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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

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Abstract. The study presents a dataset on long-term complex glaciological, hydrological, meteorological observations and isotopes sampling in an extremely underreported alpine zone of the North Caucasus. The Djankuat research basin is of 9.1 km^2, situated on elevations between 2500 – 4000 m, and ~~by 30%~~ covered with by 30% glaciers. The largest ~~biggest~~ 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 which ~~that~~ have annual mass balance series longer than 50 years (Zemp et al., 2009). The dataset reported here covers 2007–2017 and contains the result of yearly measurements of snow depth ~~thickness~~ and density; dynamics of snow and ice melting; measurements of water runoff, conductivity, turbidity, temperature, $\delta^{18}O$, $\delta^{2}H$ at ~~on~~ the main gauging station (844 samples in sum) with a one-hour or several-hours (time) step depending on the parameter; data on $\delta^{18}O$ and $\delta^{2}H$ 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); precipitation amount, air temperature, relative humidity, shortwave incoming and reflected radiation, longwave downward and upward radiation, atmospheric pressure, wind speed and direction – measured at ~~on~~ 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 turbulent fluxes ~~impulse heat fluxes~~ of sensible ~~heat~~ + latent heat over the glacier surface by the eddy covariance method. All the observations were done during the ablation period (June–September) and were interrupted in winter. The dataset was published on knb.ecoinformatics.org long-term repository doi:10.5063/F1H1307Q and will be further updated. The dataset can be useful for developing and verifying hydrological, glaciological and meteorological models for high elevation territories, to study the impact of climate change on the

hydrology of mountain regions, using isotopic and hydrochemical approaches to study mountain hydrology ~~territories~~. As the dataset includes the measurements of hydrometeorological and glaciological parameters 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 phenomen~~a~~on.

1 Introduction

The important role of mountains territories and their high sensitivity to ~~the~~ climate change is concluded in vast amount of recent research (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, 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 (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, recently joined the mentioned above ~~above~~ poorly studied territories in terms of level of information availability on meteorological and glacio-hydrological topics (Barry, 1992, Dyurgerov, 2003, Shahgedanova et al., 2005, Bobrovitskaya, Kokorev, 2014).

The Djankuat research basin, 9.1 km^2 in area, is located at 43.2°N and 42.75°E in the alpine zone of the North Caucasus (Russia), between 2600 and 4000 m (Fig. 1). Djankuat glacier, occupying 27% of its area, was chosen as representative of the central North Caucasus during the International Hydrological Decade (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 standard methods (Østrem and Brugman, 1992, Boyarsky, 1978). Hydrological and meteorological complex measurements were included in the monitoring program of the station during the International Hydrological Decade and were terminated in the end of 1970^s (Boyarsky, 1978). The complex 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 measurements during the ablation season of each year and the observational program gradually increased 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 to a special military regime that was instituted/applied ~~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 (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 2) was operating

2 ?

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 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 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 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 (^{18}O and ^{2}H), as well as first samplings of liquid precipitation, snow, ice, firn in the basin on water conductivity, water salinity, δ^{18}O and δ^{2}H ~~was~~ were carried out. Since 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 of the Djankuat River water turbidity (5–7 times a day) was ~~set~~ started during 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) and will be updated as the observations in the basin are still ongoing (as of autumn 2018). Some of the data, presented in the study was already successfully approbated included / acknowledged in scientific work (Zemp et al., 2009, Rets, Kireeva, 2010, Lambrecht et al., 2011, Zemp et al., 2011, Zemp et al., 2015, Popovnin, Pylayeva, 2015, Rets et al., 2017, Toropov et al., 2017, Chernomorets et al., 2018)

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 at 2000 m, the highest point of the Greater Caucasus is Elbrus mountain (5642 m). The climate here is ~~moderate continental~~ to cold high-alpine. 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) and the influence of the Black Sea ~~is~~ are superimposed on the general western (2) circulation. Together with the complex orographic effects ~~it~~ they result~~s~~ in a complex spatial precipitation distribution and strong precipitation gradients. The precipitation decreases both southeastwards and with a decrease in elevation. Annual precipitation sum vary 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 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 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/(s*sq.km). In the foothills mean annual runoff unit discharge sharply declines to 5–15 liters/(s*sq.km). The vast plain territories do 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). or become negative depending evaporation losses.

