486.4	40.9	0.55	14
Muksu	1966	2064.8	1980	1987.5	77.3	0.27	14
Obihingou	1957	810.2	1980	705.1	105.1	0.56	23
Pyanj (1)	1957	383.7	1980	268.9	114.8	1.30	23
Pyanj (2)	1957	52.0	1980	48.1	3.9	0.32	23
Syrdarya (1)	1964	548.1	1980	449.6	98.5	1.12	16
Syrdarya (2)	1964	303.9	1980	180.1	123.8	2.55	16
Shahdara	1957	216.3	1980	166.7	49.6	1.00	23
Yazgulem	1954	330.4	1980	262.7	67. 7	0.79	26
Total		**6793.4**		**5872.5**	**920.9**	**0.65**	

Notes: Pyanj (1) – RH tributaries of the Pyanj above Gunt estuary, Pyanj (2) – RH tributaries of the Pyanj below Vanch estuary, Syrdarya (1) – LH tributaries from the Aksu estuary and further below, Syrdarya (2) – LH tributaries of the Syrdarya from Karadarya estuary to Aksu estuary.

Source: Agaltseva and Konovalov, 2005 (extracted from Kotlyakov and Severskiy, 2009)

Permafrost and rock glaciers are not yet well studied and understood in Central Asia, but they constitute a potentially significant source of water as well as a natural hazard threat. Permafrost areas are, in comparison to glaciers, less sensitive components of the cryosphere, reacting slowly to climate changes. However, field measurements carried out in a few specific locations over several decades indicate an increase in the depth of thawing and a decrease in the thickness of the seasonally frozen layer of permafrost. This attests to potential impact of climate change on such ice bodies that could lead to negative effects on water resources for the region, as well as on the potential for climate-related disasters.

While changes in temperature and precipitation constitute the major contributors to the disappearance of the glaciers, there are other factors also affecting deglaciation. These include:

- the *size* of the glacier: a small glacier reacts more to a given climatic forcing than a big one. Narama et al.(2010) explains, for example, that the Pskem region [probably] experienced the largest glacier shrinkage (19 percent) because of its high proportion (59 percent) of small glaciers.
- *local climate*: in continental climate less glacier shrinking occurs than in more humid climate (Bolch and Marchenko 2009).
- the *orientation* of glaciers: south facing slopes are on average more stable and resistant to climate change, in spite of the fact that they are, as a rule, smaller (Glazirin 2009).

The fact remains that presenting a complete picture of glacier degradation is challenging, due to the limited number of hydrometeorological services that continued to be maintained after the collapse of the Soviet Union. This situation is slowly being rectified, but data gaps remain which limit our understanding of the glaciers of Central Asia.

Key points:

- Climate change has an impact on ice bodies, but the exact effect on the water resource of the region is still being defined.
- Glaciers with heavy snow cover have a tendency toward slower degradation.
- It is difficult to present a complete picture of glacier degradation due to limited access to observational data, a situation that needs to be addressed.

Chapter 3: Understanding the Repercussions

The Central Asian countries are particularly vulnerable to climate change, as melting glaciers pose long-term threats to water supplies on which some 55 million people, irrigated agriculture, and hydroelectricity infrastructure depend.
Ben Slay and James Hughes, Development and Transition NL

The current regional rate of average annual temperature increases of less than 1.0 °C per century has reduced glacier surface in the mountains of Central Asia by more than one-third. This ongoing glacier shrinkage is expected to have two major impacts on the more populated low plains area: water shortages during summer, and increased geohazard threats, such as glacier lake outburst floods (GLOFs).

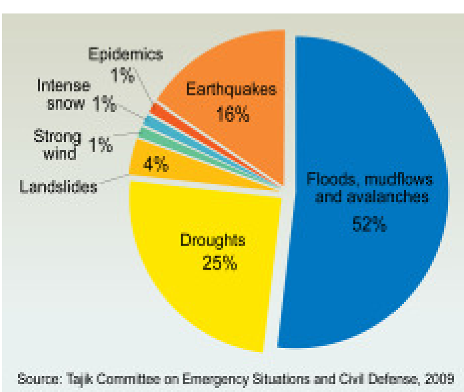
Comparison between climate change projections from the Intergovernmental Panel on Climate Change (IPCC) and actual climate values indicates that models might have underestimated the speed and magnitude of climate change, especially in terms of mountain glacier shrinking in Central Asia. If this is the case, then even if Central Asia's glaciers will not completely disappear in a near future, ongoing glacier degradation could be detrimental to food security due to changes in the inter-annual discharge that are already contributing to more extreme events.

