Formation, evolution and drainage of short-lived glacial lakes in permafrost environments of the northern Teskey Range, Central Asia

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Abstract. In the Teskey Range of the Tien Shan (Kyrgyz Republic), four outburst flood disasters from short-lived glacial lakes ~~caused severe damages in the downstream part~~ in 2006, 2008, 2013, and 2014 caused severe damages in the downstream part. Short-lived glacial- lakes grow ~~The short-lived lake grows~~ rapidly and drain within a few months, due to closure and opening of an outlet ice-tunnel in an ice-cored moraine complex at the glacier front. In addition to these factors, summer meltwater from the glacier can cause rapid growth.~~increasing of meltwater from glacier during summer causes the lake variationspositive between drainage and storage, during summer~~. ~~The o~~Outburst floods of this lake type ~~is~~ are a major hazard in this region and differ from the ~~many cases~~ ~~, it differs from many cases of~~ moraine-dam failures common to ~~in~~ the eastern Himalaya. ~~-~~To clarify how short-lived glacial lakes store and drain water over ~~for~~ short periods, we use results from a field survey and satellite data to analyse the ~~examined recent changes of Korumdu lake~~ ~~we examined its recent changes in~~ water level, area, volume, and discharge of Korumdu lake (2014–2019) as well as satellite data to monitor the appearance of 160 other short-lived lakes (2013–2018). Except in 2016, ~~with a field survey and satellite data analysis.~~ Korumdu lake appeared and drained within about one month during all the summers ~~between 2014 and 2019 except in 2016during 2014–2019 except that in 2016~~. Water-~~-~~level data recorded by a data logger and time-lapse camera images show that the lake appeared and expanded suddenly from July to August in 2017–2019. ~~During summer 2016 there was no sudden appearance and expansion (and drainage) of Korumdu lake.~~ The timing of lake appearance~~/lake formation~~ indicates that the lake formed when an outlet ice-tunnel (subsurface channel) drainage was blocked by depositions of ice-debris mixture due ~~-deposition of debris and ice due~~ to ice melting, not by freezing of stored water. ~~These annual drainages from Korumdu lake never caused hazardous floods.~~ For 2017, we used ~~Based on calculation of~~ unmanned aerial vehicle (UAV)-derived digital surface models (DSMs) and water levels, finding that ~~in 2017, t~~the lake's ~~water~~ volume reached 234,000 m^3 within 29 days, and then the water discharged for 17 days at a maximum rate of 0.66 m^3/s. This discharge rate is more than 20 times smaller than those found earlier (2006–2014) for four short-lived lakes in the region. We argue that this large variation in rates is due to variation in the dimensions of the outlet ice tunnels. ~~The small discharge indicates that the diameter of the outlet ice-tunnel was much smaller than those of four short-lived lakes in the same range that~~ showed larger drainage rates ~~caused large drainages (12-27 m^3/s) in 2006, 2008, 2013, and 2014. As the result, the dimensions of the outlet ice-tunnels of short-lived glacial lakes presently are related to the flooding scale~~discharge

(rate). Recent warming temperatures may increase both tunnel size and lake-basin size (lake volume) volume both the size of the tunnels and the basin volumes leading to increased hazard potential greater hazard from such lakes in the future. FIor the n addition to our field surveys of Korumdu lake, we investigated the timing of appearance of 160 other short-lived glacial lakes, we argue that 117 formed mainly in the Teskey Range this region using Landsat-7/8, Sentinel-2, and PlanetScope satellite images (2013–2018). We conclude that tunnel closurelake formation of 117 lakes was due to tunnel closure of deposition of debris and ice during summerresulting of positive water balance between drainage and storage, related to and increasing of meltwater from glacier during summer and tunnel size. In the Teskey Range, tThe adue to tunnel closure from deposition of ice ice-debris mixture, though increased glacial melt also likey contributed. In the Teskey Range, the appearance of a short-lived glacial lakes on the moraine complexes at glacier fronts ice-cored is inevitable in summer when the melting rate is high

in the moraine complexes at glacier fronts in the Teskey Range. Similar behaviour of The characteristics of short-lived lakes may occur in other mountain regions of Central Asia, such as the Tien Shan and Pamir mountains, wherever in the similar environments, which many ice-cored moraine complexes exist withinare distributed in mountain permafrost zone. , that existed in formation and drainage through blockage and opening of subsurface channels might also be found in oother mountain regions of Central Asia such as the Tien Shan and Pamir mountains. These mountain regions have many ice-cored moraine complexes in mountain permafrost zonesincluding mountain permafrost.Moreover, warming temperatures may increase both tunnel size and lake-basin size (lake volume) leading to increased hazard potential from such lakes in the future.

1 Introduction

Compared to the large proglacial lakes in the eastern Himalayas (Ageta et al., 2000; Komori et al., 2004; Bajracharya et al., 2007; Nagai et al., 2017), rather small glaciers in the northern Tien Shan (Central Asia) tend to have small glacial lakes near their terminial lakes can be found close to the present termini of glaciers in the northern Tien Shan (Central Asia)the northern Tien Shan, Central Asia region instead has many small glacial lakes that are distributed at glacier fronts (Janský et al., 2008; Narama et al., 2010a; 2015). Drainage events from these small glacial lakes often produce hazardous debris flows and floods. For example, debris flows in 2006, 2008, 2013, 2014, and 2019 in the Teskey Range of, the northern Tien Shan, caused severe damage (including casualties) and destroyed bridges, roads, houses, and crops (Narama et al., 2010a, 2018; Daiyrov et al., under review2020).

