To RC1:

Dear Ludwig,

Thank you for the valuable input to the paper! We've made the corrections to the paper according to your marks in the text. See the attached version bellow

To RC2:

Dear Reviewer,

On behalf of my co-authors, we thank you very much for giving suggestions to our manuscript and the evaluation of the presented dataset. We have tried our best to revise our manuscript according to the comments. The main corrections in the paper and the responds to the reviewer's comments are as flowing:

1. English is very poor and there are so many cases with typos, errors, and unclear sentences (e.g., sentences in page 2 line18-19). The entire paper needs to be proofread for grammar.

The text has been edited.

In abstract the authors mentioned 30% of the basin is covered with glaciers, in page 2 line18-19 this number is 27%, and the range of elevation is also not consistent with that in the abstract. Provide accurate numbers for glacier area and elevation range. Again in page 4, the authors report a different number for drainage area. I recommend explaining these numbers only once and avoid inconsistency.

Thank you for outlining that, the values were corrected, duplication of this information was removed.

2. Study area in section 2 should be very brief and focus on the data and basin characteristics. There are redundant information about the previous works in the region, which are not relevant to the focus of a data paper. For instance, last two paragraphs in this section (2. Study area) can easily be removed.

The Study area section was shortened, only a very brief description of the North Caucasus mountain system is given, the climate change background and hydrological characteristics and trends of direct relevance to the Study area are given.

3. For better presentation of the data, I recommend authors to provide a summary of the data and sampling time steps and record period in a table. Tables 2 and 3 and Tables 6 and 7 can be merged and modified to summarize variables name, unit, time step, record period, long term annual means, sensors (or estimation methods) used for measuring. It its current version, these information are repeated in both text and separate tables, which makes it difficult to follow. This needs more organizations. For instance, a summary table with all the information would be enough and there is no need to discuss in each subsections about the sampling intervals and instruments, and period pg 8 line 2, 11, 27, 29 or pg 10 line 6 or pg 11 line 2.

Thank you for the suggestion, the Tables were merged, we tried our best to exclude repetition from the text

4. Section 3.3 Meteorological measurements needs to be more concise avoiding instrument names. Instruments names can be provided in a table and not repeated multiple times in the text.

The section was edited according to the suggestions. Only those explanations of methods that were too long to be placed in a table were left in the text.

5. There are so many redundant figures. Figures 1, 2, and 6 can be merged. Figures 4 and 5 do not belong to the dataset provided in this paper. I suggest removing them. What is "SMOW" on Figure 12? Figure 14, annual trends are not significant, remove the trend lines and equations. What is "w.e." in y-axis. Delete Figure 16, 17. Figure 11 can also be removed and instead be illustrated in a sentence in the text.

The amount of Figures was reduced from 17 to 11. It was decided to leave the Figures 10 and 11 (previously 16 and 17) in the text as it gives an idea of what the meteorological dataset looks like that can be convenient to the readers to make a decision if it meets their needs.

On Figure 7 (previously Figure 12) it would be more correct to name the axes as “δD, ‰” and “$\delta^{18}O$, ‰”. The Figure has been edited.

The trends on the Figure 9 (previously Figure 14) are statistically significant according to the Spearman rank test at the 5% significance level. The p-values were added to the graph. w.e. is explained in the caption

6. How was snow differentiated from glacier in mass balance estimations? Explain.

As the dataset doesn’t contain the results of mass-balance calculation this part was removed from the text

7. Correct the full website address for the dataset access.

The doi of the dataset is provided that uniquely identifies its URL.

Editorial comments:

Thank you for the suggestions, the text was corrected accordingly. Except for several cases when the authors’ variant remained in the text:

all over the manuscript: add "δ" before "18O" or "2H" or "D" isotopes to be consistent. Use "δˆ18O" and not alternatives of 18O nor "δ18O".

δD and $\delta^{18}O$ is used in the text, when it means the concentrations of ^{18}O and D expressed in the values of δ: $\delta D = [(^2H/^1H_{sample} – ^2H/^1H_{standard})/^2H/^1H_{standard}] \times 1000‰$; $\delta 18O = [(^{18}O/^{16}O_{sample} – ^{18}O/^{16}O_{standard})/^{18}O/^{16}O_{standard}] \times 1000‰$. The explanation was added to the text.

Sincerely,

Authors

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Djankuat Glacier Station in the North Caucasus, Russia: A Database of ~~complex~~ glaciological, hydrological, meteorological observations and stable isotopes sampling results during 2007-2017

Ekaterina P. Rets[1], Viktor V. Popovnin[2], Pavel A. Toropov[2,8], Andrew M. Smirnov[3], Igor V. Tokarev[4], Julia N. Chizhova[5], Nadine A. Budantseva[2], Yurij K. Vasil'chuk[2], Maria B. Kireeva[2], Alexey A. Ekaykin[6,7], ~~Anna V. Kozachek[6]~~Arina N. Veres[6], Alexander A. Aleynikov[2], Natalia L. Frolova[2], Anatoly S. Tsyplenkov[2], ~~Alexey~~Alexei A. ~~Polukhov[2]~~Poliukhov[8], Sergey R. Chalov[2], Maria A. ~~Aleshina[8]~~Aleshina[9], Ekaterina D. Kornilova[2]

[1]Water Problems Institute, Russian Academy of Sciences, Moscow, 119333, Russia
[2]Faculty of Geography, Lomonosov Moscow State University, Moscow, 119991, Russia
[3]Laboratory of Glaciology, Institute of Geography, Russian Academy of Sciences, Moscow, 119017, Russia
[4]St. Petersburg State University, Geomodel Resource Center, St. Petersburg, 199034, Russia
[5]Institute of Geology of Ore Deposits, Petrography, Mineralogy and Geochemistry, Russian Academy of Science, Moscow, 109017, Russia
[6]Arctic and Antarctic Research Institute, Climate and Environmental Research Laboratory, St. Petersburg, 199397, Russia
[7]Institute of Earth Sciences, Saint Petersburg State University, St. Petersburg, 199034, Russia.
[8][8] Hydrometeorological Research Center of Russian Federation, Moscow, 123242, Russia
[9] Laboratory of Climatology, Institute of Geography, Russian Academy of Science, Moscow, 119017, Russia

Correspondence to: Ekaterina P. Rets (retska@mail.ru)

Abstract. The study presents a dataset on long-term ~~complex~~multidisciplinary glaciological, hydrological, meteorological observations and isotopes sampling in ~~an extremely underreported~~sparsely monitored alpine zone of the North Caucasus~~. The~~ in the Djankuat research basin. The Djankuat glacier which is ~~of 9.1 km², situated on elevations between 2500 – 4000 m, by 30% covered with glaciers. The biggest~~the largest in the basin~~ – the Djankuat glacier,~~ was chosen as representative of the central North Caucasus during the International Hydrological Decade and is one of 30 'reference' glaciers in the world ~~that~~which have annual mass balance series longer than 50 years (Zemp et al., 2009). The dataset ~~covers~~features a comprehensive set of variables from 2007–2017 observations and contains the ~~result of~~ yearly measurements of snow ~~thickness~~depth and density; dynamics of snow and ice melting; ~~measurements of~~ water runoff, conductivity, turbidity, temperature, $\delta^{18}O$, ~~δ^2H on~~δD at the main gauging station (844 samples in ~~sum~~total) with ~~a one-hour~~an hourly or ~~several hours~~subdaily time step depending on the parameter; data on $\delta^{18}O$ and δ^2H sampling of liquid precipitation, snow, ice, firn, groundwater in different parts of the watershed taken regularly ~~in time~~ during melting season (485 samples in ~~sum~~total); precipitation amount, air temperature, relative humidity, shortwave incoming and reflected radiation, longwave downward and upward radiation, atmospheric pressure, wind speed and direction – measured ~~on~~at several automatic weather stations within the basin with 15 min ~~–~~to one-hour step; gradient meteorological measurements to estimate turbulent fluxes of heat and moisture, measuring three components of wind speed at a frequency of 10 hertz to estimate the impulse of turbulent ~~impulse heat~~ fluxes of sensible and latent heat over the glacier

surface by the eddy covariance method. ~~All the observations were done~~Data was collected during the ablation period (June–September~~)~~). The observations and were ~~interrupted~~halted in winter. The dataset ~~was published on knb.ecoinformatics.org long-term repository doi:10.5063/F1H1307Q~~is available from Pangaea (doi:10.1594/PANGAEA.894807) and will be further updated. The dataset can be useful for developing and verifying hydrological, glaciological and meteorological models for ~~high elevation territories~~alpine areas, to study the impact of climate change on hydrology of mountain regions, using isotopic and hydrochemical approaches ~~to study mountain territories.~~in hydrology. As the dataset includes the measurements of hydrometeorological and glaciological ~~parameters~~variables during the catastrophic proglacial lake outburst in the neighboring Bashkara valley in September 2017, it is a valuable contribution to ~~the study of this dangerous hydrological phenomena~~study lake outbursts.

1 Introduction

~~The important role of mountains territories and high sensitivity to the climate change is concluded in vast amount of recent research~~Mountain areas there are highly sensitive to climate change (Dyurgerov, 2003, Weingartner et al., 2007, Auer et al., 2007, Viviroli et al., 2011, Pachauri et al., 2014, Zemp et al., 2015). However, it is widely recognized that there is still a great lack of observational data on climate, glaciers and hydrology of mountain areas (Gietl, 1990, Barry, 1992, Singh et al., 1999, ~~Global change…, 2001,~~ Schaefli et al., 2005, Bales et al., 2006~~,)~~.). The density of hydrological stations in the world's mountainous regions is from 3 (in Europe) to 100 (in Asia) times lower than those recommended by the World Meteorological Organization (Viviroli et al., 2011, Bobrovitskaya~~,~~ and Kokorev, 2014~~,)~~.). The majority of field observations in mountainous catchments are conducted in Scandinavia, the Alps and the mountains of the USA, while vast Asian territories~~,~~ and the Southern Hemisphere ~~stay extremely understudied~~are sparsely monitored (Barry, 1992, Dyurgerov, 2003, Meier et al., 2003, Zemp et al., 2009, Viviroli et al., 2011, Immerzeel et al., 2012~~,)~~.). The Great Caucasus~~, that~~ used to have a developed observational network during the Soviet Union period~~,~~. But recently ~~joined the mentioned above~~it became also a poorly ~~studied territories in terms of level of information availability on meteorological~~instrumented terrain lacking high quality glaciological and ~~glacio-hydrological topics~~hydrometeorological data (Barry, 1992, Dyurgerov, 2003, Shahgedanova et al., 2005, Bobrovitskaya~~,~~ and Kokorev, 2014).

The specificity of this dataset is a relatively long measurement period of 10 years (2007–2017) including several high discharge events covered in a multi-site measurement program and the extensive set of measured variables, which is unique for the North Caucasus area.

The Djankuat research basin, 9.1 km2 in area, is located at 43.~~2N~~2ºN and 42.~~75E~~75ºE in the alpine zone of the North Caucasus (Russia), between 2600 and 4000 m (Fig. 1). Djankuat glacier, ~~occupying~~covering 27% of its area, was chosen as representative of the central North Caucasus during the International Hydrological Decade (IHD) - research program on water problems launched by UNESCO in 1965 (Boyarsky, 1978). The mass-balance measurements have been carried out on Djankuat glacier since 1967 till now ~~without interruption (www.wgms.ch). Glaciological observations are carried out by~~on a regular basis

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Отформатировано: Цвет шрифта: Авто, Узор: Нет (www.wgms.ch) based on standard methods (Østrem and Brugman, 1992, Boyarsky, 1978). ~~Hydrological~~Detailed hydrological and meteorological ~~complex~~ measurements were included in the monitoring program of the station during the ~~International Hydrological Decade~~IHD and ~~were terminated~~ came to an end in the ~~end of~~late 1970s (Boyarsky, 1978). The ~~complex~~comprehensive hydrometeorological observation were resumed in the Djankuat research basin under the initiative of the collective of the authors since 2007. ~~The covered time period by hydrometeorological~~Hydrometeorological measurements were done during the ablation season ~~of each~~every year since 2007 and the observational program gradually ~~increased~~expanded during 2007–2017 and now goes beyond the standard network hydrological and meteorological observations. The relative cutting of the program in 2011–2012 ~~was related~~happened due to a special military regime ~~that was stated~~ in Kabardino–Balkaria republic ~~by the Government~~.

~~There are 4 main locations in the basin where the~~ Automatic Weather Stations (AWS) are ~~being~~ installed in 4 main locations in the basin (see Fig. 1, Table 1). All the meteorological stations operate only during the ablation season of each year. Two Campbell AWS are located in the central part of the Djankuat glacier above the ice surface (AWS1) and the debris of the glacier (AWS2). AWS1 operated through the period 2007–2017 (excluding 2011). The second Campbell station, located over the debris (~~AWS~~AWS2) was operating for three years (2007–2009). The both stations provide measurements of the air temperature, relative humidity, downward and upward shortwave radiation, downward and upward longwave radiation, wind speed, wind direction, atmospheric pressure. A Davis weather ~~stations~~station operated ~~in~~at Base Camp (Base Camp AWS) through 2007–2009 and 2013–2017. The second Davis (AWS3) station was placed on the upper part of the Djankuat glacier in 2017. A DAVIS Gradient mast ~~DAVIS~~ was placed in the central part of the Djankuat glacier (AWS1) in 2015 to obtain long-term meteorological data series in the surface layer. Turbulent pulsations of wind and acoustic temperature were measured in 2013, 2014 and 2016 with a 3–axis GILL WindMaster sonic anemometer ~~GILL WindMaster~~ in the central part of the Djankuat glacier (AWS1).

Hydrological measurements at the Djankuat gauging station (see Fig. 1, see Table 1) started from measuring runoff with one-hour step during 2007–2010 ablation seasons. In 2013 the first test measurements of water conductivity, water salinity, water turbidity, and stable isotopes (18O and 2H), as well as first ~~sampling~~samplings of liquid precipitation, snow, ice, firn in the basin on water conductivity, water salinity, δ18O and δ 2H ~~was~~were carried out. ~~Since~~From 2014 ~~up~~ to 2017 the stable isotopes sampling, conductivity measurements were done on a regular basis on the Gauging Station and on the watershed. A total amount of 844 samples on stable isotopes ~~was~~were collected on the Djankuat River Gauging station and 485 samples of snow, ice, firn, groundwater and liquid precipitation. ~~Regular monitoring~~At the outlet of ~~the~~ Djankuat River ~~water~~ turbidity (was recorded manually using portable turbiditimeter 5–7 times a day~~) was set during~~ in 2015–2017~~, of~~ water conductivity – during 2014–2017, water temperature – during 2015–2017.

The dataset was published on a long-term data repository (~~doi:10.5063/F1H1307Q~~doi:10.1594/PANGAEA.894807) and will be updated ~~as~~. Outcomes of the ~~observations in the basin are still ongoing (as of autumn 2018). Some~~research included studies of ~~the data, presented in the study was already successfully approbated in scientific work~~glacier mass balance (Zemp et al., 2009, Rets~~,~~ and Kireeva, 2010, Lambrecht et al., 2011, Zemp et al., 2011, Zemp et al., 2015, Popovnin~~,~~ and Pylayeva, 2015~~,~~)

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2 Study Area

The Greater Caucasus stretches 1300 km along the border between Russia and Georgia from the Black Sea to the Caspian Sea. The alpine zone extends above the orographic snowline ~~which height is approximately 2000 m, the highest point of the Greater Caucasus is Elbrus mountain (5642 m). The climate here is moderate continental. The main centers of atmospheric influence for the North Caucasus are extensions of the Icelandic depression from the west and the Siberian high from the east during the winter period and extensions of the Azores during the summer (Volodicheva, 2002, Shagedanova et al., 2005) influence of the Black Sea is superimposed on the general circulation. Together with the complex orographic effects it results in complex spatial precipitation distribution and strong precipitation gradients.~~approximately 2000 m above sea level. The Elbrus Mountain has the peak elevation in the Greater Caucasus reaching 5642 m. The climate is moderate continental to high-alpine. The precipitation decreases both southeastwards and with a decrease in elevation. Annual precipitation sum varies from 200–400 mm in Eastern plain part and 600–800 mm in Western plain part to 800–1300 and more in mountainous part (Rets at al~~,~~., 2018). ~~Great spatial variety is characteristic of river runoff~~ The water supply in the North Caucasus~~. The water supply of the region~~ is strongly dominated by runoff formed in the high mountains, a unit of area at an elevation of ~~3–4 km~~3000–4000 m can be 10 times more ~~effective~~productive in terms of water ~~resources~~yield than the lowlands. In the most alpine zone of the North Caucasus annual unit discharge varies from 20–30 to 50–60 liters~~/~~(/km2.s~~*sq.km)~~. In the foothills mean annual runoff unit discharge sharply declines to 5–15 liters~~/~~(/ km2.s~~*sq.km). The vast plain territories not add much to the total runoff of rivers: the values of unit discharge decrease gradually in the Northeast direction down to zero and even less~~ (Rets et al., 2018). ~~Rivers with a substantial share of alpine zone in the total area of the watershed are characterized by a high-water period lasting from late spring to September and stable winter low-flow period. With a decrease in elevation the share of snowmelt in river runoff diminishes, the beginning of high-water and winter low-flow periods shifts to earlier dates, rain floods start playing a more substantial role in maximum discharges, winter low flow period is more often interrupted by snowmelt winter floods. Annual water regime of rivers in the plain territory of the North Caucasus depends on annual distribution of precipitation. In the central and Eastern North Caucasian plain territory precipitation occurs mostly in summer that results in summer flood period and both winter and summer low-flow periods. Winter precipitation maximum is characteristic of the Western part of North Caucasus (Rets et al., 2018).~~

The Djankuat research basin~~ (43.2N, 42.75E)~~ is situated on the northern slope of the central part of the Main Caucasian Ridge (see Fig. 1). It is a typical alpine watershed of 9.1 km^2 with the elevation range 2600 – 4000 m, with steep slopes (more than 20° in average) and nival-glacial landscape (see Fig. ~~2~~1). An overall exposition of the basin is the North-North-West. ~~Glaciers occupy 30~~In the 2017 glaciers occupied 27% of the territory of the basin. The main glacier with the same name – Djankuat glacier – ~~gives a~~is the source of the Djankuat ~~river~~River. It is a valley glacier, with the lowest point of the tongue at approximately 2750 m, the elevation of the bergschrund ~~of~~is at 3600 m. The mean elevation of the glacier is 3210 m, the area is 2.~~6~~42 km^2~~,~~, and its length ~~–~~is 3.0 km. The maximum measured thickness of the glacier is 105 m~~ at~~, and the average thickness ~~of~~is 31 m (Lavrentiev et al., 2014). The Djankuat ~~river~~River basin also contains three small glaciers with ~~the area~~areas less than 0.5 km^2: Koyavgan, Via-Tau, and Visyachiy. These glaciers ~~give a rise~~contribute runoff to ~~water streams that join~~ the Djankuat ~~river~~River upstream ~~of~~ the main ~~Gauging~~gauging station (see Fig. 1). The Djankuat River is a source of the Adul-Su River – a tributary of the Baksan River which drains into the Caspian Sea via the Terek ~~river~~River.