Current climate change predictions indicate that glacier retreat will continue, and may lead to the deglaciation of large parts of many mountain ranges in Central Asia in the coming decades. It is projected that the disappearance of the glaciers will accelerate as a result of higher temperatures in the coming years. Because of the critical role played by glaciers in dry years and their importance for long-term water storage, these shifts are likely to impact water availability.

Water runoff is likely to be affected by glacier melt. According to the available estimates of the national hydrometerological services, by 2050, water runoff in two major basins – the Amudarya and the Syrdarya – will decrease by 10 to 15 and by 6 to 10 percent, respectively. While the estimates vary, it is generally agreed that the changes in runoff due to glacier melt will be substantial over the long term and have long-lasting impacts on the region.

In mountainous regions, the permafrost degradation will modify environmental conditions in a way that could increase slope instability and permafrost-related hazards, such as landslides and mudflows. Figure 7 shows that in Tajikistan, the risk of mudflows is the greatest natural hazard threat in the country.

Figure 7: Damage from natural disasters in Tajikistan (1998-2008) by type of hazard



Source: ZOI, 2009

The urbanization of much of Central Asia has led to construction of buildings and roads on the unstable slopes of foothills around the alluvial fans. The potential riskiness of this situation has magnified over the past century due to increased population, and the increasing number of glacial lakes that have developed due to glacier retreat. As glaciers melt, creating more and larger glacial lakes, there is increased risk that lakes will overflow and dams be breached, as already happened before during the 1960s and 1970s. In Kyrgyzstan during the last 50 years there were more than 70 incidents of glacial lake outbursts. Ikedavan lake outburst in 1998 was the largest one, taking more than 100 lives and causing damage to 5 villages.

River discharge is a key factor in glacier retreat. Today, river capacities are already fully consumed in Central Asia, but river discharge figures found in the literature still demonstrate great variability, both in terms of describing trends and in pinpointing what part of discharge is glacier contribution. They range from 4 to 70 percent. Acquiring a clearer understanding of river discharge over time is important in Central Asia: the subject is complex, principally due to the great influence of irrigation systems in the region. But at the very least it should be possible to measure the variations in water quantity through time at its source in the mountain ranges, before the water reaches the lowland irrigated areas that will consume it.

It should be noted that the changes occurring in the region due to the degradation of the glaciers – including the increased risk factors for climate-related disasters – will have profound impacts on the sustainability of current disaster management practices and the well-being of the region's populations. Certain level of dependence on glacier-fed water resources, particularly in dry years, for agricultural and economic activities increases the region's vulnerability.

Key points:

- If the current rate of deglaciation continues, glaciers may disappear completely by the end of the 21st century.
- Ongoing degradation of glaciers is expected to have two major impacts on the more populated low plains: water shortages during summer, and increased natural hazard threats.
- Changes in water runoff due to glacier melt could be substantial and have long-lasting impacts on the region.
- Shifts in environmental conditions, such as increased water runoff, could increase slope instability and permafrost-related hazards, such as rock glaciers movement, creep, thermokarst, etc.
- River discharge over time is a vital factor in understanding the glacier melt situation, but this is a highly complex issue with multiple data gaps.

Chapter 4: Filling in the Blanks – Next Steps

The lack of factual information on processes and natural phenomena at high altitudes in cold mountain regions forces scientists to use secondary data, indirect methods and to make assumptions when constructing forecast models. This explains the lack of consensus among scientists on the impact of climate change on the region's water resources in general and glaciers in particular.
Igor Vasilievich Severskiy, Head, Laboratory of Glaciology, Kazakhstan's institute of Geography, A World of Science, UNESCO

Across Central Asia, all data analysis indicates a smooth increase in temperatures. There is also general scientific consensus that glaciers are shrinking. But at the regional level, analysis of precipitation and river discharges does not -- so far -- identify any single overall trend.

Discussions and controversies are due to differences of scientific viewpoint and interpretation, fragmentation of baseline data and scientific research (past and ongoing), as well as obvious data gaps following the breakup of the USSR at the beginning of the 1990s. These circumstances add to the challenge of achieving any consensus or regional understanding of the glaciers' conditions.

Therefore, in order to get a clearer picture of glaciers and their related impacts on water resources in Central Asia, strong and clear actions must be defined and implemented as soon as possible. These are necessary preconditions for planning and improving regional water resources management in order to deal with change.