ASome/a certain number Some of these small lakes are called "short-lived" or "unstable" that as they Such short-lived glacial lakes grow rapidly and drain within a few months (Narama et al., 2010a, 2018; Daiyrov et al., 2018). TheseSuch short-lived lakes are proglacial type that appeared oin depressions of dammed by ice-cored moraine complexes at glacier fronts. SuchThe lakes drain through an outlet ice-tunnel (subsurface channel) within an ice-coredthe moraine complex (Popov, 1987; Narama et al., 2010a; 2018). Some authors call them , and are also called nnonstationary lakes (Erokhin et al., 2017), though this term also includes lakes with a long lifetime. ~~Among nonstationary~~Most ~~proglacial lakes, a a~~ short-lived glacial lake~~type may~~ fill periodically and ~~quickly~~ within one year, though some may develop for ~~(Erokhin et al., 2017). However, some of short-lived proglacial lakes have a longer lifetime which develop within~~ 2~~–~~-3 years before~~until~~ draining. The latter type can be more dangerous; for example, ~~For example, I~~in the Tajik Pamir, drainage from a short-lived glacial lake that formed within 2 years resulted in 25 casualties (Mergili et al., 2012). In northern Tien Shan, ~~Such lakes drain through an outlet ice-tunnel (subsurface channel) within an ice-cored moraine complex (Popov, 1987), and are also called nonstationary lakes (Erokhin et al., 2017), though this term also includes lakes with a long lifetime. A~~ short-lived glacial lakes can be a severe hazard for local resident~~ss in northern Tien Shan~~ because ~~it~~ they appears suddenly yet can cause large debris flows~~.~~. ~~The short-lived lakes are a major hazard in this region, and t~~ Such an ~~Th~~outburst (outburst mechanism and damage potential) ~~is~~ differs from those that are caused by ~~e outburst (lake size, damage potential/risk and outburst mechanism) which caused by~~ moraine-dam failure in the Himalaya and Andes (Costa and Schuster, 1988; Richardson and Reynolds, 2000; Shreshta 2010; Emmer and Cochachin, 2013; Neupane et al.; 2019). In those cases, ~~A~~a mass-movement triggers is~~are~~ the main cause~~factors~~ of~~for~~ dam failures of the glacial lakes in the Himalayas and Andes (Emmer and Cochachin, 2013; Neupane et al.; 2019).

~~Small and s~~Short-lived ~~pro~~glacial lakes ~~which~~that are dammed by ~~(~~partially~~)~~ frozen~~frozen~~ moraine material~~/sediments~~ (ice-cored moraine complex) ~~As such glacial lakes~~ drain through a subsurface outlet ice-tunnel.~~an outlet ice-tunnel,~~ These lakes ~~the lake~~ can expand rapidly when the outlet ice-tunnel is blocked due to either freezing of stored water or depositions of ice and debris (Narama et al., 2010a, 2018). Drainage then occurs when the outlet ice-tunnel opens during summer. Some of ~~these/~~these ~~aforementioned~~ short-lived glacial lakes reappear every year (Daiyrov et al., 2018), which is behavior they share with supraglacial lakes ~~on a debris-covered glacier~~. Several studies ~~have examined~~reported the formation and drainage supraglacial lakes are related to connectivity of ~~relationship between supraglacial lakes and their~~en~~-en~~glacial conduits on a debris-covered glacier ~~which englacial conduits determine the variation of supraglacial lakes~~ (Benn et al., 2000, 2017; Miles et al., 2016; Watson et al., 2016; Narama et al., 2017). However, the variations of the short-lived glacial lakes arise~~is~~ from their ice-tunnel opening and closing as well as the increase in glacial melt during summer (Daiyrov et al., ~~(~~2020) ~~reported that the increasing of meltwater from glacier also causes the lake-area variations during summer~~. ~~In addition, water balance is also related to the variations due to increasing of meltwater from glacier during summer (Daiyrov et al., 2020)., but this relationship has seen little study for glacial lakes.~~

~~Small and short-lived proglacial lakes which are dammed by (partially) frozen moraine material/sediments also~~ Short-lived glacial lakes appear at depressions that can be created when glacier recedes, when an ~~formed due to glacier recession or the subsidence of either an~~ ice-cored moraine complex subsides (Narama et al., 2010a, 2018; Daiyrov et al., 2018), and on ~~or on a depression formed on~~ a surging glacier (Richardson and Reynolds, 2000; Kääb et al., 2004). Narama et al. (2018) showed that such short-lived glacial lakes typically ~~exist~~form where the ~~three~~ following three ~~geomorphological~~ conditions exist~~apply~~~~tend to appear with three geomorphological characteristics~~: 1) an ice-cored moraine complex (debris landform containing ice), 2) a depression with a water supply on an ice-cored moraine complex or glacier terminus, and 3) the absence of a visible surface outflow channel from the depression. The , last condition indicatesing that the emoraine complex has an outlet icexistence of an outlet ice-tunnel to drain lake water (lake water is discharged through ice tunnel inside of a moraine complex)(the outlet of the lake which lake water flow out through an underground of lake-dam is visible).

The number and area of glacial lakes in the Tien Shan has recently increased, a trend thatPrevious studies have argued that the recent increase in number and area expansion of glacial lakes in the Tien Shan is linked to climatic warming and glacier shrinkage (Bolch et al., 2011; Wang et al., 2013; Kapitsa et al., 2017). In addition, Daiyrov et al. (2018) showed that the large variability in the number and distribution of lake type and the distribution of types of glacial lake typess in the Issyk-Kul Basin (Tien Shan) was iis not only related to the local climate conditions in the Issyk-Kul Basin, but also to regional geomorphologicalabove three conditions in the glacier forefield as described above (cf. Narama et al., 2018)such as the closure and opening of an outlet ice-tunnel. They also pointed out that ice-cored moraine complexes have developed under mountain permafrost conditions. WMelting of ground ice in moraine complexes results to the development of various landforms (Kääband Haeberli, 2001) and when the ice in the morainic material melt out it results to form a stable moraine (Lukas, 2011).Ice degradation within such complex results in moraine formation (Iveronova, 1952; Markov, 1955). Surface changes on an ice-cored moraine complex were observed in the forefield of confirmed in the Jeruy Glacier front between 1979 and 2016 due to ice melting (Daiyrov et al., 2018), and such changes likely affect the outlet ice tunnel and formation of the depressions which by down-wasting and thawing expand an outlet channel or change the its course and .enlarge depression.

Many short-lived glacial lakes have been observed in the northern Tien Shan in recent years (Daiyrov et al., 2018). They can change As surface changes can occur in the moraine complexes over very large areas and volumes of glacial lakes - in a short period of time, making their drainage features and flood scale discharge (rates) - are extremely unpredictable (Erokhin et al., 2017), but . Although many short-lived glacial lakes "…have been observed in the northern Tien Shan in recent yearsare confirmed in recent years in the northern Tien Shan (Daiyrov et al., 2018), not all short-lived glacial lakes cause large-scale floods. The difference of in flood discharge (rates) scale remains unclear. A short-lived proglacial lake's fate depends on whether the dam contains ice (Mergili et al., 2013), and if so, how the outlet ice-tunnel closes and opens. However, the mechanisms of lake closure formation and drainage remain also unclear. Hazards from an abruptly changing discharge of glacial - lakes discharge Such hazards can intensify dramatically and unexpectedly within weeks or even days (Huggel, 2004). In this study, we investigate "predict mechanisms of closure formation and drainage mechanisms of at the Korumdu lake in the (Teskey Range, Tien Shan, (Kyrgyz Republic) and the reason of for different flood discharge (rates) scales from short-lived lakes based on field survey and satellite data analysis. Findings from our study are relevant for glacier-related hazard mitigationThese new knowledges are important for glacier disaster mitigation.