The uppermost gauging station on the Baksan River was situated 12 km from its source in Usengi. The river basin area at the gauging station is 180 km^2. The mean annual ~~unit~~ discharge ~~in the upstream~~ of the Baksan River ~~is~~ at Usengi gauging station is 9.9 m^3/sec that amounts to mean unit annual discharge of 55 liters per sec. per km^2 (Rets, Kireeva, 2010). The water-abundant period~~, which lasts~~ of the Basksan River in the upstream is prolonged and steady, it extends from May to September–October~~, is prolonged and steady. The fundamental~~. The general wave of runoff hydrograph, formed by snow and ice melting, is overlain with sharp peaks of rain floods. The maximum water levels are usually recorded in July~~, while their drop starts in August.~~. A stable winter low-flow period with minimum monthly ~~unit~~ discharge of ~~10–15 liters per~~ 2.4 m^3/sec~~. per km^2~~ is observed in February~~–~~ to March ~~is characteristic of the Baksan River upstream~~ (Rets, Kireeva, 2010). Annual river runoff in the mountainous part of the North Caucasus shows a slight positive trend during 1940–2010. In the most elevated areas the long-term mean value of annual runoff remains stable (Rets et al., 2018).

The climate of the Djankuat research basin is characterized by a distinct seasonality in temperature. The mean monthly air temperatures ~~on~~at the Terskol, the closest to the research basin all-year ~~Terskol~~ meteorological station, situated 16 km northwest of the ~~glacier~~study area at an altitude of 2146 m goes below zero during November–December. The warmest months are July and August with mean monthly temperatures above 12 ºC (Fig.~~3~~ 2). Monthly precipitation totals are 40–50% higher in the warm period of the year (May–September) than during winter (Fig. ~~3~~2). The annual precipitation ~~some on~~at the Terskol weather station varied from 590 to 1330 mm with a mean annual value of 950 mm. Daily precipitation maxima occur in July~~–~~ to September in response to convective activity triggered by a combination of strong insolation and depressions developing on the Polar front and enhanced by the orographic uplift (Shagedanova, 2002).

The observations in the Djankuat research basin, included in the presented dataset, were carried out under the conditions of slightly warmer summer ~~period than~~periods in comparison to the long-term average, and substantially higher ~~amount~~amounts of precipitation, especially during the spring period – from March to May (Fig. ~~3~~2). The strong influence of spring snowfalls during the observation period also is reflected in the results of Djankuat glacier snow sampling for stable isotopes (Rets et al., 2017). The outlined tendency is likely to be the consequence of ~~the~~ climate change in the region.

According to the majority of studies (Alekseev et al., 2014, Toropov et al., 2018a, Rets, Kireeva, 2010) a statistically significant positive trend in air temperature amounting to 0.7 – 1 ºC per decade is observed during the summer period in the North Caucasus. ~~According to (Rets, Kireeva, 2010) this tendency is more clear cut in the plain territory and foothills.~~ A slight positive trend in the mean temperature ~~of~~in the ablation period (May~~–~~ to September), 0.3 ºC per decade, is observed ~~on~~at the Terskol meteorological station since the end of 1970th ~~(Fig. 4). These timing of alteration in the air temperature tendencies regime~~

corresponds well with the situation observed on the European territory of Russia, where he time period starting from 1978 is identified as a "contemporary period" in term of the recent climate forced changes in river runoff regime (Frolova et al., 2014, Rets et al., 2018).

. In the winter period the observed tendencies in air temperature in the North Caucasus are very inhomogeneous: Alekseev et al. (2014) report a statistically insignificant positive trend. Toropov et al. (2018a) claim a statistically significant rise in air temperature of the winter period is observed in the Eastern Caucasus, close to the Caspian Sea. In the study (Rets, Kireeva, In the study by Rets and Kireeva (2010) a decrease in air temperature of the winter period was revealed in the mountainous part of the North Caucasus. According to the on the Terskol meteorological station the value of mean air temperature during the accumulation season (October– to April) remains stable in the study area (Fig. 4)..

According to different studies either, a positive trend in annual precipitation sum (of 5% per decade (is reported by Alekseev et al., . (2014), orand no statically significant trend is observedreported for the most of the North Caucasus (by Toropov et al., . (2018a). An increase in annual precipitation sum was revealed for the mostmajority of mountainous stationstations and a number foothill ofof foothills located in the central part of Northern Caucasus (Rets, Kireeva, 2010). OnAt the Terskol meteorological station the amount of precipitation is constantly rising during the whole observational period (Fig. 5).. The increase in annual sum is 3.5% per decade is due todifferent for the ablation (2.1% per decade) and accumulation (5% per decade) period. The most intensive rise in precipitation is observed in spring (8.6% per decade in March, 7% per decade in April) and autumn (10.3% per decade in October). This result is consistent with the result reported by Alekseev et al. (2014) for the whole territory of the North Caucasus.

The intensive degradation of glaciation is observed in the North Caucasus (Zemp et al., 2015, Shahgedanova et al., 2014, Zemp et al., 2015). The area of glaciers in the North Caucasus dropped by 12.6% during 1970–2000 (Voitkovskiy et al., 2004), and by 4.7% between 2000 and 2010/2012 (Shahgedanova et al., 2014), amounting to approximately 17% in total during 1970–2012. The glaciers terminus retreat increased from the 1987–2000/2001 period to the 2000/2001–2010 period by the factor 2.5–3.8. The highest recession rates of 11–14 m yr^{-1} were observed in the central Main Caucasus ridge and on Mountain Elbrus. The largest total retreat was registered for the Bolshoi Azau glacier, located on Mt. Elbrus. This glacier lost 500 m, retreating at a steady rate of 22 m yr^{-1} (Shahgedanova et al., 2014). Glacier retreat and the increase in supraglacial debris cover is also accompanied by the emergence and growth of proglacial lakes and related increase in proglacial lakes outburstslake outburst floods (Stokes et al., 2007). On the 1st of September 2017 an outburst of Bashkara lake in the upstream of neighboring to the Djankuat basin valley gave a rise to catastrophic mudflow that led to major destructions and human casualties (Chernomorets et al.,2018).

Annual river runoff in the mountainous part of the North Caucasus shows a slight positive tendency during 1940–2010. In the most elevated areas the long-term mean value on annual runoff remains stable. Whereas in in the plain part and within the foothills in the North Caucasus, where the annual runoff increased by 30–70% during last 3 decades (Rets et al., 2018). An increase in amount, duration and extent of thaws and general reduction of annual cold period duration in the lowest elevation belts of the North Caucasus is reflected in a 50–100% rise in minimum monthly discharges in winter. In mountainous area long-

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~~term oscillation of winter minimum monthly discharge strongly depends on local factors, such as geological structure. In the upper reaches of some tributaries of the Terek and Kuban River positive trends are still not observed, while in neighboring macrovalleys long-term variations of winter minimum monthly discharges correlate with the corresponding variations in the foothills and on plain. On the highest elevation belts, where the temperature is still strongly negative in winter for frequent thaws generation, winter minimum monthly discharge remains stable on the long-term scale (Rets et al.,~~ 2018).

3 Methods and results

3.1 Hydrological measurements

3.1.1 Discharge measurements

Water discharge of the Djankuat River at the gauging station (see Fig. 1, see Table 1) is calculated ~~with 1-hour step~~ from the water level using a rating curve Q=f(H) (Table ~~2). Water~~2a). The water level ~~is measured on the Djankuat gauging station~~was recorded with 10 min ~~–1 hour~~to hourly time step (depending on the year of observation) by means of an automatic water level logger with a pressure sensor (ADU-02 during 2007–2013, Solinst Level logger in 2014–2017). The level logger is placed with a ripple shield in an artificial bay constructed ~~on~~at the river bank (Fig. ~~6). Control~~3b). Additionally, manual water level measurements ~~are~~were made 6–7 times a day~~ by a staff gauge.~~. Rating curves ~~are redrawn~~were drawn for each month ~~of each ablation season (Fig. 7). A dilution~~on the yearly basis. Dilution method ~~with~~using NaCl as a tracer was used for discharge ~~measurements~~metering as turbulent flow conditions make it impossible to apply the current meter (Dobriyal et al., 2017). As there is a possibility of erroneous results due to the loss ~~and~~or incomplete mixing of the tracer arising from the difference in velocity in the upper and lower ~~surfaces~~layers of the stream (Dobriyal et al., 2017), ~~in course of~~ every discharge measurement ~~all the procedure~~ is repeated twice. The value is ~~supposed to be correct~~accepted, if the difference between the two simultaneous measurements ~~doesn't~~does not exceed 10%. For the most of the discharge measurements at the Djankuat gauging station this difference was less than 5%. 50–80 water discharges are measured every ablation season to draw a rating curve.

Water discharge at the Djankuat gauging station ~~mostly stayed in the~~ is observed within a range of 1– to 2 m^3/s ~~during the~~in 2007–2017 ~~observational period~~ (Fig. ~~8a~~4a), the mean value of water discharge was 1.39 m^3/s (Table 3). ~~Low frequency water discharges (less than~~ During high discharge events (1% ~~of duration) lay in the range of~~probability) streamflow rates ranged from 3.5– to 8.46 m^3/s. The maximum discharge ~~–~~, 8.46 m^3/s, was observed on the 1st of July 2015 at 9:00.~~ It was a result of a strong~~ due to heavy rain flood caused by 227 mm of precipitation in sum ~~for~~over 7 days superimposed on an intensive snow and ice melting in the river basin.

~~According to the results of the observation, the~~The inter-annual fluctuations of the Djankuat River runoff can be quite ~~sufficient~~substantial (Fig. ~~9~~5). The Djankuat River was the most abundant in water during 2015–2016, the least –in 2013. Mean water discharge for June– to September in 2015 (1.88 m^3/s) was twice ~~bigger than~~as large as in 2013 (0.97 m^3/s). The Djankuat River is most abundant in water in July (Fig. ~~9~~5). Mean monthly discharge in this month is 1.3–2.8 m^3/s. June and August are

Отформатировано: Основной шрифт абзаца, английский (Соединенное Королевство)

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Отформатировано: не разреженный на / уплотненный на , Узор: Нет comparable in terms of mean discharge~~:~~, 0.93~~–~~ to 1.8 and 1.0~~–~~ to 2.0 m^3/s ~~correspondingly.~~, respectively. In September ~~the~~ runoff ~~formed~~ due to ice and firn melting decreases with the decrease in the incoming solar radiation, the seasonal melt water ~~resources are~~is gradually drained from the Djankuat River basin. Mean monthly discharge is 0.6–1 m^3/s. ~~In~~At the end of September, the ablation period ends with the first stable fresh snow cover on the glacier.

The Djankuat River hydrograph has a ~~typical for glacial rivers~~ saw-tooth shape with a pronounced daily maximum and minimum typical for glacial rivers (Fig. ~~10~~6). A diurnal fluctuation of discharge is great and can be compared with the overall seasonal fluctuation: up to 1.5–2 m^3/s on a day without rain. The rise of a rain flash-flood can be very intensive: more than 1 m^3/s ~~in an~~per hour.

3.1.2 Electrical Conductivity and Salinity

~~Electrical conductivity (Cond) of water was measured at the Djankuat gauging station 6–7 times a day in 2014 and 2017 with an Electrical conductivity meter (conductometer Econics Expert-002). When a conductometer with a logger function was used in 2015–2016 the measurement was done with a 1-hour time step (Table 2).~~ Water salinity is calculated from the conductivity measurements~~,~~ (Table 2a), using a dependency Salinity=f(Cond). The dependency was drawn in 2013 using the data on simultaneous measurement of electrical conductivity and complete chemical analysis in 19 samples with conductivity from 4.2 to 87.5 µS/cm ~~(Fig. 11).~~

~~Total amount of~~ . ~~3464 electrical conductivity measurements was done at the Djankuat gauging station during 2007–2017 (Table 3).~~ The Djankuat River water is low-mineralized, the value of electrical conductivity stayed in the range of 55–85 µS/cm for ~~the~~ 90% of the time (Table 3, Fig. ~~9d~~4d). The electrical conductivity value strongly depends on the percentage of snow and ice melt water in the total river runoff. During long periods without rain with intensive melting the water of the Djankuat River can be diluted up to 40–50 µS/cm ~~in the~~during day time. ~~During~~On the daily minimums of water discharge ~~–~~in early ~~the~~ morning, the electrical conductivity rises by 10–30 µS/cm. ~~In~~At the end of the ablation season, when melting is strongly reduced, the electrical conductivity of the Djankuat River reaches ~~the~~ values of 110~~–~~ to 115 µS/cm during night–morning hours, ~~that~~which is ~~supposed to be~~ close to the value of electrical conductivity of groundwater in the basin.

3.1.3 Water Temperature

~~Water temperature was measured at the Djankuat gauging station 6–7 times a day in 2017 with a water temperature sensor built in a conductometer Econics Expert-002. When a conductometer with a logger function was used in 2015–2016 the measurement was done with a 1-hour time step (Table 2). Total amount of 3259 measurements was made (Table 3).~~ Water temperature has a close to a uniform distribution on the duration curve and is mostly within the range of 1.2–4.5 °C (Fig ~~8c~~. 4c). Water temperature of the Djankuat River has a great diurnal variation ~~(~~up to 4°C~~)~~. Diurnal maximum of temperature is usually observed at day time before the beginning of an intensive rise of diurnal wave of meltwater ~~inflow~~flow. Mean daily value of water temperature generally rises trough the ablation season (Fig. ~~10~~6). The maximum value (6.63 °C) was registered on 18th of September 2016 at midday. The minimum values (0.1 ºC) are observed atduring the night hoursin the beginning of the after-winterablation period (Fig 10. 6).

3.1.4 Water Turbidity

Turbidity of the Djankuat River was measured at the gauging station 6–7 times a day during 2015–2017. On the event of heavy rainfall, the time step of measurements is reduced to 15 minutes, these measurements are included in the database 1-hour averaged. Some first test measurements of turbidity were made in 2008 and 2013. Optical turbidity was measured by a portable turbidimeter Hach 2100P in Nephelometric Turbidity Units (NTU). The values of turbidity in weight The regularity of turbidity measurement was defined for each month according to the shape of a diurnal hydrograph of the Djankuat River. The measurement Station was done manually using portable turbidity meter. During heavy rainfall events, the measurements were performed every 15 minutes, and averaged in the database of hourly time step. Additionally, water samples were taken manually under various turbidity conditions (in total 19 samples within a range from 66.7 to 36400 NTU) and filtered using 0,45 µm Millipore membrane filters to compute initial suspended sediment concentration (SSC; mg L^{-1}) The values of turbidity were converted to SSC using the above-mentioned lab samples using quadratic regression (Belozerova, Chalov, 2013). The totalunits (g/m^3) were calculated using a dependency Weight Turbidity=f(Optical Turbidity). The dependency was drawn in 2015–2016 using the data on simultaneous measurement of optical turbidity and weight turbidity analysis in 19 samples with optical turbidity from 66.7 to 36400 NTU. Total amount of 1991 measurements is included in the database (Table 3). The Djankuat River turbidity has an extremely uneven distribution (Fig 9b4b): staying lowerless than 400–500 NTU (250–350 g/m^3) most of the time, on the event of a heavy rainfall (more than 20 mm/day) water turbidity canwas abruptly riserose to 1000–5000 NTU (750–4000 g/m^3) and even 30 000 – 40 000 NTU (25 000–33 000 g/m^3) for several hours within short periods of heavy rainfalls (more than 20 mm/day) (Fig. 10). These6). Observed values are in the same range as the values of water turbidityclose a gap in alpine sediment transport observations and correspond to extreme sedimentation processes registered in such river as Huanghe (Zhang, Huang, 1993).the World (e.g. Cohen et al., 2014) and are similar to conditions observed in the most unstable volcanic environments (Chalov et al., 2017b); The maximum value of turbidity (45 060 NTU or 37 200 g/m^3) was measured on 1st of September 2017 after 87 mm of rain with average intensity of 30 mm/hour. The same rain event triggered of an outburst of Bashkara lake in the upstream of a neighboring valley, that gave a rise to a catastrophic mudflow (Chernomorets et al., 2018).