Rivers with a substantial share of the 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, and/or winter low flow period is more often interrupted by snowmelt winter floods. Annual water regime of rivers in the lowland ~~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~~ high-flow 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). redundant as mentioned above

The Djankuat research basin (43.2°N, 42.75°E) 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 km² with the elevation range 2600 – 4000 m, with steep slopes (more than 20° on ~~in~~ average) and nival-glacial landscape (Fig. 2). An overall exposition of the basin is the North-North-West. Glaciers occupy In the year.... 30% of the territory of the basin. also give date year The main glacier with the same name – Djankuat glacier – ~~gives a~~ is the source of the Djankuat 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 km², 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 basin also contains three small glaciers with ~~the~~ areas less than 0.5 km²: Koyavgan, Via-Tau, and Visyachiy. These glaciers ~~give a rise to water streams that join the~~ contribute runoff to Djankuat river upstream ~~of~~ the main 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.

The mean annual unit discharge in the upstream of the Baksan River area? is 55 liters per sec. per km² (Rets, Kireeva, 2010). also give specific value in mm/y The water-abundant period, which ~~lasts~~ extends from May to September–October, is prolonged and steady. The ~~fundamental~~ 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.~~ redundant A stable winter low-flow period with minimum monthly unit discharge of 10–15 liters per sec. per km² observed in February ~~–~~ to March is characteristic of the Baksan River upstream (Rets, Kireeva, 2010). over which area?

The climate of the Djankuat research basin is characterized by a distinct seasonality in temperature. The mean monthly air temperatures ~~on~~ at the closest to the research basin all-year Terskol meteorological station situated 6 km northwest of the glacier at an altitude of 2146 m goes below zero during November ~~–~~ and December. The warmest months are July and August with mean monthly temperatures above 12 °C (Fig.3). Monthly precipitation sums are by 40–50% higher in the warm period of the year (May–September) than during winter (Fig. 3). The annual precipitation ~~some on~~ at the Terskol weather station varied year to year by from 590 to 1330 mm with a mean annual value of ~~is~~ 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 periods in comparison to ~~than~~ the long-term average, and substantially higher amounts of precipitation, especially during the spring period – from March to May (Fig. 3). 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 to ~~–~~1 °C/10 year~~s~~ is observed during the summer period in the North Caucasus. According to ~~(~~Rets & Kireeva, (2010) this tendency is smaller more clear cut in the plain territory and foothills. A slight positive trend in the mean temperature in ~~of~~ the ablation period (May to ~~–~~September), 0.3 °C/10 year~~s~~, is observed at ~~on~~ the Terskol meteorological station since the end of 1970th (Fig. 4). The~~se~~ timing of alteration in the air temperature tendencies regime corresponds well with the situation observed in ~~on~~ the European territory of Russia, where the 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 which is ~~is~~ observed in the Eastern Caucasus, close to the Caspian Sea. In the study by Rets & 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%/10 year~~s~~ is reported by (Alekseev et al., 2014), and ~~or~~ no statically significant trend is reported ~~observed~~ for the most of the North Caucasus by (Toropov et al., 2018a). An increase in annual precipitation sum was revealed for the majority ~~most~~ of mountainous stations and a number of foothill stations in ~~of~~ the central part of Northern Caucasus (Rets, Kireeva, 2010). At ~~On~~ 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%/10 years is different for the ~~due to~~ ablation (2.1%/10 year~~s~~) and accumulation (5%/10 years) period. The most intensive rise in precipitation is observed in spring (8.6%/10 year~~s~~ in March, 7%/10 year~~s~~ in April) and autumn (10.3%/10 year~~s~~ 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). 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~~,~~ during (time period) 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 lake~~s~~ outburst~~s~~ floods (Stokes et al., 2007). On the 1st of September year? 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~~ trend during 1940–2010. In the most elevated areas the long-term mean value ~~on~~ of annual runoff remains stable. ~~Whereas in in~~ this is in contrast to 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 melting thaws and general reduction of the 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 areas, long-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 large macrovalleys long-term variations of winter minimum monthly discharges correlate with the corresponding variations in the foothills and ~~on~~ in the lowlands 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 time 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~~ (at an hourly time) step from the water level using a rating curve Q=f(H) (Table 2). Water level is measured ~~on~~ at the Djankuat gauging station with 10 min ~~–~~ to 1-hour 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 water level measurements are made 6–7 times a day by a staff gauge. Rating curves are redrawn for each month of each ablation season (Fig. 7). A dilution method with NaCl as a tracer was used for discharge measurements 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~~ stretches 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 does~~n't~~ 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 range of 1 to–2 m^3/s during the 2007–2017 observational period (Fig. 8a), the mean value of water discharge was 1.39 m^3/s (Table 3). Low frequency water discharges (less than 1% of duration) lay in the range of 3.5–8.46 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 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). The Djankuat River discharge was the most abundant flood 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). Mean monthly discharge in this month is 1.3–2.8 m^3/s. June and August are 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 (Fig. 10). glacial regime 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 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, 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 (Fig. 9d). 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~~ After 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 is supposed to be~~ which is 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 and 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). 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. Mean daily value of water temperature generally rises trough the ablation season (Fig. 10). The maximum value (6.63 °C) was registered on 18th of September 2016 at midday. The minimum values (0.1 °C) are observed ~~at the night hours~~ during the night in ~~of the after-winter period~~ early Spring when measurements started after the winter break (Fig 10).