The paper is organized as follows: ing. To understand the closure formation and drainage mechanism of the short-lived lake, we investigated the recent changes in water level, area, volume, and discharge at Korumdu lake based on field survey and satellite data. The Korumdu lake appeared and drained within about one month during all summers in recent years. To find out clear the reason how the outlet ice-tunnel closes in the Korumdu lake, we surveyed surface elevation changes around Korumdu lake in the fieldwe examined the surface changes around the Korumdu lake in field survey. To clarify how the other short-lived lakes in the Teskey Range store and drain water in the Teskey Range, we investigated their timing of appearance during summer months between 20153 and 20198 the timing of appearance of short-lived lakes for the other lakes in this region were studied in 2015–2019 using Landsat-7/8, Sentinel-2, and PlanetScope satellite images. Finally, we discussed the causes reason of outlet ice-tunnel closure for Korumdu lake and other lakes of the same type in the study area.at Korumdu lake including other lakes, and We also examine the relationship between outlet tunnel size and lake drainage scale rate under the influence of increasing air temperatureincluding influence of increasing temperature. Findings from our study are relevant for glacier-related hazard mitigation.

2 Study area

The study area is situated in the northern part of the Teskey Range, south of Lake Issyk-Kulin the northern part of the Teskey Range and near the south shoreline of the Issyk-Kul Basin, Kyrgyz Republic (Fig. 1). The glacier distribution by elevation in the western part of the range (3700–4200 m) is lower than the distribution in the eastern part (3800–4500 m) due t)o the annual precipitation being higher in the eastern part than in the western part. Thise difference is related to differences in annual precipitation, which is higher in the eastern part than in the western part. For example, during 1998–2007, the average annual precipitation at the Kara-Kujur station (2800 m) of the western part is was 255 mm, whereas that at the Tien Shan station (3614 m) of the central part is it was 378 mm, and that at the Chong-Ashu station (2788 m) of the eastern part is it was 550 mm (Podrezov and Ryskal, 2019; Fig. 1). Mean annual air temperature was 0.1°C (1961–1988) for Kara--Kujur, –6.28°C (1995–2011; Kuzmichenok, 2013) for Tien Shan, and 0.27°C (1995–2005) for Chong-AshuTheir annual average temperatures are 0.1°C (1961–1988), –6.28°C (1995–2011; Kuzmichenok, 2013), and 0.27°C (1995–2005), respectively. The western part of the range had less Recent glacier shrinkage than that was less pronounced has been smaller in the western than in the eastern part of the Teskey Range (Aizen et al., 2006; Narama et al., 2006; Kutuzov and Shahgedanova, 2009).

In this area, the four large drainage events of Kashkasuu (2006), western Zyndan (2008), Jeruy (2013), and Karateke (2014) recently occurred from short-lived glacial lakes that formed on ice-cored moraine complexes (debris landforms including ice) (Narama et al., 2010a; 2018). The ice-cored moraine complexes here glacier-moraine zones of the study area in the northern Teskey Range lie at 3200–4000 m (Daiyrov et al., 2018). Within these zones, the ice-cored moraine complexes (debris landforms including ice) at the glacier fronts that developed during the Little Ice Age (Dikih, 1982; Shatravin, 2007; Narama et al., 2010b) due to . These moraines developed due to ice and debris stagnated by several glacier advances include stagnant ice during the that separated from the glacier tgerminus during glacier shrinkage proces retreats recessions (Iwata et al., 2005). Four large drainage events of Kashkasuu (2006), west Zyndan (2008), Jeruy (2013), and Karateke (2014) occurred from short-lived glacial lakes that formed on ice-cored moraine complexes (Kashkasuu (2006), west Zyndan (2008), Jeruy (2013), and Karateke (2014) ((Narama et al., 2010a; 2018))drainages occurred from short-lived glacial lakes that appeared on the ice-cored moraine complex; specifically, from Kashkasuu (2006), west Zyndan (2008), Jeruy (2013), and Karateke (2014) (Narama et al., 2010, 2018).

We ran a field survey at Korumdu lake ~~(41°57′32″ N, 77°13′28″ E)~~ at ~~3803~~ 3806 m (Figs. 1, 2). The Korumdu catchment ~~gives~~is source to the largest tributary in the Tong River Basin, and according to a Sentinel-2 satellite image in 2019, ~~,~~Korumdu glacier occupies an area of 2.35 km^2 ~~based on Sentinel-2 satellite image in 2019~~. At the front of the Korumdu glacier lies Korumdu glacial lake (Fig. 2).~~The Korumdu catchment gives source toforms the largest tributary in the Tong River Basin. The Korumdu glacier occupies an area of 2.35 km^2 based on Sentinel-2 satellite image in 2019.~~ The dam of this~~Korumdu~~ lake is an ice-cored moraine complex. The lake ~~has direct contact with the glacier and~~. ~~At the front of the Korumdu glacier lies the Korumdu glacial lake (Fig. 2). It~~ developed in a depression that formed during the retreat of the glacier and retains direct contact with the glacier.~~ The lake basin developed inside an ice-cored moraine complex.~~ ~~As the reason why this~~ We ~~lake was~~ selected this lake for~~as a~~ research because ~~site,~~ (i) the lake is a short-lived type that~~which~~ appears every year, (ii) it is easy to access~~ the field~~, and (iii) this lake is located in~~at~~ the Tong region where four large outburst floods occurred in the past. According to data in Narama et al. (2018), drainage from Korumdu lake is the flood-wave type in the downstream region because the water stream flows on a gentle slope. In addition, we investigated the timing of appearance for 160 short-lived lakes in the northern Teskey Range during 2013–2018~~is region~~ (Fig. 1) ~~which are of the same type as Korumdu~~ using Landsat-7/8, Sentinel-2, and PlanetScope satellite images (Supplemental Table 1) ~~(2013–2018)~~. ~~These 160 lakes were chosen based on their area changes/short existence within several months of oneeach year though six years.~~