3.1.5 Stable isotopes

The first test samplingSampling of stable isotopes content in the Djankuat River was carried out induring 2013-2017 (Table 2). Its main goal was to define a needed regularity2a). The concentrations of sampling to get a representative mean daily value ^{18}O and D expressed in the values of δ: $\delta D = [(^2H/^1H_{sample} - ^2H/^1H_{standard})/^2H/^1H_{standard}] \times 1000‰$; δ18O and δD. As the daily variation of $\delta^{18}O$ and δD turned out to be low compared to other hydrological parameters of the Djankuat River, sampling was done twice a day in 2014–2017: on the maximum and minimum of water level. The total amount of 844 samples was taken from the Djankuat River at the gauging station during this period.

Отформатировано: не надстрочные/ подстрочные

$= [(^{18}O/^{16}O_{sample} - {}^{18}O/^{16}O_{standard})/^{18}O/^{16}O_{standard}] \times 1000‰.$ In 2013 all samples were ~~proceeded~~processed in the Stable Isotope Laboratory of the Geography Department of Lomonosov Moscow State University on a Finnigan ~~mass~~ Delta-V mass spectrometer. For the measurement, international standards were used: V-SMOW ($\delta^{18}O$ = 0‰, δD = 0‰), GISP ($\delta^{18}O$ = –24.76‰, δD = –189.5‰), SLAP ($\delta^{18}O$ = –55.5‰, δD = –…‰), own laboratory standard MSU (snow glacier Garabashi: $\delta^{18}O$ = –15.60‰, δD = –110.0‰). The measurement precision for δ18O was ±0.1‰.

In 2014~~–~~ to 2016 all samples were ~~proceeded~~processed in Saint Petersburg State University Resource center for Geo-Environmental Research and Modeling (GEOMODEL) on Picarro L-2120i. In 2014 50 control sampless were ~~proceeded were~~processed independently ~~processed~~ by two laboratories: a) Saint Petersburg State University Resource center for Geo-Environmental Research and Modeling (GEOMODEL) on Picarro L-2120i; b) the Stable Isotope Laboratory of the Geography Department of Lomonosov Moscow State University on a Finnigan ~~mass~~ Delta-V mass spectrometer. The difference in the definition for the same sample did not exceed 0.2‰.

In 2017 the samples were measured at Climate and Environmental Research Laboratory (CERL) of Arctic and Antarctic Research Institute on ~~lazer~~laser analyzer Picarro L2140-i that uses Cavity Ring-Down Spectroscopy (CRDS) technique to define the δD and $\delta^{18}O$ ratios in water samples. After each 5 samples we measured our work standard "SPB" (distilled Saint Petersburg tap water) calibrated against the IAEA standards, in order to obtain true values of the samples' isotopic composition. 23 % of randomly chosen samples were re-measured in order to estimate the reproducibility of the results ~~that thus equals~~, accordingly to 0.06 per mil for $\delta^{18}O$ and 0,4 per mil for δD, which is 2 orders of magnitude less than the natural variability of the isotopic composition of the studied samples.

In coarse of the first test sampling in 2013 a needed regularity of sampling to get a representative mean daily value of $\delta^{18}O$ and δD was defined. As the daily variation of $\delta^{18}O$ and δD turned out to be low compared to other hydrological parameters of the Djankuat River, sampling was done twice a day in 2014–2017: on the maximum and minimum of water level.

The values of $\delta^{18}O$ and δD in the Djankuat River waters have a relatively even duration curve (Fig ~~9~~4 e,f). The value of $\delta^{18}O$ stays in range of -13.5…-11.5‰ most of the time, δD in – -95…-80‰. The mean values of $\delta^{18}O$ and δD are correspondingly -12.5‰ and -86.2‰. Concentration of ^{18}O and D decreases with an increase in share of ice and firn melt in total river flow as shown in the beginning of June and July–August 2017 on ~~the~~ Figure ~~10~~6. Pronounced rises in $\delta^{18}O$ and δD are driven by precipitation events (Fig ~~10~~. 6). The maximum value of $\delta^{18}O$ amounting to -6.7‰ (the content of δD in this sample was -72 ‰) was ~~registered~~observed on 16th of June 2016 at 22:00 in the beginning of an ablation season after a heavy rain that doubled the mean daily runoff of the Djankuat River. The minimum values of $\delta^{18}O$ (-14.7‰) was ~~registered~~observed on the 17th of July 2016 at 21:00 in course of an intensive snow and ice melting period.

A clear-cut difference in isotopic composition of ice/snow meltwater and liquid precipitation (see the 3.1.6 section of the paper) makes it possible to estimate the ratio of these components it the total river flow. A series of articles was published from the beginning of 1970s, describing runoff hydrograph separation by nourishment sources with the use of ^{18}O and D (see for example Dincer et al., 1970, Martinec et al., 1974, Fritz et al., 1976, Hermann et al., 1978, Cable, 2011).

Отформатировано: надстрочные

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A mixing-model approach was tested for the Djankuat River to conduct river hydrograph separation in the study (Rets et al., 2017). Two equation systems were drawn:1) in terms of water routing with salinity as indicator; 2) in terms of runoff genesis with $\delta^{18}O$ as a tracer. ~~The~~In terms of water routing the Djankuat River hydrograph was separated into ~~4 components: liquid precipitation/meltwaters,~~ surface routed~~/~~ and subsurface routed waters. In terms runoff genesis the Djankuat River hydrograph was separated into liquid precipitation and meltwaters. Some 70% of the Djankuat River runoff in August–September 2014 was formed by ice and firn meltwater. Rain water is mostly subsurfacely routed; surface runoff of liquid precipitation is formed only during the most intensive rainfall (more than 20 mm on average). Ice and firn meltwater partly percolates to the glacier bottom and comes through a sub-surface layer. The fast (responsive to weather fluctuations) and regulated components of sub-glacier runoff can be distinguished. Sub-glacier runoff contributed 20–30% to the Djankuat ~~river~~River melt runoff in August 2014~~,~~ and up to 100% of the Djankuat ~~river~~River melt runoff at the end of September 2014, when ablation stopped (Rets et al., 2017).

3.1.6 Sampling snow, ice, firn, liquid precipitation and groundwater in the basin for stable isotopes and electrical Conductivity

Отформатировано: английский (США)

Regular sampling of snow, ice, firn, liquid precipitation and ground water in the Djankuat basin was carried out during 2014–2017. The first test sampling was performed in 2013. Liquid precipitation was sampled on every significant occasion of rainfall (more than 1 mm) that amounts to 25–30 samples a year ~~on~~of the Base camp weather station (Table 1). The snow, ice and firn sampling points were evenly distributed on the Djankuat basin area, the coordinates are given in the database. Samples were taken regularly during the ablation season, 40–150 samples a year. Snow samples were taken from the surface and on different depth of snowpack. The groundwater was sampled: 1) after the end of ablation season in the Djankuat River stream when the total runoff is ~~supposed~~assumed to be provided by groundwater in 2014; 2) out of the sub-glacial waters spring in 2015; 3) A groundwater-fed spring on the slope of the Djankuat River basin in 2017.

Total amount of samples taken was: 113 samples of liquid precipitation, 218 samples of snow, 116 samples of ice, 22 samples of firn and 16 samples of groundwater. The values of $\delta^{18}O$ and δD were measured in each sample. The proceeding of the samples was the same as for the stable isotopes samples taken at the gauging station (see section 3.1.5). ~~Electrical conductivity was measured in the samples of snow, ice, firn and groundwater with conductometer Econics Expert-002. Total amount of samples taken and analyzed is: 113 samples of liquid precipitation, 218 samples of snow, 116 samples of ice, 22 samples of firn and 16 samples of groundwater (Table 4).~~

Relative concentrations of ^{18}O and D in precipitation are strongly correlated and defined to a great extent by air temperature, ~~that~~which is called the “seasonal isotope phenomenon” (Dansgaard, 1964). The highest concentrations of ^{18}O and D among the samples collected in the Djankuat River basin are characteristic of liquid precipitation (Table ~~4~~3, Fig. ~~12~~7). The $\delta^{18}O$ value lies mostly between -0.5 and -7‰ with a mean value of -4.9‰, The δD value – between 0 and -40‰, the mean value is -26‰. The lowest concentrations of ^{18}O and D were registered in winter snow ($\delta^{18}O$=-28.3‰, δD=-216‰) and Djankuat glacier ice ($\delta^{18}O$=-22.0‰, δD=-159‰). The amount of stable isotopes in snow cover formed during spring snowfalls is higher and closer to the corresponding values in liquid precipitation ($\delta^{18}O$=-9…-5‰, δD=-28…-70‰). The mean concentration of ^{18}O and D is quite similar: the mean $\delta^{18}O$ is -12.2‰ in snow samples, -14.3‰ in ice samples and -11.3‰ in firn; mean δD is ~~correspondingly~~ -85.5‰, -99.3‰ and -77.1~~‰.~~‰ respectively. The surface of a glacier ablation area is always formed by ice layers of different ages, while firn samples represent the climatic conditions of the last 5–10 years. A generally warmer mean isotopic composition of firn and snow compared to ice can indicate a total warming of the climate. Groundwater is a mixture of all the stated above sources, accordingly the points of groundwater samples lie in the middle of the $\delta^{18}O$ vs. δD graph (Fig. ~~12~~7). The mean concentration of ^{18}O and D in groundwater samples (-13.3‰ and -91‰ correspondingly) indicates a bigger role of meltwater than of summer precipitation in the replenishment of groundwater layers.

The ice, snow and firn samples are ultra-fresh (Table ~~4~~3). Groundwater is enriched with dissolved salts up to 105 mg/L (114 µSm/cm).

3.2 Glaciological measurements

Glaciological observations were carried out by standard methods during 2007–2017 (Østrem and Brugman, 1992, Boyarsky, 1978). The data on snow ~~thickness measurement, ablation and~~ depth, snow density and ablation is included in the presented database~~.~~ (Table 2b).

Snow ~~thickness of~~depth on the Djankuat glacier is measured ~~by probe poles in~~at 250–300 points evenly distributed in all zones of the glacier (Fig. ~~13~~8). The snow measurement survey usually starts in late May – early June and ends ~~in~~at the end of June. ~~As the ablation season starts on Djankuat glacier in May, the measured values in the lower part of the glacier do not equal the maximum values of the winter balance. According to this in course of mass-balance calculation the measured values of accumulation on the lower parts of the glacier are being corrected using the data from the upper zones of the glacier, where ablation hasn't started yet. That is controlled by temperature measurements in snowpits (Petrakov, Popovnin, 2000). The raw values of snow thickness measurement are presented in the database, before the corrections. Total amount of 2932 measured values during 2007–2017 was included in the database (Table 5).~~ The mean value of measured snow thickness is 3.6 m, the maximum ~~–~~is 11.5 m.

Отформатировано: Цвет шрифта: Серый 80%

Snow density is measured in 2–4 snowpits placed in different elevation belts of the Djankuat glacier (Fig. 1). Density is measured in each 40–50 cm layer of a snowpack ~~by a snow sampling cylinder.~~(Fig. 3d). The measurements are repeated 2–5 times during the ablation season. ~~Total amount of 66 measurements of integral density of snowpack and 434 measurements of density in layers of the snowpack were done during 2007–2017 (Table 5).~~ Integral density of snowpack has a low variance~~,~~; total range of variation is less than 0.2 g/cm³. ~~The maximum observed value was 0.64 g/cm³, the minimum – 0.46~~ The~~g/cm³.~~ ~~While the~~ density in the layers of snowpack can greatly vary – from 0.23 to 0.92 g/cm³ according to the 2007–2017 measurements~~ (Table 5~~. The overall mean measured value of snow density in the snowpack, 0.57 g/cm³, greatly exceeds the density of fresh snow, as the database includes measurements carried out in the midsummer and at the end of the ablation period (Table 3).

35–45 ~~Ablation is measured by means of~~ ablation stakes~~. 35–45 stakes~~ were placed on the Djankuat glacier surface every year~~.~~ (Fig. 8). The time-step ~~of measurement~~between measurements depends on the accessibility of each stake and ranges from 1–5

Отформатировано: Шрифт: 9 пт, Цвет шрифта: Черный, английский (Соединенное Королевство) to 30 days. The values included in the dataset are counted from measured depth of melted snow/firn/ice in cm and corresponding values of density of melting material. Total amount of 5045 measurements of ablation was done during 2007–2017. The mean rate of snow/firn/ice ablation was 47 mm w.e./day, minimum – 0 mm w.e./day, maximum – 387 mm w.e./day.

The Djankuat glacier has experienced a general mass loss since the beginning of observation in 1968 (www.wgms.ch). But up toUntil 2005, negative mass balance years alternated with positive mass balance years (Fig. 14). Since9). After 2006 and during all period that is presented in the dataset, the annual mass balance of Djankuat glacier was negative. The annual mass balance values ranged from -2010 mm w.e. in 2007, that was the lowest value of mass balance registered since the beginning of the observation in 1968, to -230 mm w.e. in 2009. The mean value of annual mass balance during 2007–2017 was -900 mm w.e. The change inDuring 2007–2017 the area of the Djankuat glacier area is shown on the Figure 13.decreased from 2.68 to 2.42 km^2 that amounts to almost 10% of loss (Fig. 8). The front of the glacier retreated by 60–300 m in different measurement profiles during 2010–2016 (Fig 138), that amounts to 8.5–42.9 m/year retreatment rate. The main reason of the Djankuat glacier retreating during the long-term period is aan intensive decrease in summer balance, while accumulation shows a statistically insignificantslight positive trend (Fig. 149).

The information on Djankuat glacier mass balance, calculated from the presented dataset, is being published in the Glacier Mass Balance Bulletin, thatwhich is designedissued by the World Glacier Monitoring Service (wgms) to speed up and facilitate access to information concerning glacier mass balances by reporting measured values from selected reference glaciers at 2-year intervals (see for ex. Popovnin, 2013), , and in Fluctuations of Glaciers edition, continuously publishes internationally collected,along with other standardized data on changes in glaciers throughout the world at 5-yearly intervals (see for ex. Popovnin, 2012, 2013).

Отформатировано: Узор: Нет

Some of the glacial measurements data presented in this article was used in global studies on evolution of the Earth's cryosphere (Zemp et al., 2009, Zemp et al., 2011, Zemp et al., 2015). In (Popovnin, and Pylayeva, (2015) snow thickness measurements on Djankuat glacier are used to work out a methodology of estimation of avalanche feeding of a glacier from the total mass of snow accumulation.

3.3 Meteorological measurements

The main purpose of meteorological measurements in the Djankuat research basin is to provide the data needed for calculating the components of the heat balance (Toropov et al., 2017; Toropov et al., 2018b), which is a necessary input for physically-based hydrological models. Aa an example, the presented meteorological data was successfully used to model the melting regime of the Djankuat glacier in 2007 by anthe A-Melt model of ice and snow melt in alpine areas (Rets, Kireeva, 2010).

The program of meteorological observations in the Djankuat research basin during 2007–2017 included (Table 6):

1. Meteorological meteorological and actinometricradiation measurements and by means of two Campbell AWS placed above ice surface by means of Campbell AWS ((Gjankuat Glacier AWS1 in Table 1-2, Fig. 15a), including measurements of air temperature and relative humidity (Vaisala MT300 sensor), wind speed1, Fig. 3a) and direction (Campbell wind sensor) at 2 m AGL; radiation fluxes (KEEP & ZONNEN radiometers –

two of them over the debris-covered surface (Gjankuat Glacier AWS2 in Table 1-2, Fig.1). In order to measure an upward and downward short-wave radiation, another two – an upward and downward long-wave radiation); measurements of the ablation layer with a rate at both sites by Sonic Ranger sensor (, the sensor iswas located on a construction, that is drilled into the body of the glacier, and measuresmeasured the distance from the sensor to the ice (or snow) surface). These automatic measurements have a record interval of surface. Standard meteorological characteristics were monitored at the Base Camp by means of DAVIS 15 min. The weather station was placed in the central part of the Djankuat glacier (Djankuat Glacier AWS 1 on Fig. 1, Table 1)

2. The second Campbell(Base Camp AWS with the same parameters was placed in the central part of the glacier over the debris surface in 2007, 2008 and 2009 (Djankuat Glacier AWS 2 on Fig. 1, Table 1). 2, Fig.1, Fig. 3c). In 2017 a Davis AWS was also placed in the upper part of the glacier (Djankuat Glacier AWS 3 in Table 1-2, Fig.1).