3.1.4 Water Turbidity

Turbidity of the Djankuat River was measured at the gauging station 6–7 times a day during 2015 to 2017. ~~On~~ At the event of heavy rainfall, ~~the time-step of measurements is reduced~~ measuring frequency increased ? to 15 minutes, ~~these measurements are included~~ and averaged in the database of 1-hour ~~averaged~~ time steps. at an hourly time span 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 units (g/m^3) were calculated using a dependency Weight Turbidity=f(Optical Turbidity). The dependency was drawn in 2015 to 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. The Total amount of 1991 measurements is included in the database (Table 3). The Djankuat River turbidity has an extremely uneven distribution (Fig 9b): staying low~~er~~ 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 can abruptly rise 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 (Fig. 10). These values are in the same range as the values of water turbidity registered in such river as Huanghe (Zhang, Huang, 1993). 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 sampling of stable isotopes content in the Djankuat River was carried out in 2013 (Table 2). Its main goal was to define a needed regularity of sampling to get a representative mean daily value of $\delta^{18}O$ 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.

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 spectrometer. For the measurement, international standards were used: V-SMOW (δ18O = 0‰, δD = 0‰), GISP (δ18O = –24.76‰, δD = –189.5‰), SLAP (δ18O = –55.5‰, δD = –…‰), own laboratory standard MSU (snow glacier Garabashi: δ18O = –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 processed proceeded ~~were~~ 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 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 las lazer 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 amounting to ~~that thus equals~~ 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.

The values of $\delta^{18}O$ and δD in the Djankuat River waters have a relatively even duration curve (Fig 9 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 in ~~on the~~ Figure 10. Pronounced rises in $\delta^{18}O$ and δD are driven by precipitation events (Fig 10). The maximum value of $\delta^{18}O$ amounting to -6.7‰ (the content of δD in this sample was -72 ‰) was observed ~~registered~~ 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 observed registered 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).

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) runoff genesis with $\delta^{18}O$ as a tracer. The Djankuat River hydrograph was separated into 4 components: liquid precipitation/meltwaters, surface routed/subsurface routed waters. not clear 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 in contact with the ~~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 melt runoff in August 2014, and up to 100% of the Djankuat 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 for values of δ18O and δD in the basin

Regular sampling of snow, ice, firn, liquid precipitation and ground water in the Djankuat basin was carried out during 2014~~–~~ to 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 at ~~on~~ 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 assumed ~~supposed~~ 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.

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, which ~~that~~ 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, Fig. 12). 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). The mean concentration of ^{18}O and D in groundwater samples (-13.3‰ and -91‰ correspondingly) indicates a more important ~~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). Groundwater is enriched with dissolved salts up to 105 mg/L (114 µSm/cm).

? practically distilled water

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~~ depth measurement, ablation and snow density is included in the presented database.

Snow ~~thickness~~ depth ~~of the~~ on Djankuat glacier is measured by probe poles ~~in~~ at 250–300 points evenly distributed in all zones of the glacier (Fig. 13). 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~~ Therefore, the mass-balance calculation based on the measured values of accumulation ~~on~~ in the lower parts of the glacier are being corrected using the data from the upper zones of the glacier, where ablation ~~hasn't~~ has not started yet. ~~That~~ This is ~~controlled~~ shown 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.