3 Methods

3.1 Field observations at Korumdu lake

The field survey at Korumdu lake (Figs. 1, 2) was run during the summers of 2015–2019 ~~(Figs. 1, 2)~~. We installed water level and water temperature data loggers (Hobo U20) at lake bottom and ground surface on the moraine to collect measurements once per ~~at an inte~~hour ~~rval of 1 h~~ since 21 August 2015. ~~The survey involved measuring the water level and water temperature at the lake bottom with a data logger (Hobo U20) at an interval of 1 h since 21 August 2015.~~ Water level logger measurements (water pressure data) at lake bottom were converted~~corrected~~ to the water level (meter) using atmospheric pressure data at the adjacent ground surface on the moraine ~~on moraine~~.~~We also placed/installedset water-level water level data loggers (Hobo U20) at lake bottom (water pressure) and ground levelssurface on moraine (atmospheric pressure). Water-levelWater level logger measurements were corrected to water level (meter) using atmospheric pressure data at the ground.~~ A time-lapse camera (Brinto) was installed as well and took one oblique image of the area per day~~also set with an interval of 1 day~~.

In addition, we obtained aerial images of the ~~Korumdu~~ lake- basin acquired by Phantom-4 (DJI) and JABO H601G (Medix) unmanned aerial vehicles (UAVs) with a mounted camera (Ricoh GR) on 21 August ~~Aug~~ 2015, 12 Aug 2016, 6 August 2017, 20 July 2018, and 4 August 2019. High-resolution orthoimages and digital surface models (DSMs; resolution of 0.2 m) were made using the Pix4D mapper (Pix4D SA) of Structure from Motion (SfM) software ~~with~~ and ground control points (GCPs). We collected/~~surveyed~~ ~~obtained~~ the GCPs around the lake using ~~the~~ a Trimble GeoExplore 6000 Global Navigation Satellite System (GNSS). The absolute positions of GCPs were corrected during post-processing using data from the Kyrgyz GNSS reference station and had an accuracy of 30–40 cm~~were accurate to 30–40 cm at GCPs positions by post-processing with data~~

from the Kyrgyz GNSS reference station. Surface elevation changes of thean ice-cored moraine complex surrounding the lake were computed in ArcGIS 10.5 by comparing UAV-derived DSMs from 2015 and 2016We also investigated the surface changes in an ice-cored moraine complex around the lake by comparing DSMs obtained in 2015 and 2016 on ArcGIS 10.5. The daily volume and discharge of the lake in during the summers of 2017–2019 were calculated using the daily water level data and, the 2017–2019 UAV-derived DSMs combined with the 2016 UAV-derived DSM (without water)UAV DSMs, and time-lapse data on in ArcGIS 10.5. For the The daily lake volume was calculated based on the 2016 DSM (without water)wWater volume at theof lake lake bottom, we part was used the 2016 DSM, because the 2017–2019 DSMs hadremains water at the lake bottom., combined with the DSMs of other years (including amount of glacier recession). In addition, we investigated whether satellite remote sensing data could (completely) replace an in situ water level logger data to calculate lake water levels using the combined DSMs. We found that the water-levelwater level logger measurements agreed with the derived water levels that were reconstructed frombased on time-lapse camerasatellite data and/ combined with based on UAV-derived DSMs. For example, we confirmed the position of the water level by comparing a -UAV orthorectify image and satellite data on 1--m counter lines extracted by the combined UAV-derived DSMs. Finally, we obtained the water level and water area based onfrom satellite data. Using the is methodsame methodcontour line from UAV DSMs, we also reconstructed the water level data between August 4 and 31 based on 10 satellite images from PlanetScope, Landsat-8/Operational Land Imager (OLI), and Sentinel-2 to compare different data sources to get the same resultsalong with UAV DSMs, because we do not have water level data after our last visiting on visited at the lake on 4 August 2019. In addition, we investigated whether satellite remote sensing data could (completely) replace in situ water level logger data to calculate lake water levels using the combined DSMs.Here, based on these satellites we manually digitized lake areas and then compared lake areas. We also investigated the changes in lake area during 2017–2019 by comparing lake polygons that had been digitized manually using PlanetScope images (Table 1).

Finally, we examined the meteorological climatic and thermal conditions using air and ground temperature data loggers (TR-52i; T&D Co.; resolution accuracy within ± 0.3°C) to log data at 1-hour intervals around the lake (Fig. 2). Mean annual air temperature (MAAT) between 2015 and 2017 and mean annual ground surface temperature (MAGST) during in 2015–2019 were calculated for whole year round of 2016–2017. .

3.2 Timing of appearance of short-lived lakes using satellite data

Short-lived glacial lakes in the northern Teskey Range were identified inin ArcGIS 10.5 using satellite images (Landsat-7/Enhanced Thematic Mapper Plus (ETM+, SLC-off), Landsat-8/OLI), using satellite images on ArcGIS 10.5. For analyses we used different satellite imagery acquired during 2013–2018 shown in (Supplemental Table 1). In particular, 91 images from Landsat-7/Enhanced Thematic Mapper Plus (ETM+, SLC-off) and Landsat-8/OLI, 31 images from Sentinel-2, and 16 images from PlanetScope acquired during 2013–2018. The resolutions of these images are 15 m (pan-sharpened images of Landsat-7/8), 10 m (Sentinel-2), and 3 m (PlanetScope). We used the definition by Daiyrov et al. (2018) for short-lived lakes, which is based on seasonal changes in lake area over the summer months of each yearAs a definition of short-lived lake, we use that in

Daiyrov et al. (2018), which is based on its seasonal change in area from June to September of each year. Specifically, a short-lived lake is a temporary lake, lasting just one or two years, that suddenly appears and/or increases substantially appears or doubles in area, then disappears or shrinks within the same year. We counted the number of lakes that appeared from June to September each year. In addition, the number of lakes was tracked in each given year to examine how it changed from one year to the next. Polygon shapefiles of lakes were digitized extracted manually from the images using ArcGIS 10.35.