3. Number of experimental observations were carried out at the Gjankuat Glacier AWS1: Gradient mast DAVIS placed in the central part of the Djankuat glacier (observations to obtain turbulent heat fluxes estimations with the Monin–Obukhov method in 2015, that includedDjankuat Glacier AWS 1 on Fig. 1, Table 1) includes 4 temperature and humidity sensors and 4 wind sensors located at 0.25, 0.5, 1 and 2 m AGL (Fig. 15c, Table 6). Measurements were recorded with a above the glacier surface; measurements of high frequency 15 min interval. Observations were carried out in 2015 to obtain long-term meteorological data series in the surface layer, which is necessary for the turbulent heat fluxes estimation with the Monin-Obukhov method (Zilitinkevich, S.S., 1972).

4. Measurements of turbulent pulsations of wind and acoustic temperature with a 3-axis sonic anemometer GILL WindMaster (Table 6) in the central part of the Djankuat glacier (Djankuat Glacier AWS 1 on Fig. 1, Table 1). The measurement frequency is (10 Hz. This measurement method is necessary for estimating turbulent heat, moisture and momentum fluxes by a very promising method called «eddy-covariance» (Andreas et al., 2005).

5. Measurements of the basic meteorological parameters in the base camp area at an altitude of 2640 m.a.s.l. (Base Camp AWS on Fig.1, Table 1) by a Davis meteorological station These automatic measurements also have a record interval of 3c). 15 min.

6. In 2017 a Davis AWS was also placed in the upper part of the glacier (Djankuat Glacier AWS 3 on Fig. 1, Table 1). The station worked in a standard complectation, with a record interval of 15 min (Table 6).

The Figure 1610 shows an example of the course of the average daily values of the basic meteorological variables during the ablation season of 2007 measured onby Campbell AWS 1. It is clearly seen that changes in air temperature associated with synoptic events are expressed quite well, their average amplitude is 3 °C (the same values were observed the other years). The average temperature during the ablation period is around 8 °C, while the minimum values almost reach 0 °C annually, and the maximums are 16…. to 18 °C. The variability of the radiation balance is determined mainly by cloudiness, which has primarily

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Отформатировано: Обычный, без нумерации

Отформатировано: Шрифт: 9 пт, Цвет шрифта: Черный

Отформатировано: Шрифт: 9 пт, Цвет шрифта: Черный

Отформатировано: без нумерации

a pronounced daily variation. The albedo effect is also clearly manifested – especially in June and September, when fresh snow ~~often~~frequently falls on the surface of the glacier. The maximum values of incoming shortwave radiation can reach 1100 W/m^2. The wind regime is stable to a great extent and varies little from year to year. The average wind speed over the tongue of the glacier is fairly stable ~~and equals 4 m/s, while the maximum does not exceed 12 m/s.~~at 4-6 m/s. Above the glacier, stable katabatic winds blow, which is characterized by a pronounced diurnal course. ~~The maximum speed values are associated with hair dryers, observed 3–4 times per season. Table 7~~The most probable value of the maximum gusts is 10-12 m/s. The absolute maximum for the period under review was 16.6 m/s above the surface of the glacier and 21 m/s above the moraine ridge. The strongest glacial wind is observed in the lower part of the glacier, in the area of the weather station AWS-1, where the maximum slope angle and density contrast between glacial and valley air are combined. The wind decreases down the valley, and in the area of the base camp its gusts rarely exceed 10 m/s. The maximum speed values are associated with foehn winds, observed 3–4 times per season. Table 4 shows the average July values of the main meteorological characteristics.

Figure ~~17~~11 gives an example of the variability of the main meteorological characteristics in the ~~Adyl-Su river~~Djankuat River valley, in the area of the base camp at an altitude of 2640 meters above sea level (Table 1, Fig. 1). The average daily temperature is about 12 °C, the average wind speed is about ~~5~~2 m/s, despite the fact that the maximum gusts are stronger than over the glacier and reach 18 m/s. This is due to the density difference between the cold air flowing from the glacier and the local air mass forming over the heated alpine meadows and rocks. ~~The precipitation data is of interest: it~~ Heavy rains can be ~~clearly seen that heavy rains~~ observed in ~~this~~the study area ~~are normal. So~~. For example, in 2017, the daily precipitation of about 20 mm was observed 6 times. From August 31 to September 1, about 48 mm of precipitation fell within 48 hours, which is a ~~catastrophic~~very high amount. This rainfall caused the above mentioned ~~above breakthrough~~outburst of the Bashkara glacial lake in the neighboring valley and the formation of a catastrophic mudflow (Chernomorets et al., 2018).

4 Conclusion

With ~~given above~~the detailed measurement program described here, the Djankuat basin is ~~now~~expected to serve as a ~~unique research site not only~~highly valuable benchmark for ~~the high elevation territories~~evaluating, calibrating and further developing glaciological and hydro-sedimentological catchment models of the alpine catchments. of the North Caucasus~~, but for the~~ and Russian Federation as whole (Konovalov et al., 2018, Stokes et al., 2006, Shagedanova et al., 2005, Hagg et al., 2010). ~~Nowadays the~~The aim of the ~~complex~~multidisciplinary monitoring in the Djankuat basin is not only to fill a "blind-spot" in extremely underreported North Caucasus alpine territories but to provide data for detailed studies of hydrometeorological processes in mountain areas (Rets et al., 2017, Toropov et al., 2017).

The dataset presented ~~in the research~~here covers the period of 2007–2017 and can be useful to researchers developing and verifying hydrological, glaciological and meteorological models for mountainous territories, studying the recent climate and its impact on the cryosphere and hydrology, using isotopic and hydrochemical approaches to study ~~mountainous territories~~the source areas of runoff.

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We want to give our gratitude to all members of the ~~Glacial Party~~glacial party of Moscow State University, ~~that~~who were working on the Djankuat glacier station during 2007–2017, ~~that will be~~amounting to more than 100 people in ~~sum~~total. It would not be able to collect the data presented in this paper if it were not for them. Especially we would like to thank Fedor Andryushchenko, Elena Astafyeva, Anna Avilova, Varvara Bazilova, Egor Belozerov, Victorya Bychkova, Vasily Efimov, Natalia Ezerova, Maria Gaydamukha, Aphanasy Gubanov, Valera Ivanov, Maria Kaminskaya, Nickolay Kovalenko, Ekaterina Kuzmina, Nadezhda Loshakova, Pavel Lysenok, Ilya Marchuk, Tatiana Matveeva, Polina Morozova, Evgenia Panchenko, Valentin Pastukhov, Alexey Rezepkin, ~~Yana Sergievskaya,~~ Alexander Rostiashvili, ~~Nadezhda Loshakova, Maria Gaydamukha, Ekaterina Kuzmina, Natalia Ezerova, Evgenia Panchenko, Maria Tereshina, Vasily Efimov, Egor Belozerov, Maria Kaminskaya, Varvara Bazilova, Arina Veres,~~ Yana Sergievskaya, Anna Shestakova, ~~Irina Geleznova, Tatiana Matveeva, Elena Astafyeva, Victorya Bychkova, Polina Morozova,~~ Maria Tereshina, Denis Zakharhenko~~, Aphanasy Gubanov, Anna Avilova, Ilya Marchuk, Fedor Andryushchenko, Pavel Lysenok, Valera Ivanov.~~ and Irina Zheleznova,

References

Alekseev, G.V., Ananicheva, M.D~~. ,~~., Anisimov, O.A., Ashik, I.M., Bardin, M.Yu., and E.G. Bogdanova: The second assessment report of Roshydromet on climate change and its consequences on the territory of the Russian Federation, State Scientific Center of the Russian Federation "Arctic and Antarctic Research Institute" Federal Service of Russia for Hydrometeorology and Environmental Monitoring, Moscow, Russia, 2014.

~~Andreas, E. L., Jordan, R. E., and Makshtas, A. P.: Parameterizing turbulent exchange over sea ice: the ice station Weddell results, Boundary-Layer Meteorology, 114, 439–460, 2005. doi: 10.1007/s10546-004-1414-7~~

Auer, I., Böhm, R., Jurkovic, A., Lipa, W., Orlik, A., Potzmann, R., Schöner, W., Ungersböck, M., Matulla, C., Briffa, K., Jones, P., Efthymiadis, D., Brunetti, M., Nanni, T., Maugeri, M., Mercalli, L., Mestre, O., Moisselin, J., Begert, M., Müller-Westermeier, G., Kveton, V., Bochnicek, O., Stastny, P., Lapin, M., Szalai, S., Szentimrey, T., Cegnar, T., Dolinar, M., Gajic-Capka, M., Zaninovic, K., Majstorovic, Z. and Nieplova, E. (2007), HISTALP—historical instrumental climatological surface time series of the Greater Alpine Region. Int. J. Climatol., 27: 17-46. doi:10.1002/joc.1377

Bales, R. C., Molotch, N. P., Painter, T. H., Dettinger, M. D., Rice, R., and Dozier, J.: Mountain hydrology of the western United States, Water Resour. Res., 42, 8, W08432, doi: 10.1029/2005WR004387, 2006.

Barry, R. G.: Mountain Climatology and Past and Potential Future Climatic Changes in Mountain Regions: A Review, Mountain Research and Development 12, 1, 71-86, doi:10.2307/3673749, 1992.

~~Becker, A. (Ed.): Global change and mountain regions, IGBP, Stockholm, Sweden, 2001.~~

Отформатировано: Цвет шрифта: Авто

Отформатировано: Цвет шрифта: Авто

Belozerova E.V., Chalov S.R. Assessment of river water turbidity using the optic methods, Vestnik Moskovskogo Universiteta, Seriya 5: Geografiya 6, 39-45, 2013

Bobrovitskaya, N. N. and Kokorev, A. V.: Current problems of hydrological networks design and optimization, Background material for the fourteenth session of the Commission for Hydrology (CHy-14), Geneva, Switzerland, 2014.

Boyarsky, I. Y. (Ed.) Lednik Djankuat (Djankuat Glacier), Gidrometeoizdat, Saint Petersburg, Russia, 1978.

Cable, J., Ogle, K., and Williams, D.: Contribution of glacier meltwater to streamflow in the Wind River Range, Wyoming, inferred via a Bayesian mixing model applied to isotopic measurements, Hydrol. Process., 25(14), 2228–2236, doi: 10.1002/hyp.7982, 2011.

Chalov S., Golosov V., Tsyplenkov A., Theuring P., Zakerinejad R., Märker M., Samokhin M. A toolbox for sediment budget research in small catchments, *Geography, environment, sustainability*. 10(4):43-68. DOI:10.24057/2071-9388-2017-10-4-43-68, 2017a

Chalov, Sergey R, Tsyplenkov, Anatolii S, Pietron, Jan, Chalova, Aleksandra S, Shkolny, Danila I, Jahsjo J. Maerker, Michael Sediment transport in headwaters of a volcanic catchment—Kamchatka Peninsula case study // Front. Earth Sci. Frontiers of Earth Science 11(3), pp 565–578 DOI 10.1134/S0097807812010022, 2017b

Chernomorets, S. S., Petrakov, D. A., Aleynikov, A. A., Bekkiev, M. Y., Viskhadzhieva, K. S., Dokukin, M. D., Kalov, R. K., Kidyaeva, V. M., Krylenko, V. V., Krylenko, I. V., Krylenko, I. N., Rets, E. P., Savernyuk, E. A., and Smirnov, A. M.: The outburst of Bashkara glacier lake (central Caucasus, Russia) on september 1, 2017, *Earth's Cryosphere, 22,* 2, 70–80, doi: 10.21782/kz1560-7496-2018-2(70-80), 2018.

Cohen S., Kettner A.J., Syvitski J.P.M. Global suspended sediment and water discharge dynamics between 1960 and 2010: Continental trends and intra-basin sensitivity // Glob. Planet. Change. 115. 44–58. 2014

Dansgaard, W.: Stable isotopes in precipitation, Tellus, 16, 4, 436–468, 1964.

Dincer, T., Payne, B. R., Flowkowski, T., Martinec, J., and Tongiorgi, E.: Snowmelt runoff from measurements of tritium and oxygen-18, Water Resour. Res., 6, 110–124, doi:10.1029/WR006i001p00110, 1970.

Dobriyal, P., Badola, R., Tuboi, C., and Hussain, S. A.: A review of methods for monitoring streamflow for sustainable water resource management, Appl. Water Sci., 7(6), 2617-2628, doi:10.1007/s13201-016-0488-y, 2017.

Dyurgerov, M.: Mountain and subpolar glaciers show an increase in sensitivity to climate warming and intensification of the water cycle, Journal of Hydrology, 282(1-4), 164-176, doi: 10.1016/S0022-1694(03)00254-3, 2003.

Fritz, P., Cherry, J., Weyer, K., and Sklash, M.: Storm runoff analyses using environmental isotopes and major ions, in Interpretation of Environmental Isotope and Hydrochemical Data in Groundwater, Panel Proc. Ser. – Int. Atomic Energy Agency, Vienna: Int. Atomic Energy Agency, 111–130, 1976.

Frolova, N. L., Kireeva, M. B., Nesterenko, D. P., Agafonova, S. A., and Tersky, P. N.: Up-to-date climate forced seasonal flood changes (the case study for European part of Russia), IAHS Publ, 363, 113–118, 2014.

Gietl, G.: Collection and processing of hydrometeorological and hydrological data in mountainous areas, Hydrology of Mountainous areas, Proceedings of the ~~âtrbské~~atrbske Pleso Workshop, Czechoslovakia, June 1988, IAHS Publ, 190, 1990.

Hagg, W., Shahgedanova, M., Mayer, C., Lambrecht, A., and Popovnin, V.: A sensitivity study for water availability in the Northern Caucasus based on climate projections, Global and Planetary Change, 73(3-4), 161-171, doi: 10.1016/j.gloplacha.2010.05.005, 2010.

Hermann, A., Martinec, J., and Stichler, W.: Study of snowmelt-runoff components using isotope measurements, In: Colbeck S C, Ray M, eds. Proceedings of Modeling of Snow Cover Runoff, U.S. Army CRREL Special Report, 79-36, 288–296, 1978.

Immerzeel, W. W., van Beek, L. P. H., Konz, M., Shrestha, A. B., and Bierkens M. F. P.: Climatic Change, 110, 721, doi: 10.1007/s10584-011-0143-4, doi:10.1007/s10584-011-0143-4, 2012.

Kireeva M., Frolova N., Rets E. Telegina, E. A., Telegina, A. A., and Ezerova, N. N.:The role of seasonal and occasional floods in the origin of extreme hydrological events, Proc. IAHS, 369, 37–41, 2015.

Konovalov V. G., Rets E. P., and Pimankina N. A.: Hydrological essense of glacier's summer mass balance in mountain river basins, Collective monograph on materials of the annual International scientific and practical conference LXXI Gertsenovsky readings, to the 155 anniversary since the birth of Vladimir Ivanovich Vernadsky, Geography: development of science and education, 1, St. Petersburg, RSPU of A.I. Herzen, on April 18-21, 2018, V.P. Solomin, V.A. Rumyantsev, D.A. Subetto, N.V. Lovelius (eds.), St. Petersburg, RSPU of name A.I. Herzen pubishing house, Russia, 2018.

Lambrecht, A., Mayer, C., Hagg, W., Popovnin, V., Rezepkin, A., Lomidze, N., and Svanadze, D.: A comparison of glacier melt on debris-covered glaciers in the northern and southern Caucasus, The Cryosphere, 5, 525-538, doi: 10.5194/tc-5-525-2011, 2011.

Lavrentiev I. I., Kutuzov S. S., Petrakov D. A., Popov G. A., and Popovnin V. V.: Ice thickness, volume and subglacial relief of Djankuat Glacier (Central Caucasus), Ice and Snow, 54(4), 7-19, doi: 10.15356/2076-6734-2014-4-7-19, 2014.

Martinec, J., Siegenthaler, U., Oeschger, H., and Tongiorgi, E.: New insights into the run-off mechanism by environmental isotopes, Proc. Sympos. Isotope Tech. in Groundwater Hydrol., Vienna: Int. Atomic Energy Agency, 4, 129–143, RN:38048670, 1974.

Meier, M. F., Dyurgerov, M. B., and McCabe, G. J.: Climatic Change, 59, 123, doi: 10.1023/A:1024410528427, 2003.

Østrem, G. and Brugman, M.: Glacier Mass–Balance Measurements. A manual for field and office work, NHRI Science Report No. 4, 1991.