Is this necessary? not standard procedure

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. 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 to 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 is 0.46 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 to 2017 measurements (Table 5).

overall mean value of density?

SI-units kg/m³

Ablation is measured by means of ablation stakes. 35–45 stakes were placed on the Djankuat glacier surface every year. The time-step ~~of~~ between measurements depends on the accessibility of each stake and ranges from 1–5 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 to 2017. The mean rate of snow/firn/ice ablation was 47 mm w.e./day, with a minimum 0 mm w.e./day and a maximum 387 mm w.e./day.

≙ 39 cm which is impossible energy-wise

So high?

The Djankuat glacier has experienced a general mass loss since the beginning of observation in 1968 (www.wgms.ch). ~~But up to~~ Until 2005, negative mass balance years alternated with positive mass balance years (Fig. 14). ~~Since~~ After 2006 and during all period that is presented in the dataset, the annual mass balance of Djankuat glacier was negative. The mass balance values ranged from –2010 mm w.e. in 2007, that was the lowest value of mass balance ~~registered~~ calculated since the beginning of the observation in 1968, to -230 mm w.e. in 2009. The mean value of mass balance during 2007–2017 was -900 mm w.e. The change in the Djankuat glacier area values? is shown on the Figure 13. The front of the glacier retreated by 60–300 m in different measurement profiles during 2010–2016 (Fig 13), 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 a decrease in summer balance, while accumulation shows a statistically insignificant positive trend (Fig. 14).

also show figures!

must be an erroneous measurement

along with other

The information on Djankuat glacier mass balance, calculated from the presented dataset, is being published in the Glacier Mass Balance Bulletin, ~~that~~ which is ~~designed~~ issued 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,~~ standardized data on changes in glaciers throughout the world at 5-yearly intervals (see for ex. Popovnin, 2012 and 2013).

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 & 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 sophisticated hydrological models. Aa an example, the presented meteorological data was successfully used to model the melting regime of the Djankuat glacier in 2007 by ~~an~~ the A-Melt model of ice and snow melt in alpine areas developed by (Rets, Kireeva, 2010).

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

1. Meteorological and actinometric radiation measurements above ice surface by means of Campbell AWS (Fig. 15a), including measurements of air temperature and relative humidity (Vaisala MT300 sensor), wind speed and direction (Campbell wind sensor) at 2 m AGL; radiation fluxes (KEEP & ZONNEN radiometers – two of them measure ~~an~~ incoming and outgoing ~~upward and downward~~ short-wave radiation, another two ~~– an~~ upward and downward long-wave radiation); measurements of ablation layer using with a Sonic Ranger sensor (the sensor is located on a construction, ~~that~~ which is drilled into the body of the glacier, and measures the distance from the sensor to the ice or (snow) surface). These automatic measurements have a record interval of 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 AWS with the same parameters was placed in the central part of the glacier over the debris covered surface in 2007, 2008 and 2009 (Djankuat Glacier AWS 2 on Fig. 1, Table 1).
3. Gradient mast DAVIS placed in the central part of the Djankuat glacier (Djankuat 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 above the glacier surface ~~AGL~~ (Fig. 15c, Table 6). Measurements were recorded with a 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~~ to obtain turbulent heat ~~fluxes~~ flux estimations 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~~

yields fluxes of turbulent heat, moisture and momentum ~~fluxes~~ by ~~a very promising method called~~ the «eddy-covariance» method (Andreas et al., 2005).

5. Measurements of the basic meteorological parameters such as air temp, precip... 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 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 mode ?, with a record interval of 15 min (Table 6).

The Figure 16 shows an example of the course of the average daily values of the basic meteorological variables during the ablation season of 2007 measured ~~on~~ by 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~~ a pronounced daily variation. The albedo effect is also clearly manifested – especially in June and September, when fresh snow frequently ~~often~~ falls on the surface of the glacier. The maximum values of incoming shortwave radiation can reach 1100 W/m². 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~~ at 4 m/s, while the maximum does not exceed 12 m/s. Above the glacier, stable katabatic winds blow, which is characterized by a pronounced diurnal course. The maximum speed values are ~~associated~~ obtained with hair dryers, ~~observed~~ ? determined 3–4 times per season to test the equipment. Table 7 shows the average July values of the main meteorological characteristics.