4 Results

4.1 Areal variabilityAreal variations of Korumdu lake

ALOS/AVNIR-2 data taken on 17 September 2007 indicated that At the front of the Korumdu glacier lies the Korumdu glacial lake (Fig. 2). It sits in a basin that formed during glacier recession. The basin developed inside an ice-cored moraine complex. Although mMmost of the lake basin area had been covered by the Korumdu glacier, based on ALOS/AVNIR-2 data taken on 17 September 2007., Thus, the lake basin developed in a depression that formed during the retreat of the glacier. Tthe UAV ortho-images in 2019 indicated a lake basin length of 360 m, a width of 110 m, with with and a total area of the lake basin of 00.062 km^2 in 2019. The lake basin volume increased from 264,000 m^3 toin 2017 to 330,000 m^3 from 2017 to in 2019 (Fig. 2) due to retreat of the glacier terminus. In the field, we observed ice ridging and debris sliding on the basin's slope of the lake basin, indicating that the ice was melting from around the shore, thus increasing the basin's width of the lake basin.

The lake had no discernable surface drainage channel, but we found an outlet point where meltwater from the lake emerges from a subsurface ice-tunnel within the frozenice-cored moraine complex which isthat connectsed to the lake (Fig. 2). The existence of the outlet shows that lake water flows through an outlet ice-tunnel from the lake. The length of the outlet ice-tunnel is 60 m from the entrance of the lake basin. During the fieldwork, we observed melt draining Lleakage of meltwater Drainage water was observed at the outlet point oin 30 July 2015, 6 August 2017, and 4 August 2019, but not in 12 August 2016 and 20 July 2018. We found that the Korumdu lake was not release sudden appearance and expansion (and drainage) during summers 2015 and 2016.

Concerning lake size changes, in 2015, the lake appeared sometime before 30in July, becoming large (reached its maximum) on 30 July, then shrank significantly by 21 August (Fig. 3). In 2016, according to the water level data and on-site time-lapse camera images, the lake area did not appear. For 2017–2019, we had more images of the area and thus a a more precise sequence of complete story of changes in lake size is shown with a sequence of PlanetScope satellite the changes appears in the images in Fig. 4, which are based on PlanetScope satellite data. The images show that the lake appears suddenly at the end of July to the beginning of August and then shrinks and vanishes by the end of August (Fig. 4a–c). Although the timing of lake expansion differs slightly over the years 2017–2019, the lake always appears in summer. The time-lapse on-site images show the same behavior from a different view (Fig. 5). These images also indicate that the lake began to expand from mid-July and reached its maximum size at some time between late July and early August. In addition, we checked Landsat-8/OLI data in

2014, finding that the lake existed on 5 May, 27 June, and 10 September in 2014. Thusese, the satellite data demonstrate that the lake is a short-lived glacial lake.

The time-lapse on-site images show the same behavior from a different view (Fig. 5). These images also indicate that the lake began to expand from mid-July and reached its maximum level size at some time between late July and early August. In contrast, according to the on-site time-lapse camera, the lake area did not change dynamically i.e. the lake area did not expand substantially in 2016. Based on Landsat 8/OLI data, we also found that the lake appeared in 2014 (May 5, June 27, and September 10) existing for four months, but unknown its drainages. Although these images show rapid drainage, we did not find evidence that the drainage caused flooding during the survey period. According to data in Narama et al. (2018), drainage from Korumdu lake is the flood-wave type in the downstream region because the water stream flows on a gentle slope.

4.2 Changes in water level, area, volume, and discharge of Korumdu lake

Consider the properties of Korumdu lake from 2017 to 2019. Figure 6 shows the measured water level, lake area and volume, and inflow–outflow dischargerate of Korumdu lake from 2017 to 2019. For 2017, we also show the water temperature (Fig. 6a).water temperature data were also recorded (Fig. 6a), and water level data between 4 and 31 August were reconstructed based on 10 satellite images we also show the water temperature (Fig. 6a). We also reconstructed the water level data between August 4 and 31 based on 10 satellite images (yellow points in Fig. 6a). Lake volume and discharge were calculated based on the water level dataWe calculated volume and discharge using the water levels and the UAV-derived DSMs.

Consider the trends in Korumdu lake during the three summers of 2017–2019. ForIn 2017, Fig. 6a shows the water level starts increasing from 6 July, reaching a maximum on 3 August 3, and then the lake is emptyvanishes on 19 August (Fig. 6a). Within In the first 29 days, the water lake level increases 13 m, the volume reaches 234,000 m^3, and the area reaches 0.36 km^2 (Fig. 6ba–c), and the volume reaches 234,000 m^3 (Fig. 6c). The resulting rate of lake volume increase was 8,070 1 m^3/ per day. During the emptying of the lake, 234,000 m^3 of water drain discharge, 234,000 m3 of water drains in 17 days, with half of the volume draining from 3 to 7 August 2017 (Fig. 6b6c), resulting in a maximum net outflow discharge of 0.66 m^3/s (Fig. 6d). Although the water level increases intermittently before 3 August 3, the net outflow is relatively smooth. The lake water temperature averagesd about 1°C (Fig. 6a). -The temperature fluctuates more when the lake is shallower because the heating of shallower water by solar irradiance is stronger than cooling from inflowing ice meltwater..

The same figures show the cases for It means the heating of shallower lake with less water by solar irradiance is stronger than cooling from inflowing ice meltwater.

In 2018 and 2019. In 2018, the water level peaks three times, though reaches only about half that of 2017 (Fig. 6a). The first peak, on 25 July, occurs withshowing a lake depth of reaches 3.5 m and a volume of 21,000 m^3 (Fig. 6a, bc). The second-, and maximum peak, occurs , the yearly maximum, on 11 August, with a lake depth of reaches 6 m and a volume of 53,000 m^3, . which corresponds to the maximum values in 2018. The third peak occurs on 17 August with, showing a lake depth Finally, the third peak, on 17 August, reaches a level of 5 m and a volume of 39,000 m^3. The maximum net discharge occurs after the second peak, reaching 0.32 m^3/s (Fig. 6d). Compared to the case in 20172018, the maximum lake level and volume are much smaller in 2018. Similar to 2017, the net inflow rate also clearly varies over time However, like that in 2017, the inflow rate is also intermittent in 2018. The three peaks in water level, area, and volume of Korumdu lake indicate that large closure of the ice-tunnel occurred several times during the a 1one-month period.

In 2019, the lake water level rises and falls before water level goes up and down until 22 July, when it rises sharply (Fig. 6a). Then, the water level shows an intermittenta local maximum around the level has a local maximum on 30–31 July, reaching a lake depth of 5 m and a volume of 53,000 m^3, . The 2019 maximum level occurs values were recorded followed by a yearly maximum on on 11 August, with a lake depth of 6.5 m and a corresponding volume of reaching 6.5 m and 74,000 m^3 (Fig. 6a, bc). The maximum discharge occurs right after the second peak, reaching 0.24 m^3/s (Fig. 6d).