Pachauri, R. K., Allen, M. R., Barros, V. R., Broome, J., Cramer, W., Christ, R., Church, J. A., Clarke, L., Dahe, Q., Dasgupta, P., …and van Ypserle, J.Dubash, N. K., Edenhofer, O., Elgizouli, I., Field, C. B., Forster, P., Friedlingstein, P., Fuglestvedt, J., Gomez-Echeverri, L., Hallegatte, S., Hegerl, G., Howden, M., Jiang, K., Jimenez Cisneroz, B., Kattsov, V., Lee, H., Mach, K. J., Marotzke, J., Mastrandrea, M. D., Meyer, L., Minx, J., Mulugetta, Y., O'Brien, K., Oppenheimer, M., Pereira, J. J., Pichs-Madruga, R., Plattner, G. K., Pörtner, H. O., Power, S. B., Preston, B., Ravindranath, N. H., Reisinger, A., Riahi, K., Rusticucci, M., Scholes, R., Seyboth, K., Sokona, Y., Stavins, R., Stocker, T. F., Tschakert, P., van Vuuren, D. and van Ypserle, J. P.: Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. R. Pachauri and L. Meyer (editors), Geneva, Switzerland, IPCC, 151, ISBN: 978-92-9169-143-2, 2014.

Petrakov, D. A., Popovnin V. V.: Accumulation field of a mountain glacier and its stability in time, Earth's Cryosphere, 4, 2, 67-76, 2000.

Popovnin, V. V.: Djankuat, Glacier Mass Balance Bulletin, 12, 3, 8, 14, 89–89, 99, 105, 2013.

Popovnin, V. V.: Djankuat, Fluctuations of Glaciers, 10, 8, 55, 129, 164, 196–197, 261, 2012.

Popovnin V. V. and Pylayeva T. V.: Avalanche feeding of the Djankuat Glacier, Ice and Snow, 55 (2), 21-32, doi:10.15356/2076-6734-2015-2-21-32, 2015.

Rets, E., Chizhova, J. N., Loshakova, N., Tokarev, I., Kireeva, M. B., Budantseva, N. A., Vasil'chuk, Y. K., Frolova, N., Popovnin, V., Toropov, P., Terskaya, E., Smirnov, A. M., Belozerov, E., and Karashova, M.: Using isotope methods to study alpine headwater regions in the northern Caucasus and Tien Shan, Frontiers of the Earth Science, 11, 3, 531–543, doi: 10.1007/s11707-017-0668-6, 2017.

Rets E.P., Dzhamalov R.G., Kireeva M.B., Frolova N.L., Durmanov I.N., Telegina A.A., Telegina E.A., and Grigoriev V.Y.: Recent trends of river runoff in the North Caucasus. Geography, Environment, Sustainability, 11, 3, 61–70, doi:10.24057/2071-9388-2018-11-3-61-70, 2018.

Rets E. and Kireeva M.: Hazardous hydrological processes in mountainous areas under the impact of recent climate change: case study of Terek River basin, Global Change: Facing Risks and Threats to Water Resources: proc. of the Sixth World FRIEND Conference, IAHS Publ, 340,126−134, 2010.

Rets, E. Popovnin, V., Toropov, P., Smirnov, A., Tokarev, I., Budantseva, N., Vasil'chuk, Y., Kireeva, M., Ekaykin, A., ~~Kozachek~~Veres, A., Aleynikov A., Frolova, N., Tsyplenkov, A., Polukhov, A., Chalov S., Aleshina, M., and Kornilova, E.: ~~Djankuat Glacier Station in the North Caucasus, Russia: A Database of complex glaciological~~Glaciological, hydrological, meteorological observations and isotopes sampling results during 2007-2017~~. Knowledge Network for Biocomplexity. doi:10.5063/F1H1307Q~~ at Djankuat Glacier Station in the North Caucasus, Russia. PANGAEA, https://doi.org/10.1594/PANGAEA.894807, 2018.

Shahgedanova, M.: Climate at present and in the historical past, The Physical Geography of Northern Eurasia, edited by M. Shahgedanova, Oxford Univ. Press, New York, 70–102, 2002.

Shahgedanova, M., Stokes, C. R., Gurney, S. D. and Popovnin, V. V.: Interactions between mass balance, atmospheric circulation and recent climate change on the Djankuat glacier, Caucasus Mountains, J. Geophys. Res., 110(D4), D04108. doi: 10.1029/2004JD005213., 2005.

Shahgedanova, M., Nosenko, G., Kutuzov, S., Rototaeva, O., and Khromova, T.: Deglaciation of the Caucasus Mountains, Russia/Georgia, in the 21st century observed with ASTER satellite imagery and aerial photography, The Cryosphere, 8, 2367-2379, doi: 10.5194/tc-8-2367-2014, 2014.

Schaefli, B., Hingray, B., Niggli, M., Musy, A.: A concepttual glacio-hydrological model for high mountainous catchments, Hydrol. Earth Syst. Sci., 9, 95-109, 2005.

Singh, P., Bhatnagar, N. K., and Kumar, N.: Status and problems related with mountain hydrology, National Institute of Hydrology, 1999.

Stokes, C., Gurney, S., Shahgedanova, M., and Popovnin, V.: Late-20th-century changes in glacier extent in the Caucasus Mountains, Russia/Georgia, Journal of Glaciology, 52(176), 99-109, doi:10.3189/172756506781828827, 2006.

Stokes, C. R., Popovnin, V., Aleynikov, A., Gurney, S. D., and Shahgedanova, M.: Recent glacier retreat in the Caucasus Mountains, Russia, and associated increase in supraglacial debris cover and supra-/proglacial lake development, Annals of Glaciology, 46, 195-203, doi: 10.3189/172756407782871468, 2007.

Toropov, P. A., Aleshina, M. A., Kislov, A. V., and Semenov, V. A. Trends of climate change in the Black sea – Caspian region in the last 30 years, Moscow University Vestnik, Series 5, Geography, 2, 67-77, 2018.

Toropov, P. A., Shestakova, A. A., and Smirnov, A. M.: Methodological aspects of heat balance components estimation on mountain glaciers, Russian Journal of Earth Sciences, ES4002, 1–9, doi:10.2205/2017ES000605, 2017.

Toropov P. A., Shestakova A. A. , Smirnov A. M. , and Popovnin V.V.: Evaluation of the componentcomponents of the heat balance of the Djankuat glacier (Central Caucasus) during the period of ablation in 2007-2015, Earth's Cryosphere, 22, 4, 42–54, 2018.

Viviroli, D., Archer, D. R., Buytaert, W., Fowler, H. J., Greenwood, G. B., Hamlet, A. F., Huang, Y., Koboltschnig, G., Litaor, M. I., López-Moreno, J. I., Lorentz, S., Schädler, B., Schreier, H., Schwaiger, K., Vuille, M., and Woods, R.: Climate change and mountain water resources: overview and recommendations for research, management and policy, Hydrol. Earth Syst. Sci., 15, 471-504, doi:10.5194/hess-15-471-2011, 2011.

Volodicheva, N.: The Caucasus M. Shahgedanova (Ed.), The Physical Geography of Northern Eurasia, Oxford Univ. Press, New York, 352-376, 2002.

Weingartner, R., Viviroli, D., and Schädler, B.: Water resources in mountain regions: a methodological approach to assess the water balance in a highland-lowland-system, Hydrological Processes: An International Journal, 21(5), 578-585, doi:10.1002/hyp.6268, 2007.

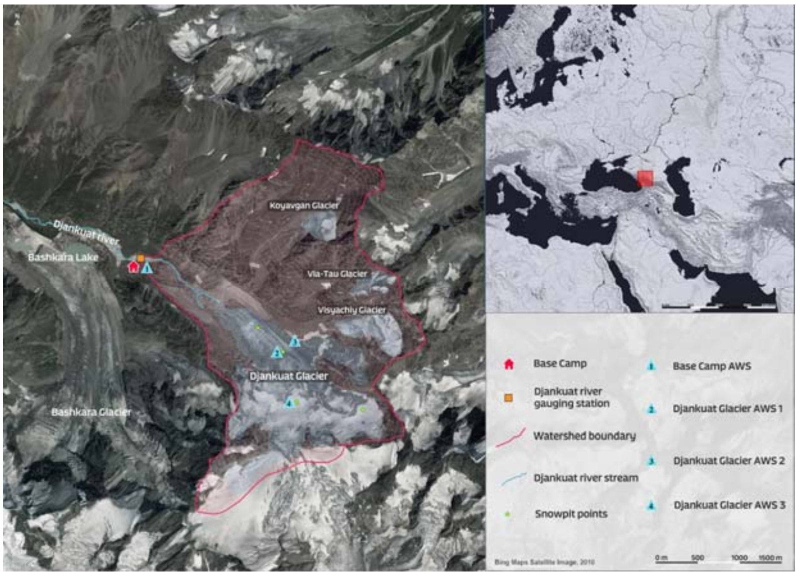
Zemp, M., Hoelzle, M., and Haeberli, W.: Six decades of glacier mass-balance observations: a review of the worldwide monitoring network, Annals of Glaciology, 50(50), 101-111, doi:10.3189/172756409787769591, 2009.

Zemp, M., Frey, H., Gärtner-Roer, I., Nussbaumer, S., Hoelzle, M., Paul, F., … and Vincent, C.: Historically unprecedented global glacier decline in the early 21st century. Journal of Glaciology, 61(228), 745-762, doi:10.3189/2015JoG15J017, 2015.

Zemp, M., Paul, F., Andreassen, L., M., Arino, O., Bippus, G., Bolch, T., Braithwaite, R., Braun, L., Cáceres, B. E., Casassa, G., Casey, K. A., Ceballos, C. L., Citterio, M., Delgado, H., Demuth, M., Espizua, L. E., Farokhnia, A., Fischer, A., Foppa, N., Frey, H., Fujita, K., Gärtner-Roer, I., Glowacki, P., Haeberli, W., Hagen, J. O., Hoelzle, M., Holmlund, P., Giesen, R. H., Kääb, A., Khromova, T., Kotlarski, S., Le- Bris, R., Li, Z., Meier, M., Meneghel, M., Mool, P., Nussbaumer, S. U., Peduzzi, P., Plummer, S., Popovnin, V., Prinz, R., Rack, W., Rastner, P., Raup, B., Rinne, E., Seifert, F. M., Seiz, G., Severskiy, I., Shepherd, A., Sigurðsson, O., Strozzi, T., Vincent, C., Wheate, R., and Yakovlev, A.: Summary of international glacier monitoring summit, The Earth Observer, 23, 4, 28–31, 2011.

Zhang, J., and Huang, W. W.: Dissolved trace metals in the Huanghe: the most turbid large river in the world, Water Research, 27(1), 1-8, doi:10.1016/0043-1354(93)90188-N, 1993.

Zilitinkevich, S. S.: The Dynamics of the Atmospheric Boundary Layer, Gidrometeoizdat, Leningrad, Russia, 1972.



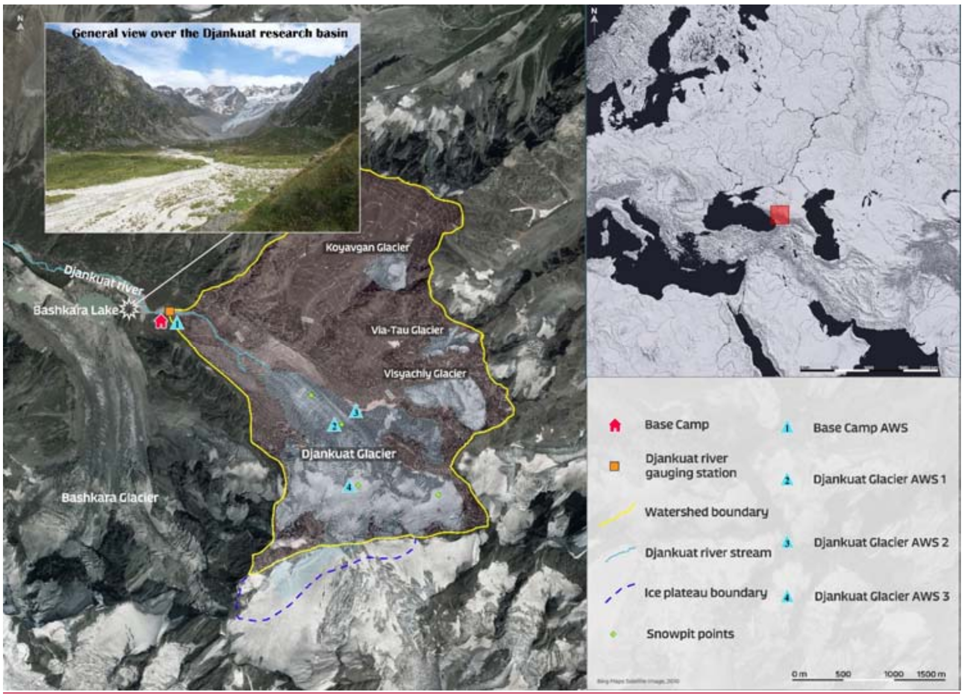
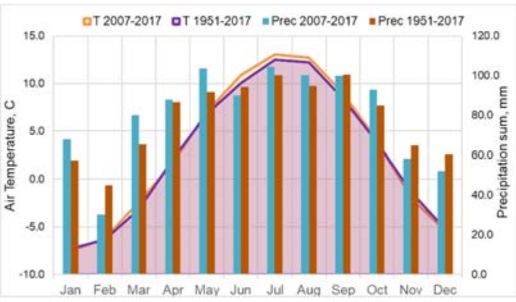


Figure 1: The Djankuat ~~river~~River basin with the depicted location of the Base camp, main weather stations, snowpits and the Djankuat ~~river~~River gauging station.

~~**Figure 2: A general view over the Djankuat research basin (photo by E.Rets).**~~



~~Figure 3~~

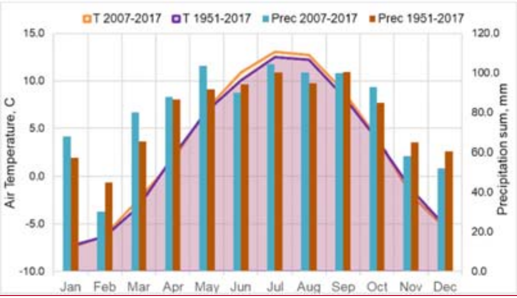


Figure 2: Monthly distribution of air temperature and precipitation for the period of the dataset (2007–2017) compared to the long-term period (1951–2017) on the nearest to the Djankuat research basin all-year weather station Terskol (2146 m).

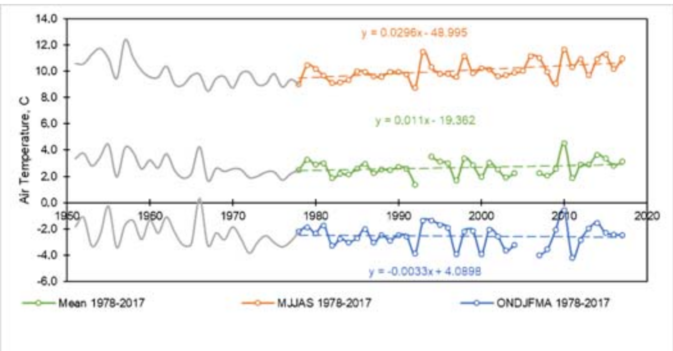


Figure 4: The fluctuations of the mean air temperature: (Mean) annual, (MJJAS) from May to September, (ONDJFMA) – from October to April – according on the nearest to the Djankuat research basin all-year weather station Terskol (2146 m). The linear trends are shown for the period 1978–2017 which is identified as a "contemporary period" in term of the recent climate forced changes in river runoff regime on the European territory of Russia (Frolova et al., 2014, Rets et al., 2018).

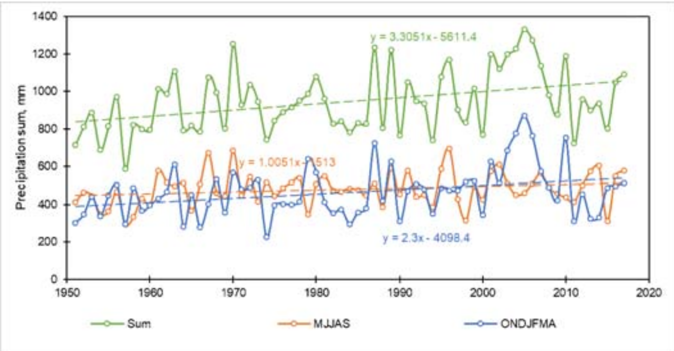
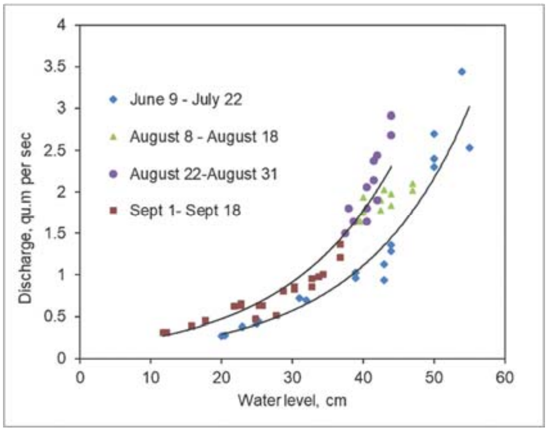


Figure 5: The fluctuations of the precipitation sum: (Sum) annual, (MJJAS) from May to September, (ONDJFMA) – from October to April – according on the nearest to the Djankuat research basin all-year weather station Terskol (2146 m)

Figure 6: The construction of the Djankuat Gauging Station (photo by E.Rets).