Figure 17 gives an example of the variability of the main meteorological characteristics in the Adyl-Su 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 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 ~~can be clearly seen that heavy rains in this area are normal.~~ ? For example ~~So~~, in 2017, the daily precipitation of about 20 mm was observed 6 times and from August 31 to September 1, about 48 mm of precipitation fell within 48 hours, which is a very high catastrophic amount. This rainfall caused the ~~mentioned above~~ above-mentioned outburst ~~breakthrough~~ 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 ~~the Djankuat basin~~ is now a unique research site not only for the high elevation territories of the North Caucasus, but for the Russian Federation as whole (Konovalov et al., 2018, Stokes et al., 2006, Shagedanova et al., 2005, Hagg et al., 2010). Nowadays the aim of the complex monitoring in the Djankuat basin is not only to fill a “blindspot" 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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sequence in alphabetical order?

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exactly the same title as this paper with E P Rets as first author in a different journal?

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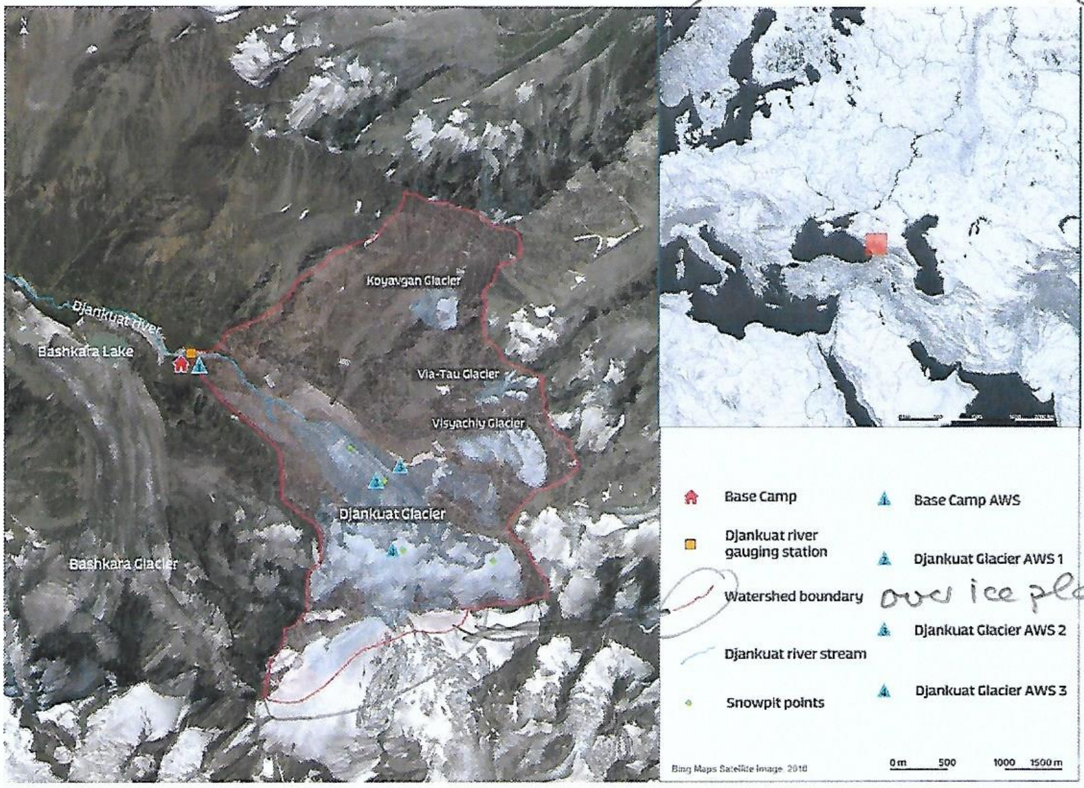
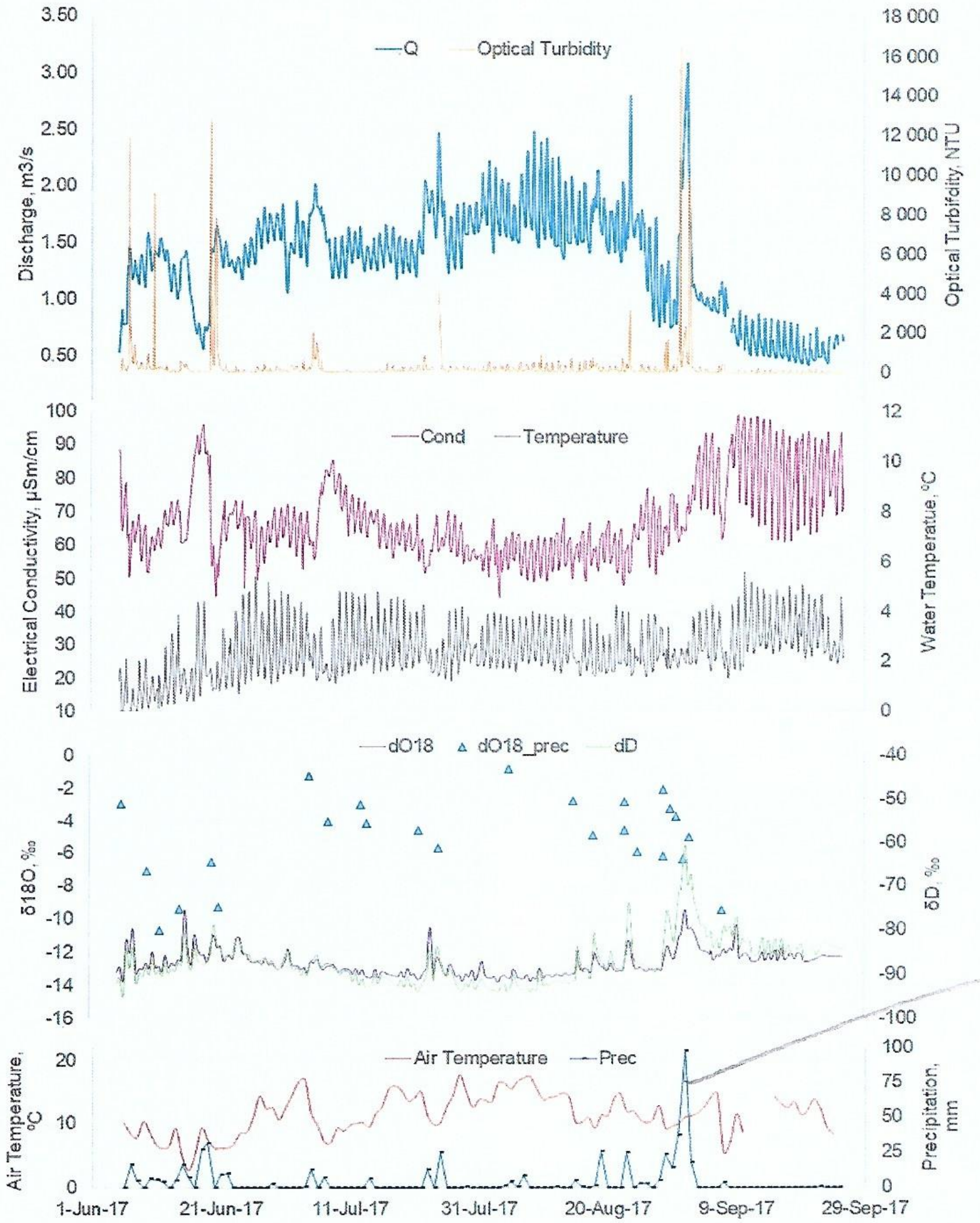
poorly visible boundary: draw it Broader or in yellow