Considering Over all three years, the maximum highest water level is highest in 2017 (Fig. 6a). Over these years, oOther differences In general, each year had a different include the timing of the lake-level increases, the number of peaks, and the maximum water volume. All three years had relatively small lakenet discharge rates (maxima of 0.66, 0.32, and 0.24 m^3/s in 2017, 2018, and 2019), which is consistent with the absence lack of reported flooding.

During each of these years, Concerning fluctuations, aAccording to the water level data for of 2017–2019, the lake level rose and fell several times, indicating repeated storage-drainage level increased with repeated storage–drainage cycles. In the field, we observed sudden small increases of in water level in 2016 and 2017, with the lake level increasing tens of centimeters within 3 h (Fig. 7). These results indicate that water level fluctuations occurred frequently due to closing and opening of the outlet ice-tunnel.

During the fieldwork, Wwe observed lake water leakagedraining out drainage water at an outlet point in 2015, 2017, and 2019, but not in 2016 and 2018. We argue that this might be due to the difference in relative elevations between the lake level and the outlet ice-tunnel entranceThe reason we argue is due to the relative elevations. In particular, Tthe water levels were at 3,810 m a.s.l on 21 August 2015, 3,816 m a.s.l on 6 August 2017, and 3,810 m a.s.l on 4 August 2019, thus the water levelsalways were all of which are higher than that of the outlet ice-tunnel entrance at approximately 3,807.5 m a.s.lpoint at the basin. In 2016 and 2018, lake water levels were at 3,806.5 m a.s.l and 3,807.5 m a.s.l, respectively, thus the water levels were always lower than the outlet ice-tunnel entrance at approximately 3,807.5 m a.s.l However, we did not observe water drainage in 2016 and 2018 because the water levels were 3,806.5 and 3,807.5 m, respectively (Fig. 8a, c). Therefore, we observed no drainage lake water leakage was observed at the outlet point of the ice-tunnel in 2016 and 2018 during our visit. These results indicate that the entrance of the outlet ice-tunnel at the basin is at approximately 3,807.5 m, water level too low for drainage.

4.3 Surface elevation changes around Korumdu lake

To investigate annual surface elevation changes near the entrance of the outlet ice-tunnel, we compared UAV-derived orthoimages with DSMs from Between Over a period of one year, how does the region near the entrance of the outlet ice-tunnel change? To answer this question, we compared UAV orthoimages with DSM data in 2015 and 2016, d (Fig. 9). Debris sliding and horizontal backwasting around the lake exposed up to by 7 m of an exposed ice ridge between 2015 and 2016 appear from the comparison of the orthophotos (Fig. 9)A comparison of Fig. 9a,b shows debris sliding, with horizontal backwasting of an exposed ice ridge by 7 m. The backwasting indicates that melting of debris-covered icemelting occurred, which is supported by comparing the UAV-derived DSMs from both years (in Fig. 9c). For instance, along thea cross-sectional profile (see a–a' in Fig. 9b)In particular, along the profile (a–a'; Fig. 9b) of the landform between 2015 and 2016, the surface elevation decreases decreased by about 5 m (Fig. 9c). These results are consistent with closure in the outlet ice-tunnel during being duet to indicate that the surface motion and ice-debris deposition. During our of debrisdue to ice-melting can might cause closure in closure of the outlet ice-tunnel during summer, comparable to supraglacial lake on debris-covered glaciers (Sakai et al., 2000; Benn et al., 2000; Miles et al., 2016; Watson et al., 2017). "the fieldwork in 2016, we observed the entrance of an ice-tunnel and water flow to itsthe entrance of ice-tunnel. After two or three hours, we confirmed the increase ofthe lake level increased s in field (Fig. 7), consistent with the cause being closure of the indicating that closure of ice-tunnel. and 2017, we observed increase of lake levels during two or three hours in field (Fig. Fig. 7).

, comparable to supraglacial lake on debris-covered glaciers (Sakai et al., 2000; Benn et al., 2000; Miles et al., 2016; Watson et al., 2017).

In the northern part of the Teskey Range, the mountain discontinuous mountain permafrost zone lies above 3,100–3,200 m a.s.l (Daiyrov et al., 2018). Around Korumdu lake (3,806 m a.s.l), the mean annual air temperature (MAAT) during 2015–2017 between in 2015– and 2017 was –4.8°C and the mean annual ground surface temperature (MAGST) during in 2015–2019 was –2.9°C. Thus, the buried ice of the ice-cored moraine complex at Korumdu lake is maintained under a permafrost environment. Melting of buried ice causes surface changes including expansion of the lake basin, expansion and deposition (closure) in the outlet ice-tunnel. We estimated daily lake discharge and approximate dimensions of the ice-tunnel based on combining water level data and UAV-derived DSMs from consecutive years. In addition, melting can lead to closure of an outlet ice-tunnel such as that for a supraglacial lake on a debris-covered glacier (Sakai et al., 2000; Benn et al., 2000; Miles et al., 2016; Watson et al., 2017).

4.4 Comparison to other short-lived glacial lakes of the Teskey Rangein the area

Korumdu lake appeared during July–August and showed had relatively little drainage during emptying, whereas four other short-lived lakes (western Zyndan, Kashkasuu, Jeruy, Karateke) that appeared in May–June caused larger drainages and serious damages (Narama et al., 2010a, 2018). The different appearance times might reflect different processes causing formation of short-lived laketunnel closure. To help determine how common these appearance times ofwhen other short-lived glacial lakes areform, we used satellite images during 2013–2018 to identify and examined 160 such short-lived glacial lakes in the northern Teskey Range.investigated the timing of appearance of short-lived lakes in the northern part of the Teskey Range from June to September during 2013–2018 using Landsat-7/8, Sentinel-2, and PlanetScope satellite images (Table 1).