~~**Figure 7: An example of the Q=f(H) rating curve. Derived for the Djankuat Gauging Station for the 2016 ablation season**~~

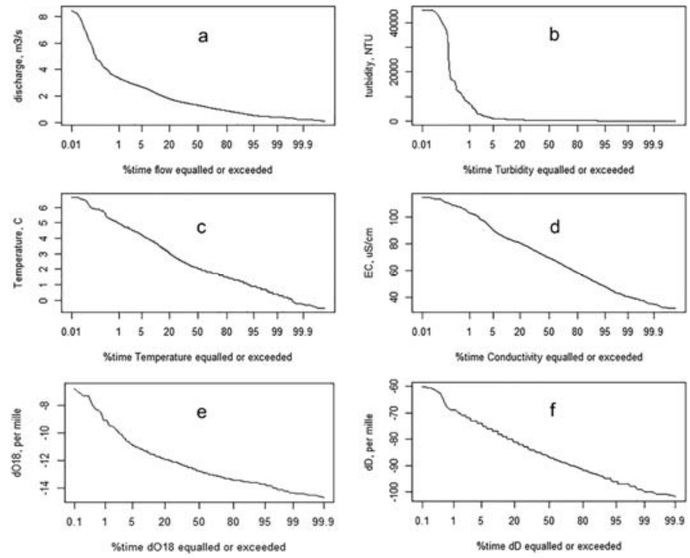


Figure 8

Figure 3: (a) Campbell meteorological complex with a set of Kip & Zonen radiometers and GILL three-component acoustic anemometer at the Djankuat GlacierAWS1 location; (b) the construction of the Djankuat Gauging Station; (c) Djankuat Base Camp AWS - Davis meteorological station; (d) Snow density measurement in a snowpit at the stake 49.

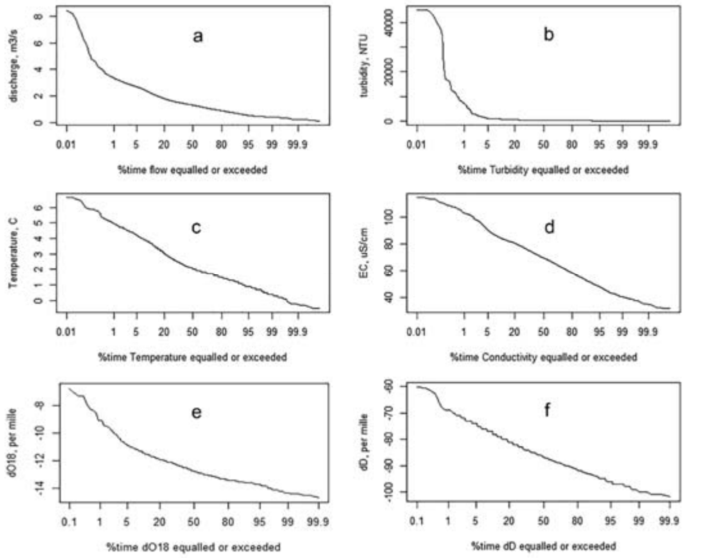
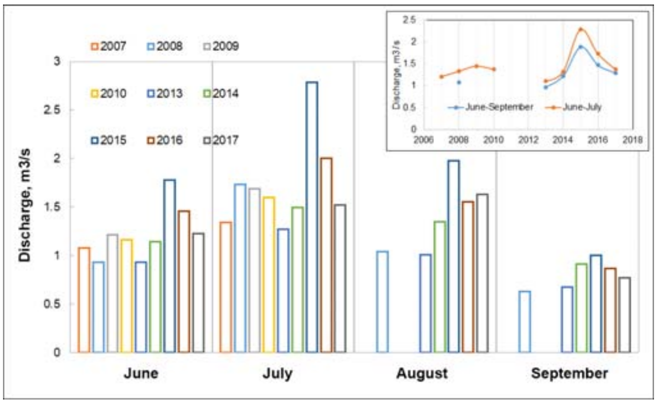


Figure 4: Duration curves of the parameters measured during 2007–2017 on the Djankuat Gauging Station: (a) Water discharge, (b) Optical turbidity, (c) Water temperature, (d) Water Electrical Conductivity, (e) δ^18O, (f) δD.



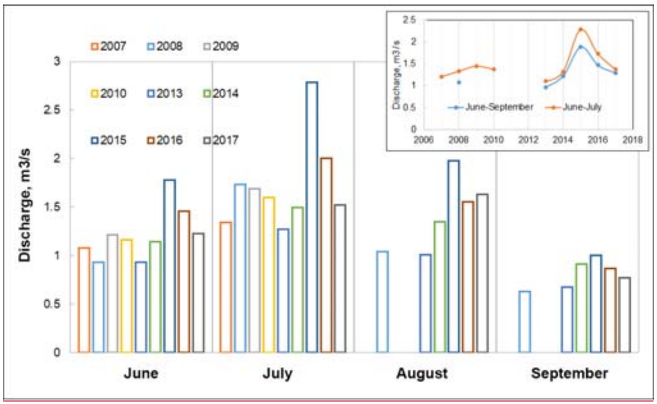
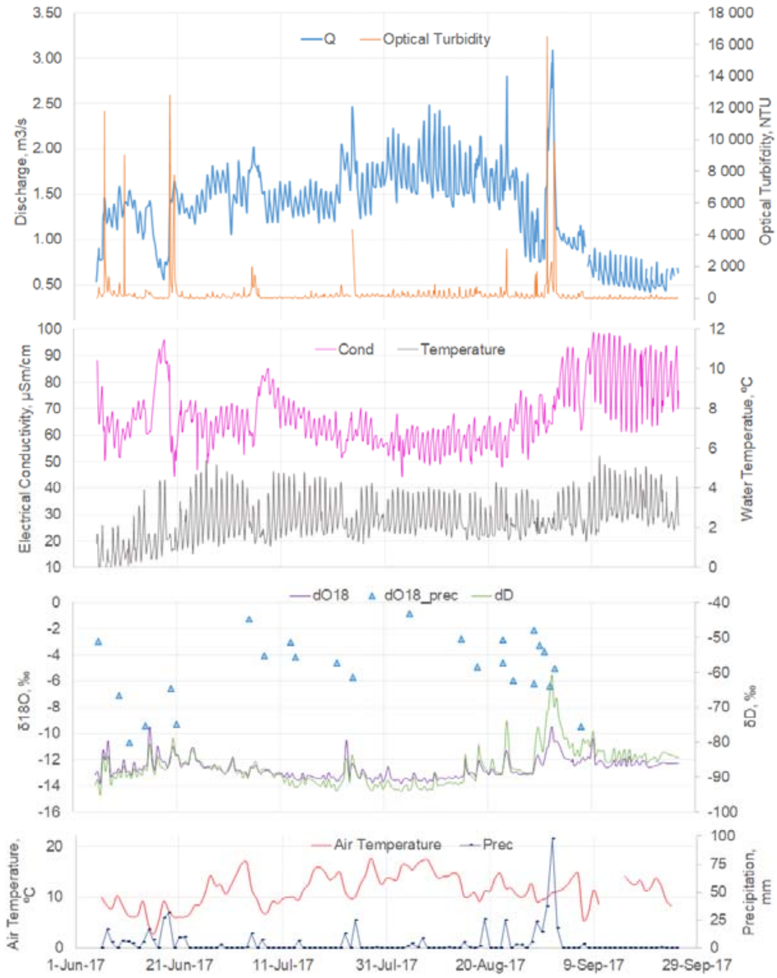


Figure ~~9~~5: Fluctuations of mean monthly and mean seasonal runoff of Djankuat ~~river~~River during the whole period of observation (2007–2017).



Q
Optical Turbidity
Discharge, m3/s
Optical Turbidity, NTU
3.50
3.00
2.50
2.00
1.50
1.00
0.50
18 000
16 000
14 000
12 000
10 000
8 000
6 000
4 000
2 000
0
Cond
Temperature
Electrical Conductivity, µSm/cm
Water Temperatue, ºC
100
90
80
70
60
50
40
30
20
10
12
10
8
6
4
2
0
dO18
dO18_prec
dD
δ18O, ‰
δD, ‰
0
-2
-4
-6
-8
-10
-12
-14
-16
-40
-50
-60
-70
-80
-90
-100
Air Temperature
Prec
Air Temperature, ºC
Precipitation, mm
20
10
0
100
75
50
25
0
1-Jun-17
21-Jun-17
11-Jul-17
31-Jul-17
20-Aug-17
9-Sep-17
29-Sep-17

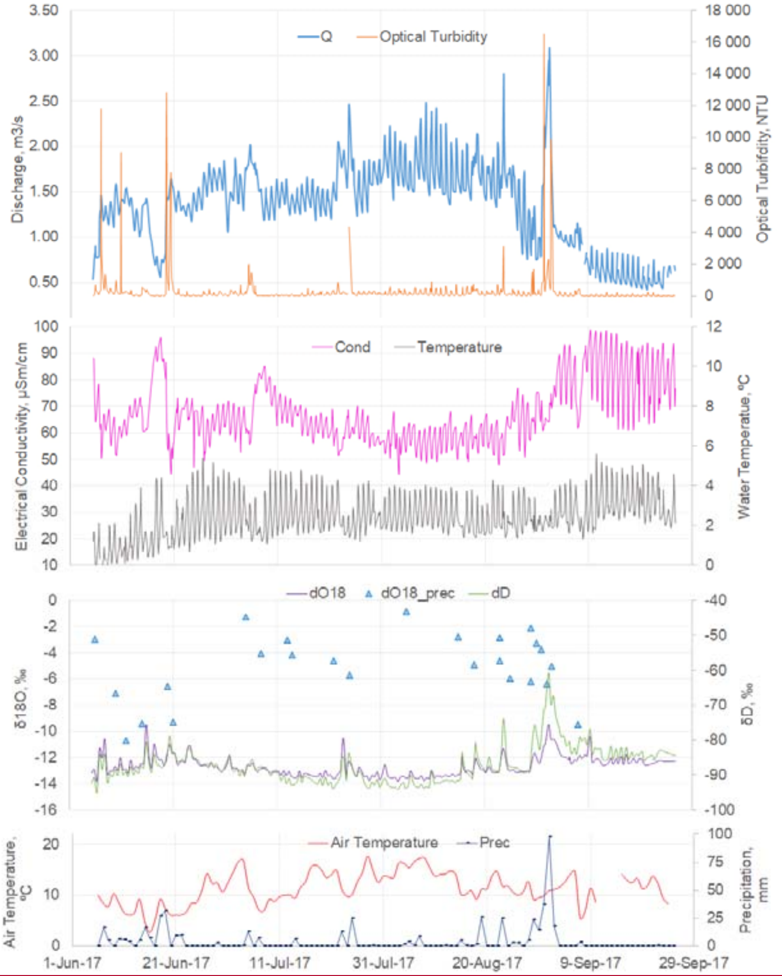


Figure ~~10~~6: Example of the fluctuations of the water discharge (Q), optical turbidity (Optical Turbidity), electrical conductivity (Cond), water temperature (Temperature), δ^{18}O (dO18), δD, (dD) in Djankuat ~~river~~River during the ablation season accompained with mean daily air temperature (Air Temperature), precipitation amount (Prec) and δ^{18}O in liquid precipitation (dO18_prec). Drawn using the observational data for June–September 2017.

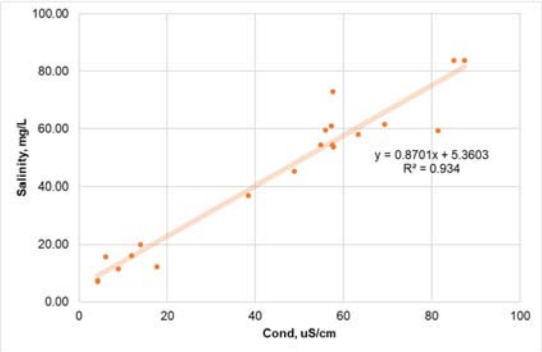
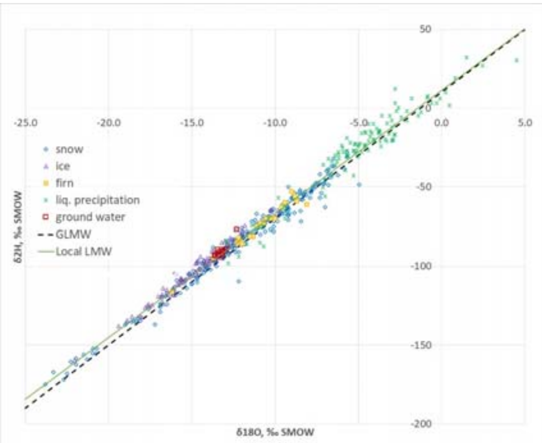
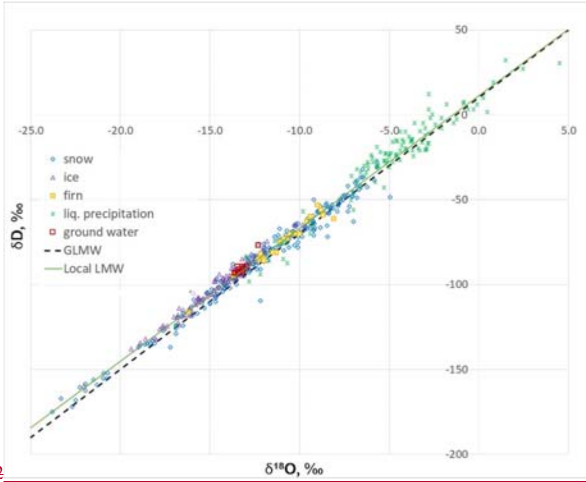


Figure 11: Dependency between water electrical conductivity and Salinity for the Djankuat River basin.





~~Figure 12~~

Figure 7: δ^{18}O vs. δD graph for the samples of snow, ice, firn, liquid precipitation and groundwater collected in the Djankuat River basin in 2013–2017, plotted with a global and local meteoric water line.

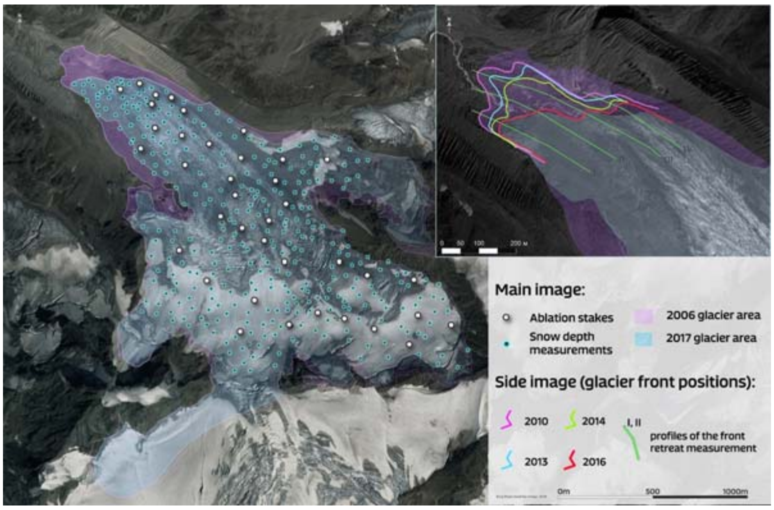


Figure ~~13~~8: The spatial distribution of ablation stakes and snow thickness measurement points, change in the Djankuat glacier area during the study period and glacier front position.

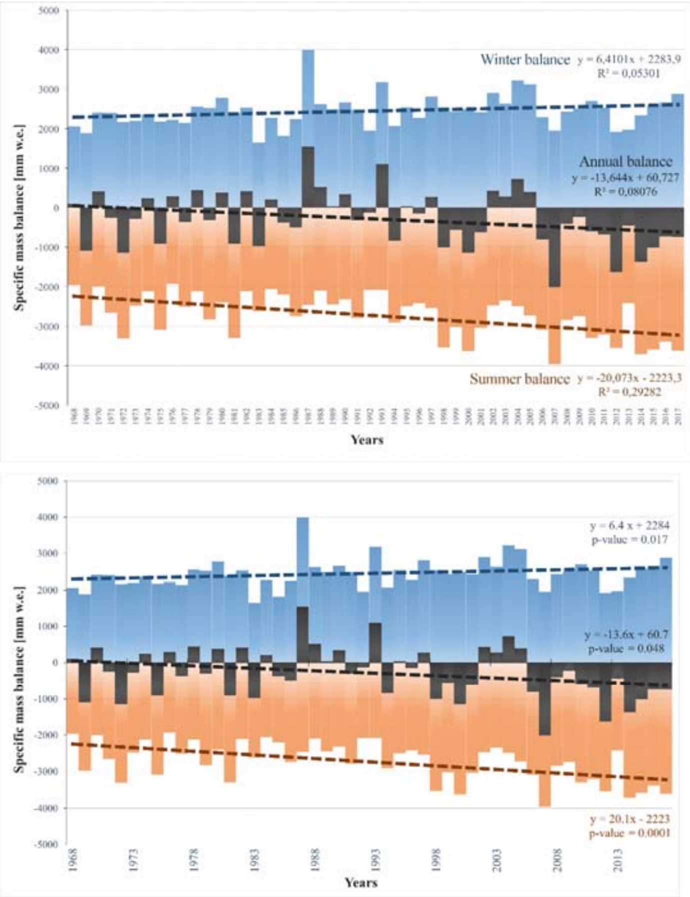


Figure ~~14~~9: Fluctuations of the Djankuat glacier mass balance components in mm of water equivalent (mm w.e.) since the beginning of the observations in 1968 (www.wgms.ch).