In the first instance, strong emphasis must be placed on the scientific assessment of glaciers' situation and potential impacts on the region. Some of the priority actions include:

I. Managing existing data

A key element when studying climate change and its impacts on glaciers is the availability of solid baseline data. Reliable data remains a weak point in the region. Possible means of addressing these issues include:

1. Establishing a multi-country catalogue of metadata on glacier monitoring, climate and hydrology, in order to organize the next phase of the data process.
2. Centralizing the key parameters (climatic, hydrologic and glacier monitoring) in a common database following international recommendations and standards.
3. Digitizing of printed-on-paper, or so-called lost data, with a state of the art quality check before integrating them into the database.
4. Sharing data, among regional and international stakeholders, to increase the exchange capacity at regional and international levels, the visibility of scientific activities in the region as well as the acceptance of common baseline references.

II. Generating new data

1. Monitoring is another key element of sound scientific research. The re-activation of monitoring interrupted in the 1990s is essential, and should include:

- In-depth study (field and remote sensing) of "strategic" glaciers and rivers.

- Basic study (field and remote sensing) of a larger panel of glaciers and rivers to intersect with the "strategic" one.
- Remote sensing monitoring of the remaining glaciers with the aim to create a new catalogue of glaciers.

2. Another avenue for future development is the improvement of infrastructure in terms of satellite imagery reception. For example, while equipment was installed in Kazakhstan between 2000 and 2005, a network for sharing high-volume data is still missing, as well as the capacity and the knowledge to process and store them.

3. There is currently no effective connection between international remote sensing activities, such as such as GLIMS (Global Land Ice Measurements from Space) and in-field activities. There is a need to reinforce local remote sensing capacities, but just as important is the need for checking and calibration through ground observation. Field expeditions will have to be organized. For these activities to be cost-effective, collaborative (i.e. multi-organization) studies should be conducted.

4. Installing automatic stations is another possible avenue for future development. While critics highlight the high cost and fragility (in term of degradation, vandalism or simply maintenance) of such equipment, others believe that it is the only way to guarantee proper data transmission and storage. A possible solution may be found through involving the local communities and authorities in glacier and station surveillance activities.

III. Supporting scientific research

Specific studies devoted to glacier and permafrost related hazards in mountain areas are needed. The task is colossal and, in order to be effective, activities will have to be prioritized and focused, keeping in mind a climate change study time scale (meaning a 10- to 20-year timeframe that will necessarily involve trans-boundary and international collaborations). It is also important to support modeling of climate-induced glacier change and its potential impacts on regional water resources.

IV. Regional cooperation

The last piece to be filled in is the strengthening of regional cooperation in Central Asia. Building better partnerships is a crucial last step and one that will impact significantly on every other initiative in the region. In conjunction with efforts to expand cooperation, it is also essential to foster capacity-building within regional governmental services along with awareness-raising at the grassroots level. These initiatives will help ensure proper monitoring of the glaciers, assist with protection of on-the-ground material and improve the region's potential for implementing early warning systems. The Central Asian Regional Glaciological Centre in Kazakhstan, under the auspices of UNESCO (category 2), will work to promote regional cooperation and advance other priority areas mentioned above.

Key points:

- It is vital to improve regional and international collaboration on glacier monitoring.
- Development of increased data monitoring equipment and practices is a key avenue for improvement.

- Data sharing among regional and international partners will foster better understanding of the glacier situation.
- Engaging the local populations and local authorities can greatly improve and expand monitoring activities as well as allow for better early warning systems for climate-related disasters.
- Digitizing of printed-on-paper data and dissemination of data would help to partially fill the knowledge gaps.

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Table 5. Selection Of Global Data Sets Available at No Cost on the Internet