~~We identified and examined 160 such short-lived glacial lakes in the northern Teskey Range during 2013–2018 (the total number of lakes includes re-appearances of the same lake in different years) in the study area.~~ A classification of these lakes by month of appearance is shown in Fig. 10~~ for the six year period~~~~In Fig. 10, we classify these by month of appearance~~. Most lakes appeared in June (43 lakes) ~~of~~during~~The appearance months with the most lakes are June,~~ the ~~period of maximum~~ snow-melt ~~-~~period, and in July (90 lakes) ~~of,~~ during the ~~period of maximum~~ ice-melt period~~; specifically, 43 lakes in June and 90 in July~~. The total numbers and the proportions of the numbers for ~~in~~ these two periods varied during the 6 years. ~~This large~~ Such variability has been argued to be ~~lis r~~related to ~~inked to~~ geomorphological conditions such as drainage through ice tunnel inside of ice-cored moraine complex~~ and was not directly related to local climate change~~ (Daiyrov et al., 2018). ~~However, we are not fully rule out its relationship to different meteorological conditions during summer months of 2013–2018.~~

Concerning re-appearances, 81 lakes appeared only once during ~~for 6~~six years. Of the remaining, 19 lakes appeared twice, 7 lakes appeared ~~3~~ three times, 2 lakes appeared ~~4~~ four times, and 2 lakes appeared ~~every year~~all 6 years.~~,~~ These results are consistent with ~~indicate~~ing ~~that~~ tunnel closure~~ caused short-lived of these 111 glacial lakes in the northern Teskey Range occurred with a different month each year~~ being the main cause of formation. ~~In addition, S~~sShort-lived glacial lakes that reappear during many years likely has an environment that either favors ~~show geomorphological settings at the drainage tunnel entrance which favor~~ tunnel closure and hence lake formation~~,~~ or an ~~positive water balance between drainage and storage, related to~~ increase in meltwater from glacier during summer (Daiyrov et al., 2020). ~~or water balance related to increasing of meltwater from glacier during summer (Daiyrov et al., 2020). at the drainage tunnel entrance which favor tunnel closure and hence lake formation~~~~have a tunnel condition in which closure occurs easily.~~

5 Discussion

5.1 Causes of outlet ice-tunnel closure in the northern Teskey Range~~at Korumdu lake~~

We first consider four previously studied short-lived lakes in the area. The Kashkasuu, western Zyndan, Jeruy, and Karateke lakes appeared in May–June and expanded in area until June–July, then all had relatively large drainage events leading to serious damages (Narama et al., 2010a, 2018). This timing of lake appearance suggests an ice-tunnel closure that is caused by the freezing of stored water during winter or deposition of ice-debris mixture as sketched in Fig. 11a (Popov, 1987; Narama et al., 2010a, 2018). We call this the deposition–freezing type of ice-tunnel closure.

In contrast, Korumdu lake appeared during July–August (except in 2016) and produced relatively little drainage during emptying. This different appearance time might reflect a different formation process. ~~Four short-lived glacial lakes of the Teskey Range that caused four large drainage events The short-lived lakes of the Teskey Range here that caused the four large drainages (2006, 2008, 2013, and 2014) appeared between May and June in May–June and expanded in area until June–July (Narama et al., 2010a, 2018). The timing of lake appearance suggests their ice tunnels closed via the freezing of stored water during winter or deposition of ice-debris mixture as sketched in Fig. 11a (Popov, 1987; Narama et al., 2010a, 2018). We call this the deposition–freezing type of ice-tunnel closure. an ice-tunnela closure that is caused by the freezing of stored water during winter or ice-debris deposition of ice-debris mixture (Fig. 11a). We call this the deposition–freezing type of ice-tunnel~~

~~closure.The Korumdu lake case differs significantly in timing from the previously studied Kashkasuu, Western Zyndan, Jeruy, and Karateke lakes. For Korumdu lake, except for 2016, the tunnel closed in July–August of every year since 2014. In the context of ice-tunnel closure, Narama et al. (2017) report that the supraglacial lakes on the debris-covered Inylcheck Glacier appear in April–May due to the closure of englacial conduits by freezing of stored waterIn the case of ice tunnel closure, the supraglacial lakes on the debris-covered southern Inylchek Glacier in April–May are likely to appear due to the closure of englacial conduits when stored water freezes (Narama et al., 2017). The closure of englacial conduits on a debris-covered glacier can be due to roof collapses, creep closure, freezing of stored water, or deposition of ice and debris (Gully and Benn, 2009; Narama et al., 2017). Collapse of an outlet ice-tunnel wall in a debris-covered glacier can occur by thermal and mechanical erosion (Sakai et al., 2000; Roberts, 2005; Bjornsson, 2010) or by ice deformation (Clague and O'Connor, 2015). For comparison, in the northern Teskey Rangestudy region, the outlet ice-tunnel blockages could be caused by the freezing of stored water during winter or by blockage with depositions of ice-debris mixture after channel wallroof collapsing by collapsing with deposition of mixed debris and ice (Popov, 1987; Narama et al., 2010a, 2018). In addition, changes in the ice-cored moraine complex due to subsidence or downwasting might cause a blockage in an outlet ice-tunnel (Daiyrov et al., 2018). . Four short-lived glacial lakes of the Teskey Range that caused four large drainage events The short-lived lakes here that caused the four large drainages (2006, 2008, 2013, and 2014) appeared between May and June in May–June and expanded in area until June–July (Narama et al., 2010a, 2018). The timing of lake appearance suggests an ice-tunnela closure that is caused by the freezing of stored water during winter or ice-debris deposition of ice-debris mixture (Fig. 11a). We call this the deposition–freezing type of ice-tunnel closure. However, for none of the case studies investigated by previous studiesNarama et al. (2010, 2018), neither geomorphological behavior of the ice-tunnel nor water level fluctuations were studied in detailno case was reported in which the tunnel condition and water level fluctuations were compared in detail.~~

~~In the case of Korumdu lake, the tunnel closed in July–August of every year since 2014 (excluding the case of no lake expansion in 2016) based on water-level our field surveys and satellite data analyseswater level of a data logger and time-lapse camera images.~~ As we observed subsidence and downwasting changing ~~changes in~~ the lake basin ~~on the ice-cored moraine complex caused by subsidence or downwasting~~ (Fig. 9), the blockages of the outlet ice-tunnel at its entrance or interior were likely ~~was~~ caused by deposition of ice~~ and ~~-debris mixture ~~due to~~from thermal erosion. This type of blockage (deposition-closure type) is sketched in Fig. 11b. ~~Looking at~~The water level fluctuations ~~of Korumdu lake gives further evidence for lake formation by deposition of ice- and debris mixture.~~supports this mechanism.~~sFurther evidence that Korumdu lake forms by the deposition process comes from consideration of water-levelwater level fluctuations.~~ The fluctuations of lake water level and discharge ~~, such as~~ spikes~~,~~ reveal changes in the ice-tunnel morphology ~~condition~~ (Fig. 6d). A sudden blockage of an outlet ice-tunnel can cause a rapid increase in water level within ~~even~~ a few weeks. Also ~~For Korumdu lake~~, the water level increase was sporadic, indicating that the outlet ice-tunnel was not completely closed, the blockage was temporary, and the size of the ice~~-~~tunnel is ~~quite~~ small. As a result, lake drainages can ~~also~~ occur any time in summer, depending on how the outlet ice-tunnel responds to changes in ~~the~~ water pressure or deposition of ice-debris mixture through melting processes~~thermal erosion~~.