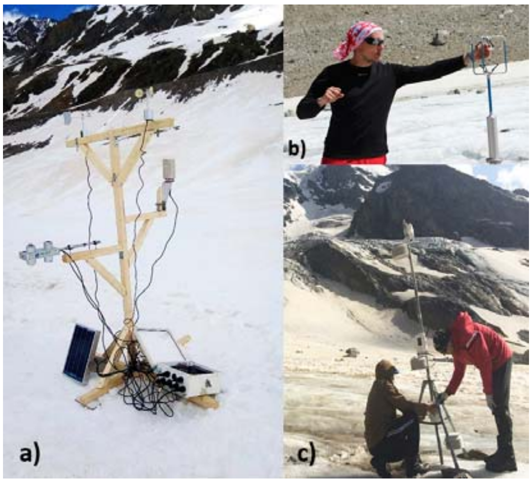
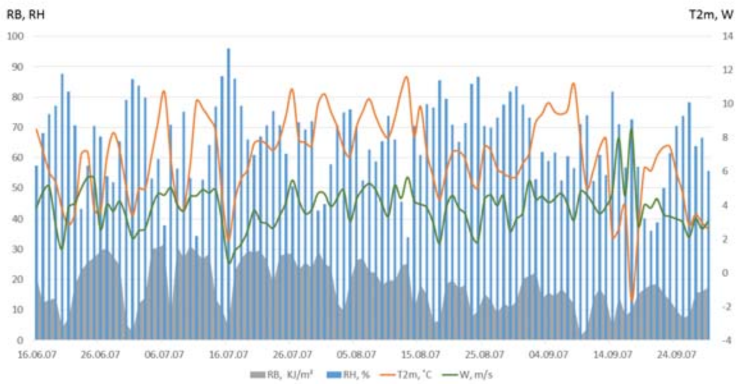
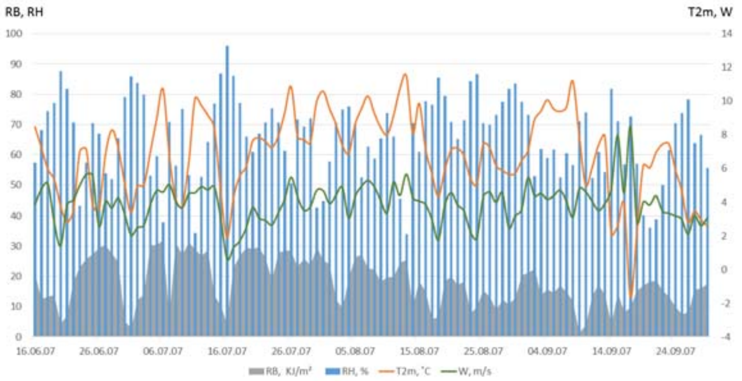
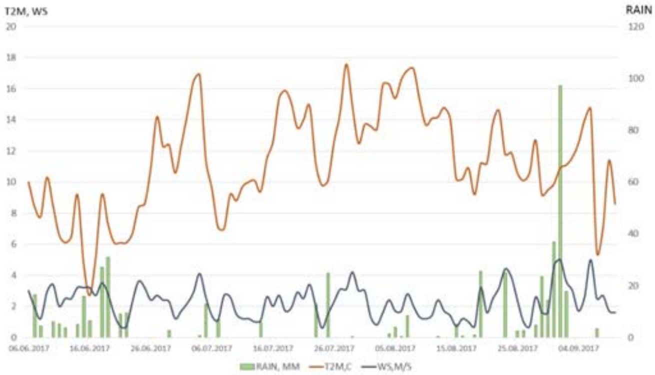


Figure 15: Meteorological measurements on the Dzhankuat glacier at AWS-1: a) Campbell meteorological complex with a set of Kip & Zonen radiometers b) GILL three-component acoustic anemometer c) gradient mast equipped with temperature-humidity and wind sensors Davis (photo by M. Aleshina).





~~Figure 16~~
Figure 10: An example of temporal variability of average daily values on the Djankuat glacier (measured in Djankuat glacier AWS-1 location) in 2007: RB – radiation balance, KJ/m^2 , RH – relative humidity,% T2m – air temperature, °C, W – wind speed, m/s.



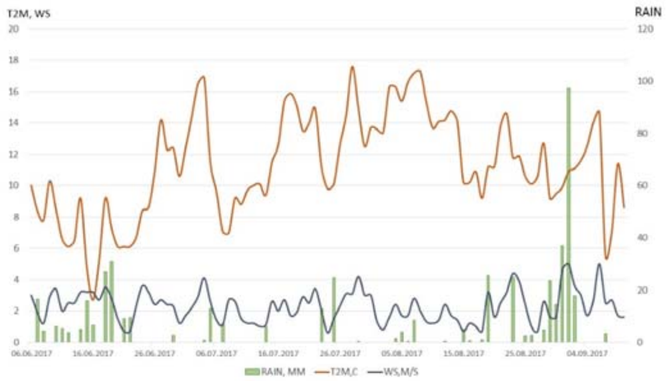


Figure ~~17~~11: An example of temporal variability of average daily temperature, wind speed and precipitation sum on base camp (point AWS–«base camp»): ~~RB – radiation balance, KJ/m² RH – relative humidity,%~~ RAIN –precipitation, mm/day, T2m – air temperature, °C, WS – wind speed, m/s.

Table 1: Location of main Sites within the Djankuat research basin

#	Name	x (longitude), decimal degrees	y (latitude), decimal degrees	Elevation, m
1	Djankuat Base Camp	42.735	43.208	2635
2	Djankuat Base Camp AWS	42.736	43.208	2640
3	Djankuat Glacier AWS 1	42.757	43.198	3000
4	Djankuat Glacier AWS 2	42.759	43.2	3050
5	Djankuat Glacier AWS 3	42.759	43.193	3200
6	Djankuat River Gauging Station	42.736	43.209	2630

Table ~~2~~2a: Hydrological characteristics measured in the Djankuat research basin and included in the database

#	~~Name~~Site	Characteristic	Unit	~~Time step~~Sampling intervals	~~Sites~~Accuracy modulus	Method	Period of measurements of days in brackets)
1	Djankuat River Gauging Station	Water Discharge	m³/s	1 hour	~~Gauging Station~~<10%	Calculated from water level measurements (see in the text)	15.06.07 – 12.07.07 (28) 06. 15.09.08 (102) 15.06.09 – 19 14.06.10 – 14.07.10 (31) 10. 26.09.13 (109) 08.06.14 – 30 09.06.15 – 19.09.15 (103) 14 27.09.16 (106) 03.06.17 – 25
2		Water Temperature	°C		0.5	Electrical conductivity meter Econics Expert-002	28.06.08 – 26.07.08 (29) 15. 19.06.09 (5) 09.06.15 – 19.0

Отформатировано: Узор: Нет (Белый)
Отформатированная таблица
Отформатировано: Шрифт: 9 пт
Отформатировано: Шрифт: 9 пт
Отформатировано: Шрифт: 9 пт, английский (Соединенное Королевство)
Добавленные ячейки
Отформатировано: Шрифт: 9 пт
Отформатировано: Шрифт: 9 пт
Отформатировано: Шрифт: 9 пт, английский (Соединенное Королевство)
Добавленные ячейки
Отформатировано: Шрифт: 9 пт, английский (Соединенное Королевство)
Отформатировано: Шрифт: 9 пт, английский (Соединенное Королевство)
Отформатировано: Шрифт: 9 пт
Отформатировано: Шрифт: 9 пт
Добавленные ячейки
Отформатировано: Шрифт: 9 пт, английский (Соединенное Королевство)
Отформатировано: Шрифт: 9 пт
Отформатировано: Шрифт: 9 пт
Отформатировано: Шрифт: 9 пт, английский (Соединенное Королевство)
Отформатировано: По ширине

#	NameSite	Characteristic	Unit	Time stepSampling intervals	SitesAccuracy modulus	Method	Period of measurements (number of days in brackets)	
							09.06.16 – 18.09.16 (74) 03. 25.09.17 (115)	
3		Water Electrical Conductivity	µS/cm	1 hour step or 6-7 times daily	2%		28.06.08 – 26.07.08 (29) 15. 19.06.09 (5) 10.06.13 – 19.0 19.06.14 – 30.09.14 (104) 09 19.09.15 (67) 09.06.16 – 18. 03.06.17 – 25.09.17 (115)	
4		Water Salinity	mg/L		-	Calculated from Electrical conductivity (see in the text)		
5		Optical Turbidity	NTU	6-7 times daily	2%+0.02 NTU	Portable turbidity meter HACH 2100P	28.06.08 – 17.07.08 (20) 10. 20.06.13 (5) 31.08.14 – 08.0 08.06.15 – 19.09.15 (104) 09 19.09.16 (103) 03.06.17 – 25	
6		Turbidity in weight units	SSC		-	Calculated from Turbidity measured in NTU (see in the text)		
7		^{18}O concentration as δ-notion	‰	2 times daily	0.06-0.1	2013:mass spectrometer, 2014-2016:laser-based spectrometer; 2017 - Cavity Ring-Down Spectroscopy (see text for details)	11.06.2013 – 19.09.13 (4) 08 30.09.14 (115) 08.06.15 – 18 06.06.16 – 18.09.16 (105) 03 25.09.17 (115)	
8		^{2}H concentration as δ-notion	‰		0.4-2	2014-2016:laser-based spectrometer; 2017 - Cavity Ring-Down Spectroscopy (see text for details)	08.06.14 – 30.09.14 (115) 08 18.09.15 (98) 06.06.16 – 18. 03.06.17 – 25.09.17 (115)	
29	Snow, Ice, Firn, Ground water, Liquid precipitation samples in different parts of the watershed	Water Electrical Conductivity	µS/cm	1 hour step or 6-7 times daily on the Gauge; and 60–-200 samples of S, I, F, GW&LPeach Snow, Ice, Firn, Ground water, Liquid precipitation a year	2%	Electrical conductivity meter Econics Expert-002	Gauging Station; Snow (S), Ice (I), Firn (F), Ground water (GW), Liquid precipitation (LP) samples in different parts of the watersheds8 samples in 2013 104 samples in 2014 – 64 samples in 2015 100 samples in 2016 209 samples in 2017	Elect Cond meter
310		Water Salinity	mg/L		-	Calculated from Electrical conductivity (see in the text)		

4	Water Temperature	ºC	1 hour step or 6–7 times daily	Gauging Station	Temperature sensor in Conductometer
5	Turbidity measured in Nephelometric Turbidity Unit	NTU	6–7 times daily	Gauging Station	Turbidimeter
6	Turbidity in weight units	g/m³		Gauging Station	Calculated (see in the text)

Отформатировано: Шрифт: 9 пт
Отформатировано: Шрифт: 9 пт
Отформатировано: Шрифт: 9 пт, английский (Соединенное Королевство)
Добавленные ячейки
Отформатировано: Шрифт: 9 пт
Отформатировано: Шрифт: 9 пт
Отформатировано: Шрифт: 9 пт, английский (Соединенное Королевство)
Добавленные ячейки
Отформатировано: Шрифт: 9 пт, английский (Соединенное Королевство)
Отформатировано: Шрифт: 9 пт, английский (Соединенное Королевство)
Удаленные ячейки
Отформатировано: Шрифт: 9 пт
Отформатировано: Шрифт: 9 пт
Добавленные ячейки
Отформатировано: По левому краю
Добавленные ячейки
Отформатировано: Шрифт: 9 пт
Добавленные ячейки
Отформатировано: Шрифт: 9 пт, английский (Соединенное Королевство)
Отформатировано: Шрифт: 9 пт
Отформатировано: По ширине
Отформатировано: Шрифт: 9 пт, английский (Соединенное Королевство)
Отформатировано: Шрифт: 9 пт, английский (Соединенное Королевство)
Отформатировано: Шрифт: 8 пт
Отформатировано: Шрифт: 9 пт
Добавленные ячейки
Отформатировано: Шрифт: 9 пт
Отформатировано: По ширине
Отформатировано: Шрифт: 9 пт, английский (Соединенное Королевство)
Разделенные ячейки
Отформатировано: Шрифт: Calibri, 9 пт, английский (Соединенное Королевство)
Отформатировано: Шрифт: 9 пт, английский (Соединенное Королевство)

#	NameSite	Characteristic	Unit	Time stepSampling intervals	SitesAccuracy modulus	Method	Period of measurements (number of days in brackets)
711		^{18}O concentration as δ-notion	‰	2 times daily on the Gauge; and 60–200 samples of S, I, F, GW&LP a year	Gauging Station; S, I, F, GW, LP samples in different parts of the watershed 0.06-0.1	2013:mass spectrometer, 2014–2016:laser-based spectrometer; 2017 – Cavity Ring-Down Spectroscopy (see text for details)	
812		^{2}H concentration as δ-notion	‰		0.4-2	2014–2016:laser-based spectrometer; 2017 – Cavity Ring-Down Spectroscopy (see text for details)	

Table 3: Main statistical2b: Glaciological characteristics of the parameters measured onin the Djankuat Gauging Station during 2007–2017research basin and included in the database

Parameter	Water Discharge	Water Electrical Conductivity	Water Salinity	Water Temperature	Optical Turbidity	Weight Turbidity	δ^{18}O	δD
#	Site	Characteristic	Unit	m^3/sSampling intervals	Accuracy modulus μS/cm	mg/LMethod	ºCPeriod of measurements	NTU
						g/L	‰	‰
number of values	16971	3464	3464	3259	1991	1991	844	842
min	0.11	31.70	32.94	0.10	6.9	27.8	-14.7	-102.0
max 1	8.46At 250–300 evenly distributed points on the Djankuat Glacier Surface	114.60Snow thickness	cm	1 time yearly	5	Probe poles	105.0712.06.07 – 30.06.07 12.06.08 – 07.07.08 08.06.09 – 07.07.09 19.05.10 – 10.07.10 04.06.1	6.63 / 45060.0 / 37163.7 / -6.7 / -60.0

Отформатировано ... [2]
Отформатировано ... [1]
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Отформатировано ... [4]
Отформатировано ... [7]
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Добавленные ячейки ... [33]
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Удаленные ячейки ... [56]
Удаленные ячейки ... [57]
Отформатировано ... [45]
Добавленные ячейки ... [51]
Отформатировано ... [44]
Отформатировано ... [46]
Отформатировано ... [47]
Добавленные ячейки ... [48]
Добавленные ячейки ... [49]
Добавленные ячейки ... [50]

								2 – 06.07.12 05.06.13 – 01.07.13 04.06.14 – 04.07.14 04.06.15 – 12.07.15 26.05.16 – 15.07.16 04.06.17 – 11.07.17					
range	8.3 5	82.90	72.1 3	6.53	4505 3.1	37135. 9		8.0	42.0				
mea n2	1.39At 35–45 evenly distributed points on the Djankuat Glacier Surface	Ablatio n56.76	69.3 6mm of water equiv alent	2.2 61-30 day s	467.9	368.2	Ablatio n stakes	- 12.612.06.07 – 10.09.07 16.05.08 – 07.10.08 08.06.09 – 25.09.09 18.06.10 – 02.10.10 03.06.12 – 04.10.12 05.06.13 – 21.09.13 04.06.14 – 30.09.14 04.06.15 – 20.09.15 26.05.16 – 20.09.16 03.06.17 – 24.09.17					-86.2
std.dev	0.6 6	13.13	11.4 2	0.99	1932. 9	1587.8		1.0	6.6				
coef. var3	0.47Stake 9, 18, 49, 65/68	Snow density	g/cm³	1-5 times in each snowpit yearly		0.1901	Snow sampling cylinder	0.1719.05.07 – 13.06.07 16.05.08 – 14.07.08 03.06.09 – 01.09.09 21.05.1	0.44	4.1	4.3	-0.1	0.1

Отформатировано: Шрифт: 8 пт
Удаленные ячейки
Удаленные ячейки
Отформатировано: По ширине
Отформатировано: По ширине
Добавленные ячейки
Отформатировано: Шрифт: 9 пт, Цвет шрифта: Черный, английский (Соединенное Королевство)
Отформатировано: Шрифт: 9 пт
Отформатировано: По ширине
Отформатировано: Шрифт: 9 пт
Отформатировано: Шрифт: 9 пт, английский (США)
Отформатировано: Шрифт: 9 пт
Отформатировано: Шрифт: 9 пт
Отформатировано: Шрифт: 9 пт
Отформатировано: Шрифт: 8 пт
Отформатировано: По ширине
Удаленные ячейки
Удаленные ячейки
Удаленные ячейки
Удаленные ячейки
Удаленные ячейки
Добавленные ячейки
Добавленные ячейки
Отформатировано: По ширине
Добавленные ячейки
Отформатировано: Шрифт: 9 пт
Отформатировано: Шрифт: 9 пт
Отформатировано: По ширине
Отформатировано: Шрифт: 9 пт
Отформатировано: Шрифт: 9 пт
Добавленные ячейки