over ice plateau?

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

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



Precip usually given as column

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

°/C

mm/d

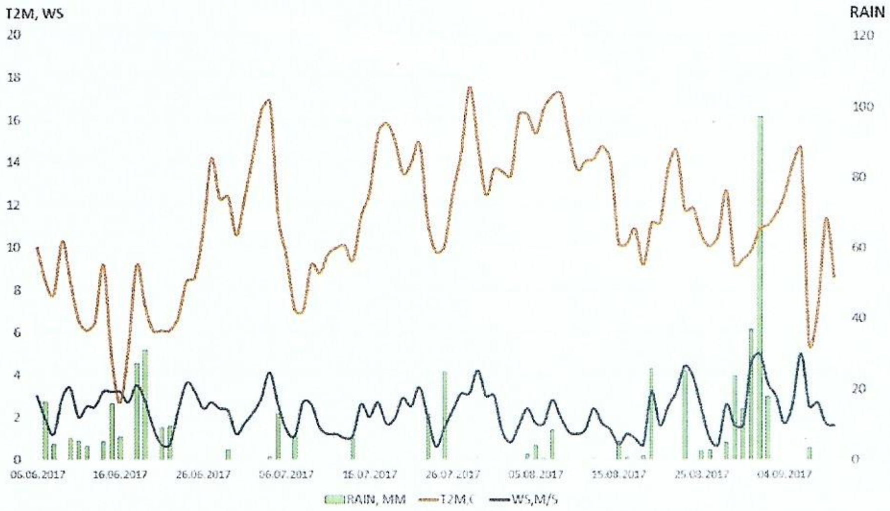


Figure 17: An example of temporal variability of average daily temperature, wind speed and precipitation on base camp (point AWS–«base camp»): RB – radiation balance, KJ/m², RH – relative humidity,%, T2m – air temperature, WS – wind speed, m/s.

precipitation (mm/d)

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: Hydrological characteristics measured in the Djankuat research basin and included in the database

#	Name	Unit	Time step	Sites	Method
1	Water Discharge	m^3/s	1 hour	Gauging Station	Calculated (see in the text)
2	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&LP a year	Gauging Station; Snow (S), Ice (I), Firn (F), Ground water (GW), Liquid precipitation (LP) samples in different parts of the watershed	Electrical Conductivity meter
3	Water Salinity	mg/L			Calculated (see in the text)
4	Water Temperature	°C	1 hour step or 6–7 times daily	Gauging Station	Temperature sensor in Conductometer
5	Turbidity measured in Nephelometric	NTU	6–7 times daily	Gauging Station	Turbidimeter

	Turbidity Unit				
6	Turbidity in weight units	g/m^3		Gauging Station	Calculated (see in the text)
7	^{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	2013:mass spectrometer, 2014–2016:laser-based spectrometer; 2017 – Cavity Ring-Down Spectroscopy
8	^{2}H concentration as δ-notion	‰			2014–2016:laser-based spectrometer; 2017 – Cavity Ring-Down Spectroscopy

Table 3: Main statistical characteristics of the parameters measured on the Djankuat Gauging Station during 2007–2017

Parameter	Water Discharge	Water Electrical Conductivity	Water Salinity	Water Temperature	Optical Turbidity	Weight Turbidity	δ^{18}O	δD
Unit	m^3/s	µS/cm	mg/L	°C	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	8.46	114.60	105.07	6.63	45060.0	37163.7	-6.7	-60.0
range	8.35	82.90	72.13	6.53	45053.1	37135.9	8.0	42.0
mean	1.39	56.76	69.36	2.26	467.9	368.2	-12.6	-86.2
std.dev	0.66	13.13	11.42	0.99	1932.9	1587.8	1.0	6.6
coef.var	0.47	0.19	0.17	0.44	4.1	4.3	-0.1	0.1

significant ?

Table 4: Stable isotopes content and conductivity of snow, ice, firn, liquid precipitation and groundwater in the Djankuat River basin

Type of sample	Amount of samples	δ18O, ‰			δ2H, ‰			Conductivity, uS/cm		
		max	min	mean	max	min	mean	max	min	mean
Snow	218	-5.0	-28.3	-12.2	-28.0	-216.0	-85.5	37.2	0.3	9.3
Ice	116	-9.8	-22.0	-14.3	-64.0	-159.7	-99.3	63.7	0.7	14.8
Firn	22	-8.1	-16.2	-11.3	-53.0	-116.0	-77.1	23.0	4.1	13.7
Liquid precipitation	113	5.6	-16.9	-4.9	32.0	-124.0	-26.2	n/a	n/a	n/a
Groundwater	16	-12.3	-13.6	-13.3	-77.0	-93.5	-91.1	114.6	104.0	109.4

Table 5: Statistical characteristics of glaciological parameters measured on the Djankuat Glacier during 2007–2017

Parameter	Snow thickness	Ablation	Snow density	
			Mean for the snowpack	by layers

Very high!!

Unit	cm	mm w.e.	g/cm^3	
number of values	2932	5045	66	434
Mean	360	47*	0.57	0.57
Max	1155	387*	0.64	0.92
Min	7	0*	0.46	0.23

* 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/m^2	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) 26.08.13 – 06.09.13 (42) 30.06.14 – 30.07.14 (30) 17.06.16 – 01.08.16 (45)	10 Hz
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. July daily averaged meteorological variables on Djankuat glacier in 2007–2017 (with RMS in brackets)

are these max. windspeed obtained by using hairdrier? see p. 13 line 218,

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