	Glacier database	*Digital Elevation Model (DEM)*	*River discharge*
	Global Land Ice Measurements from Space (GLIMS) http://glims.colorado.edu International consortium established to acquire satellite images of the world's glaciers, analyze them for glacier extent and changes, and to assess these change data in terms of forcing. GLIMS Glacier Database contains a polygon and a point layer including 85'442 records in total. Although this inventory is occasionally updated, it is essentially a static snapshot of glaciers, and not designed to enable tracking of glacier evolution over time.	**CGIAR Consortium for Spatial Information** http://srtm.csi.cgiar.org/ The CGIAR-CSI GeoPortal is able to provide SRTM 90m Digital Elevation Data for the entire world. The SRTM digital elevation data, produced by NASA originally, is a major breakthrough in digital mapping of the world, and provides a major advance in the accessibility of high quality elevation data for large portions of the tropics and other areas of the developing world. The SRTM digital elevation data provided on this site has been processed to fill data voids and to facilitate its ease of use by a wide group of potential users.	**Global Runoff Data Centre (GRDC)** http://www.bafg.de/cln_005/nn_266934/GRDC/EN/Home/ International data centre operating under the auspices of the World Meteorological Organization (WMO). Contains collection of river discharge data collected at daily or monthly intervals from more than 7700 stations in 156 countries. This adds up to around 310 000 station-years with an average record of 40 years. The GRDC provides discharge data and data products for non-commercial applications.
World Glacier Inventory (WGI) http://nsidc.org/data/g01130.html The collection and compilation of measurements of glaciers from around the world, based mainly on satellite images. Parameters within the inventory include: geographic location, area, length, orientation, elevation, and classification of morphological type and moraines. The inventory entries are based upon a single observation in time and can be viewed as a "snapshot" of the glacier at this time.	**National Snow and Ice Data Centre NSIDC** http://nsidc.org/data/index.html The database contains information for over 100 000 glaciers throughout the world. Being a part of the Cooperative Institute for Research in Environmental Sciences, NSIDC supports research into our world's frozen realms: the snow, ice, glaciers, frozen ground, and climate interactions that make up Earth's cryosphere. NSIDC manages and distributes scientific data, creates tools for data access, supports data users, performs scientific research, and educates the public about the cryosphere.	***Central Asia Water Information*** **Central Asian Knowledge Portal** http://www.cawater-info.net/index_e.htm Portal that focuses on water and land resources and environmental problems in the Aral Sea basin. The website centralize and distribute a selection of tools, data set and documents related to legal, operational, and thematic information on water management and use in Central Asia, as well as data, updated every 10 days, telling how much water the region gets, how this water is allocated, whether actual values are lower of higher than forecasts or planned values, and, the most important, where do we move with our water use.	**Russian River Flow Data by Bodo, Enhanced** http://dss.ucar.edu/data sets/ds553.2/. Source of data for Central Asia, contains monthly river flow rates for Russia and former Soviet Union countries augmented with data from Russia's State Hydrological Institute (SHI) and a few sites from the Global Hydroclimatic Data Network (GHCDN) . This compendium (v1.1 September 2001) includes 2458 gauges spanning all major river and oceanographic basins of the entire former Soviet Union.
World Glacier Monitoring Service (WGMS) http://www.wgms.ch Network of local investigators and national correspondents in all countries involved in glacier monitoring. WGMS collects and publishes worldwide standardized glacier observations on changes in mass, volume, area and length of glaciers with time (glacier fluctuations), as well as statistical information on the distribution of perennial surface ice in space (glacier inventories).	***Satellite imagery*** **Global land Cover Facility (GLCF)** http://ftp.glcf.umd.edu/index.shtml A common source of free satellite imagery. GLCF develops and distributes remotely sensed satellite data and products that explain land cover from the local to global scales. GLCF research focuses on determining land cover and land cover change around the world. Primary data and products available at the GLCF are free to anyone via FTP.	***Climate information*** **KNMI Climate Explorer** http://climexp.knmi.nl/ Global climatic data set available at the Royal Netherlands Meteorological Institute (KNMI). It is a web application and scientific tool used for analysis of climate data statistically. This data set unfortunately contains numerous gaps and a net decrease of precipitation records since 1990.	**International Hydrological Programme (IHP)** http://webworld.unesco.org/water/ihp/db/shiklomanov/ Observation of data on monthly and annual river runoff from major stations (more than 2000 hydrological stations) located in different countries in each continent. These data have been taken from different sources (e.g., GRDC, publications of UNESCO and of other international organizations, archives of the State Hydrological Institute, national sources, including data on special request) and have been used for the assessment of the dynamics of renewable water resources on the global scale and fresh water inflow to the World Ocean.
Global Terrestrial Network for Glaciers (GTN-G) http://gtn-g.org/ Network that attempts to connect intensive local studies on individual glaciers with coverage of large glacier ensembles. GTN-G aims to combine field observations with remotely sensed data, process understanding with global coverage, traditional measurements with new technologies by using an integrated and multi-level monitoring strategy.	**Planet Action** http://www.planet-action.org/ The project, that supports local projects acting on climate change-related issues by providing geographic information and technology to NGOs, universities, research centres, etc through the supply of SPOT satellite imagery (10-20 m multi-spectral and 2.5 m. panchromatic).	**The National Climatic Data Centre (NCDC)** http://www.ncdc.noaa.gov/oa/ncdc.html Database that centralizes and distributes hydrometeorological data sets called Global Summary of the Day (GSOD). The data set contains daily: mean temperature, mean dew point, mean sea level pressure, mean station pressure, mean visibility, mean wind speed, maximum sustained wind speed, maximum wind gust, maximum temperature, minimum temperature, precipitation amount, snow depth, indicator for occurrence of fog, rain or drizzle, snow or ice pellets, hail, thunder, tornado/funnel cloud.	***General Data*** **Natural Earth** http://www.naturalearthdata.com/ Public domain that centralizes map data set freely available at different scales. It features tightly integrated vector and raster data that allows to create well-crafted maps with cartography or GIS software.