							0 – 06.07.10 04.06.12 – 06.07.12 06.06.13 – 22.06.13 05.06.14 – 02.09.14 05.06.15 – 04.09.15 29.05.16 – 07.10.16 06.06.17 – 10.08.17					

Table 4: Stable isotopes content and conductivity of snow, ice, firn, liquid precipitation and groundwater2c: Meteorological characteristics measured in the Djankuat Riverresearch basin and included in the database

Type of sample#	Site	Characteristic	Unit	mean	max	Sampling intervals	Accu... mod...
1	Djankuat Glacier AWS 1	maxAir temperature at 2 m	min°C			15 min	mea
2		Relative humidity at 2 m	%				5
3		Wind speed at 2 m	m/s				(0.5
4		Wind diection at 2 m	°				10
5		Atmospheric pressue	hPa				1
6		Incoming shortwave radiation	Wt/m^2				
7		Reflected shortwave radiation	Wt/m^3				15
8		Downward longwave radiation	Wt/m^4				
9		Upward longwave radiation	Wt/m^2				

Отформатировано: Шрифт: 8 пт
Отформатировано: Шрифт: Times New Roman, 10 пт, английский (США)
Удаленные ячейки
Разделенные ячейки
Отформатировано: По ширине
Удаленные ячейки
Удаленные ячейки
Добавленные ячейки
Разделенные ячейки
Отформатировано: Шрифт: 9 пт, английский (Соединенное Королевство)
Отформатировано: По ширине
Добавленные ячейки
Добавленные ячейки
Добавленные ячейки
Добавленные ячейки
Добавленные ячейки
Отформатировано: Шрифт: 9 пт, английский (США)
Удаленные ячейки
Удаленные ячейки
Объединенные ячейки
Отформатировано: По левому краю
Объединенные ячейки
Отформатировано: Шрифт: 9 пт
Отформатировано: междустрочный, одинарный
Отформатировано: Шрифт: 9 пт
Объединенные ячейки
Отформатировано: Шрифт: 9 пт, Цвет шрифта: Черный
Отформатировано: Шрифт: 9 пт
Отформатировано: Шрифт: 9 пт
Отформатировано: Шрифт: 9 пт
Объединенные ячейки
Отформатировано: Шрифт: 9 пт
Отформатировано: Шрифт: 9 пт, английский (США)
Отформатировано: Шрифт: 8 пт
Разделенные ячейки

~~Type of sample~~#	Site	Characteristic	Unit	Sampling intervals	Accu mod…
10		Sensor-surface distance	m		0.01
11		Air temperature at 0.25, 0.5, 1 and 2 m	°C		±0.4
12		Relative humidity at 0.25, 0.5, 1 and 2 m	%		±10
~~Snow~~13	~~218~~	~~-5.0~~Mean wind speed at 0.25, 0.5, 1 and 2 m	~~-28.3~~m/s	~~-12.2~~ ~~28.0~~ ~~216.0~~	~~-85±~~
~~Ice~~ ~~116~~ ~~-9.8~~ ~~-22.0~~ -14~~.3~~		~~-64.0~~Maximum wind speed at 0.25, 0.5, 1 and 2 m	~~-159.7~~m/s	~~-99.3~~	~~63.7~~
15		Wind direction at 0.25, 0.5, 1 and 2 m	rhumb		-
~~Firn~~ ~~22~~ ~~-8.1~~ -16~~.2~~	~~-11.3~~	~~-53.0~~Three components of wind speed	~~-116.0~~m/s	10 Hz~~-77.1~~	~~23.~~0 ~~0.1~~
17		T - acoustic temperature	°C		
~~Liquid precipitation~~18	~~113~~Djankuat Glacier AWS 2	~~5.6~~Air temperature at 2 m	~~-16.9~~°C	15 min~~-4.9~~	~~32.~~0
19		Relative humidity at 2 m	%		5
20		Wind speed at 2 m	m/s		0.5
21		Wind diection at 2 m	°		10
22		Atmospheric pressue	hPa		1
23		Incoming shortwave radiation	Wt/m^2		
24		Reflected shortwave radiation	Wt/m^3		15
25		Downward longwave radiation	Wt/m^4		
26		Upward longwave radiation	Wt/m^2		
27		Sensor-surface distance	m		0.04
28	Djankuat Glacier AWS 3	Air temperature	°C	15 min	0.4
29		Relative humidity	%		10
30		Wind speed	m/s		0.6
31		Wind diection	°		5
~~Groundwater~~32	~~16~~Base Camp AWS	Air temperature ~~-12.3~~	~~-13.6~~°C	15 min	0.4

Удаленные ячейки ... [70]
Разделенные ячейки ... [67]
Удаленные ячейки ... [71]
Удаленные ячейки ... [72]
Отформатировано ... [68]
Добавленные ячейки ... [65]
Разделенные ячейки ... [58]
Отформатировано ... [59]
Отформатировано ... [60]
Добавленные ячейки ... [61]
Добавленные ячейки ... [62]
Добавленные ячейки ... [63]
Добавленные ячейки ... [64]
Добавленные ячейки ... [66]
Отформатировано ... [69]
Удаленные ячейки ... [80]
Удаленные ячейки ... [81]
Удаленные ячейки ... [90]
Объединенные ячейки ... [74]
Отформатировано ... [73]
Отформатировано ... [75]
Отформатировано ... [76]
Объединенные ячейки ... [82]
Отформатировано ... [83]
Отформатировано ... [84]
Объединенные ячейки ... [85]
Отформатировано ... [86]
Объединенные ячейки ... [87]
Отформатировано ... [89]
Отформатировано ... [88]
Отформатировано ... [78]
Отформатировано ... [79]
Отформатировано ... [77]
Удаленные ячейки ... [91]
Удаленные ячейки ... [92]
Удаленные ячейки ... [93]
Удаленные ячейки ... [94]
Отформатировано ... [95]
Отформатировано ... [98]
Отформатировано ... [101]
Отформатировано ... [102]
Отформатировано ... [103]
Отформатировано ... [104]
Отформатировано ... [105]
Добавленные ячейки ... [97]
Отформатировано ... [96]
Отформатировано ... [100]
Отформатировано ... [99]
Удаленные ячейки ... [106]
Удаленные ячейки ... [107]
Удаленные ячейки ... [108]
Отформатировано ... [118]
Отформатировано ... [109]
Объединенные ячейки ... [115]
Отформатировано ... [116]
Отформатировано ... [111]
Отформатировано ... [110]
Отформатировано ... [112]
Отформатировано ... [113]
Отформатировано ... [114]
Отформатировано ... [117]

~~Type of sample~~#	Site	Characteristic	Unit	Sampling intervals	Accu mod…
33		Relative humidity	%		10
34		Wind speed	m/s		(0.6…
35		Wind diection	°		15
36		Atmospheric pressue	hPa		1
37		Liquid precipitation	mm	24 hours	5% …

Table ~~5: Statistical characteristics~~3: Mean value and range of ~~glaciological~~ some of the parameters measured ~~on~~in the Djankuat ~~Glacier during 2007–2017~~research basin

Parameter	Site	Unit	Number of values	Mean
Water Discharge	Djankuat River Gauging Station	m^3/s	16971	1.39
Water Temperature		ºC	3259	2.26
Optical Turbidity		NTU	1991	468
Weight Turbidity		g/L	1991	368
Water Electrical Conductivity	Djankuat River Gauging Station	µS/cm	3464	56.76
	Snow samples		218	9.3
	Ice samples		116	14.8
	Firn samples		22	13.7
	Groundwater samples		16	109
$\delta^{18}O$	Djankuat River Gauging Station	‰	844	-12.6
	Snow samples		218	-12.2
	Ice samples		116	-14.3
	Firn samples		22	-11.3
	Liquid precipitation samples		113	-4.9
	Groundwater samples		16	-13.3
δD	Djankuat River Gauging Station	‰	842	-86.2
	Snow samples		218	-85.5
	Ice samples		116	-99.3
	Firn samples		22	-77.1
	Liquid precipitation samples		113	-26.2
	Groundwater samples		16	-91.1
~~Parameter~~ Snow thickness		~~Snow density~~cm	2932	360
Ablation	~~Ablation~~Djankuat Glacier	mm w.e./day	5045	47
Mean snow density for the snowpack	~~by layers~~	g/cm³	66	0.57
~~Unit~~	~~cm~~	~~mm w.e.~~	~~g/cm³~~	

Удаленные ячейки ... [162]
Разделенные ячейки ... [159]
Удаленные ячейки ... [163]
Отформатировано ... [160]
Удаленные ячейки ... [164]
Добавленные ячейки ... [157]
Разделенные ячейки ... [150]
Отформатировано ... [152]
Отформатировано ... [151]
Добавленные ячейки ... [153]
Добавленные ячейки ... [154]
Добавленные ячейки ... [155]
Добавленные ячейки ... [156]
Добавленные ячейки ... [158]
Отформатировано ... [161]
Отформатировано ... [165]
Отформатировано ... [166]
Удаленные ячейки ... [167]
Отформатировано ... [173]
Разделенные ячейки ... [168]
Отформатировано ... [169]
Отформатировано ... [170]
Отформатировано ... [171]
Добавленные ячейки ... [174]
Добавленные ячейки ... [175]
Добавленные ячейки ... [176]
Добавленные ячейки ... [177]
Отформатировано ... [172]
Удаленные ячейки ... [178]
Удаленные ячейки ... [179]
Удаленные ячейки ... [180]
Объединенные ячейки ... [185]
Отформатировано ... [186]
Отформатировано ... [181]
Отформатировано ... [182]
Отформатировано ... [183]
Отформатировано ... [184]
Добавленные ячейки ... [187]
Добавленные ячейки ... [188]
Добавленные ячейки ... [189]
Добавленные ячейки ... [190]
Добавленные ячейки ... [191]

number of values	2932	5045	66	434	

MeanSnow density by layers of the snowpack	360	g/cm³47*	434	0.57
Air temperature at 2 m_hourly	Base Camp AWS	°C	5340	10.2
	Djankuat Glacier AWS 1		17551	6.60
	Djankuat Glacier AWS 2		4901	6.37
MaxRelative humidity at 2 m_hourly	Base Camp AWS1155	387*%	5340	65 0.64
	Djankuat Glacier AWS 1		17526	68.4
	Djankuat Glacier AWS 2		4901	68.0
Wind speed at 2 m_hourly	Base Camp AWS	m/s	5095	1.93
	Djankuat Glacier AWS 1		17469	3.95
	Djankuat Glacier AWS 2		6095	5.50
MinIncoming shortwave radiation_hourly	7Djankuat Glacier AWS 1	0*Wt/m²	13728	273.8
	Djankuat Glacier AWS 2		3706	330.2
Downward longwave_radiation_hourly	Djankuat Glacier AWS 1	Wt/m²	16920	295.4
	Djankuat Glacier AWS 2		6466	286.6
Upward longwave_radiation_hourly	Djankuat Glacier AWS 1	Wt/m²	17548	313.7
	Djankuat Glacier AWS 2		6466	353.1
Liquid precipitation daily sum	Base Camp AWS	mm/day	232	11.2

* the value given as a rate (mm w.e./day)

Table 6. Meteorological data measured in the Djankuat research basin in 2007–2017 included in the dataset

Data source	Measured value and its accuracy (modulus)					Period of measurements (with number of days in brackets)	Sampling interval
	Air temperature T, °C	Relative humidity F, %	Wind speed V, m/s	Components of radiation balance B, Wt/m²	Sensor–surface distance H, m		
AWS 1 CAMPBEL	0.2	5	0.5–2	15	0.04-0.06	15.06.07 – 30.09.07 (107) 17.06.08 – 30.09.08 (105) 01.07.09 – 30.09.09 (91) 09.07.10 – 29.09.10 (82) 10.07.12 – 05.08.12 (26) 07.07.13 – 09.09.13 (64) 19.06.14 – 30.09.14 (103) 07.07.15 – 04.09.15 (59) 20.06.16 – 05.09.16 (77) 19.06.17 – 02.09.17 (75)	15 min
AWS 2 CAMPBEL	0.2	5	0.5–2	15	0.04-0.06	17.06.07 – 07.09.07 (82) 02.07.08 – 26.09.08 (86) 23.06.09 – 02.10.09 (101)	15 min
AWS 3 DAVIS	0.4	10	0.5 – 2	–	–	19.06.17 – 21.08.17 (63)	15 min
Gradient mast DAVIS	0.4	10	0.5 – 2	–	–	05.07.15 – 15.08.15 (41)	15 min
Sonic anemometer GILL	0.05 – 0.1	–	0.01-0.05	–	–	12.07.13 – 03.08.13 (22) 09.08.13 – 16.08.13 (7)	10 Hz

Отформатировано: Шрифт: 9 пт, английский (США)
Отформатировано: По левому краю
Отформатировано: Шрифт: 9 пт
Объединенные ячейки
Отформатировано: Шрифт: 9 пт, английский (США)
Отформатировано: Шрифт: 9 пт, русский
Отформатировано: Шрифт: 9 пт, русский
Добавленные ячейки
Отформатировано: Шрифт: 9 пт
Отформатировано: По левому краю
Добавленные ячейки
Объединенные ячейки
Объединенные ячейки
Отформатировано: По левому краю
Отформатировано: Шрифт: 9 пт, английский (США)
Отформатировано: Шрифт: 9 пт, русский
Отформатировано: По левому краю
Отформатировано: Шрифт: 9 пт, русский
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Отформатировано: Шрифт: 9 пт, русский
Добавленные ячейки
Добавленные ячейки
Отформатировано: Шрифт: 9 пт, русский
Объединенные ячейки
Отформатировано: По левому краю
Отформатировано: Шрифт: 9 пт, русский
Отформатировано: Шрифт: 9 пт, русский
Объединенные ячейки
Отформатировано: Шрифт: 9 пт, русский
Отформатировано: По левому краю
Отформатировано: Шрифт: 9 пт, русский
Отформатировано: Шрифт: 9 пт
Отформатировано: Шрифт: 9 пт, русский
Отформатировано: Шрифт: 9 пт, русский
Добавленные ячейки
Добавленные ячейки

						26.08.13 – 06.09.13 (42) 30.06.14 – 30.07.14 (30) 17.06.16 – 01.08.16 (45)	
AWS «Base Camp» DAVIS	0.4	10	0.5 – 2	–	–	26.06.09 – 04.10.09 (100) 08.07.09 – 07.09.09 (61) 06.06.09 – 25.09.09 (110)	15 min

Table 7.

Table 4. July daily averaged meteorological variables on Djankuat glacier in 2007–2017 (with RMS in brackets)

Year	Air temperature, °C			Relative humidity, %		Wind speed, m/s		Components of radiation balance, Wt/m^2 Albedo A, %				
	Mean	Min	Max	Mean	Min	Mean	Max	SW+	SW-	LW+	LW-	A, %
2007	8.0(±2.6)	0.4	13.5	66 (±19)	13	3.8 (±1.7)	8.4	247(±99)	68(±39)	280(±27)	314(±3)	19
2008	8.1(±2.1)	2.3	13.9	72 (±15)	24	4.2 (±1.8)	9.3	237(±105)	88(±58)	291(±26)	315(±4)	32
2009	6.0(±2.5)	-0.5	14.2	76 (±13)	36	3.8 (±1.7)	9.0	225(±88)	71(±48)	286(±29)	313(±8)	23
2010	8.3(±2.2)	2.9	15.2	68 (±14)	31	4.2 (±1.3)	8.5	265(±84)	43(±15)	293(±21)	317(±5)	18
2012	7.7(±2.0)	1.7	15.2	71 (±15)	31	3.9 (±1.6)	7.9	267(±104)	57(±25)	290(±19)	323(±3)	21
2013	5.0(±2.2)	-0.7	10.7	77 (±12)	40	3.5 (±2.0)	10.5	225(±98)	53(±30)	300(±22)	325(±4)	24
2014	7.6(±2.1)	2.4	14.7	67 (±16)	18	3.6 (±1.6)	8.3	274(±111)	47(±18)	306(±18)	293(±6)	19
2015	8.8(±2.8)	-0.1	17.9	65 (±17)	15	4.0 (±1.8)	8.9	308(±78)	75(±22)	357(±10)	332(±5)	24
2016	7.6(±2.8)	0.2	15.1	69 (±16)	24	3.8 (±1.9)	9.0	235(±92)	65(±23)	305(±15)	315(±6)	23
2017	8.3(±2.3)	0.5	17.6	63 (±15)	20	4.2 (±2.0)	10.1	224(±98)	54(±30)	301(±22)	324(±4)	25
Mean	7.6(±2.3)	1.1	14.5	68 (±17)	25	3.9 (±1.7)	8.9	231(±94)	63(±25)	300(±10)	317(±5)	24

Отформатировано: Положение: По горизонтали: слева, Относительно: Колонны, По вертикали: в строке, Относительно: поля, По горизонтали: 0 см, обтекание текстом

Отформатированная таблица

Отформатировано: Положение: По горизонтали: слева, Относительно: Колонны, По вертикали: в строке, Относительно: поля, По горизонтали: 0 см, обтекание текстом