In the northern Teskey Range, the Toguz-Bulak glacial lake~~ which caused outburst flood on 8 August 2019,~~ appeared in June and disappeareds in September every year from 2010 through 2019~~,~~ due to the inflow of glacier meltwater (Daiyrov et al., 2020). Th~~e Toguz-Bulak glacial~~is lake has a surface drainage channel from the lake, but~~and~~ its incoming glacial runoff controls its behaviour, such as its area. Thus, in addition to the closure of deposition, the lake-area changes during summer is also likely influenced by changes in the rate of incoming meltwater.

In 2017, there were two trends~~periods of varying patterns of~~ in lake water volume~~ increase~~ ~~the trend of water volume increase consisted of two parts: 5 to 25 July and 26 July to 3 August~~ (Fig. 6b). The first period (5~~–to~~25 July) involved ~~revealed~~ sporadic fluctuations superimposed on an ~~in i~~increas~~e~~ing in water volume~~had sporadic fluctuations~~, indicating incomplete closure of the ice-tunn~~el~~. Then,~~el, . but However,~~ in the second period of ~~(~~26 July to 3 August, the volume ~~) showed a~~ continuously and rapidly increases~~ in water volume~~~~had a smooth increase~~, indicating complete closure of the ice-tunnel. Hence, we argue that the main factor of these rapid lake-area changes is tunnel closure. The lake area reached its maximum ~~value~~ in 2017. This indicates that the~~ period of~~ tunnel closure was longer in 2017 than in 2018 or 2019. Longer periods of tunnel closure ~~closure periods~~ are associated with the formation of larger short-lived glacial lakes (Narama et al., 2018). Thus, the period of closure is likely determined by the morphology of the ice-tunnel and deposition condition of tunnel-closure point~~might be determined by the condition of the tunnel~~.

~~As for Korumdu lake, m~~Many of the other short-lived glacial lakes in the northern Teskey Range, observed via ~~which were detected based on~~ satellite imagery, are likely to belong to the deposition-closure type as well. However, some likely have a larger influence from the water balance between drainage and storage, related to increasing glacial meltwater and tunnel size.~~Many of the other short-lived lakes that also appear in the ice-melting period are likely to be the deposition–closure type, for the same reasons we applied to Korumdu lake.~~ Consider ~~For example, Figure 12 shows changes in surface elevation and the outlet ice-tunnel of the~~ ~~in Fig. 12, we show surface changes in the outlet ice-tunnel at the~~ Jeruy glacial lake between 2014 and 2016 (Fig. 12). Ice melting caused distinct ~~large~~ changes and rapid deposition within the outlet ice-tunnel, which likely led to tunnel closure~~making closure likely~~. Thus, morphology and surface characteristics of an ice-cored moraine complex within the mountain permafrost zone are prone to frequent changes~~the surface condition always changes on an ice-cored moraine complex within the mountain permafrost zone~~, and the deposition–closure type is likely the main type for ~~drainage tunnel blockage and hence formation of~~the short-lived glacial lakes in the northern Teskey Range~~the major type in this region~~. If the deposition–closure processes occur in summer when the melting rate is high, the formation of a short-lived glacial lake is highly likely~~Thus, the appearance of a short-lived glacial lake is inevitable in summer when the melting rate is high~~. ~~The characteristics of this lake disaster might be shown in another Asian mountain permafrost regions.~~

5.2 Relationship between outlet tunnel size and lake drainage ~~scale~~

Of the 160 short-lived lakes we identified in 2013–20192018, only Jeruy lake (in 2013) and Karateke lake (in 2014) showed considerable had large drainages. The estimated maximum discharges from Jeruy (182,000 m^3) and Karateke (123,000 m^3) lakes were 14.9 and 11.5 m^3/s, respectively (Narama et al., 2018). These lakes had relatively large outlet tunnels, with onea at Jeruy, as well as one at Karateke, having a cross-section measuringof about 8 m^2 in area at Jeruy Jeruy's cross-section being 4 x 2 m^2 (Fig. 12a,b) and a cross-section of Karateke's about the same size or larger at Karatekeor larger (not shown). Earlier, inIn 2008, the w-Zyndan lake (437,000 m^3) emptied atEarlier, back in 2008, the w-Zyndan lake of 437,000 m^3 had the highera d discharge rate of 27 m^3/s (Narama et al., 2010a). Most of the water in these three cases drained over a period of several hours. In contrast, Korumdu lake did not show as such high drainage rates during have a large drainage in 2014–2019, draining at a maximum rate of 0.66 m^3/s in 2017, taking 17 days to drain 234,000 m^3, and its tunnel cross-and its tunnel cross-seesection was much smaller than those of at Jeruy or Karateke lakes. For example, in 2017, 234,000 m^3 drained from the lake over 17 days, with a maximum discharge rate of 0.66 m^3/s, about 20 times smaller than that of the two large drainage sevents of Jeruy and Karateke.

In addition, with for Korumdu lake exhibitedwe observed sudden fluctuations of water level over several hours, which we argued was related to closure of the small outlet ice-tunnelis behavior consistent with closure of a small channel caused by deposition of and blockage by debris. The relatively small tunnel size of this lake resulted in slower lake discharge even when lake volume reached its maximum ensured a slower discharge even when it became full (330,000 m^3). During 2017–2019, the lake size was largest in 2017, yet the discharge rates were nearly the same every year. These results show that, at least for Korumdu lake, the lake size and the dimensions of the outlet ice-tunnel were the dominant factor controlling lake are related to the scale of discharge rates. However, tunnel dimensions could increase in the future due to thermal erosion, allowing greater discharge rates. Meltwater and increasing temperature can accelerate thermokarst processes enlarging the outlet ice-tunnel (Sakai et al., 2000; Kääb et al., 2001; Miles et al., 2018), enlarging the outlet ice tunnel. In addition, although lake basin -size changes on ice-cored moraine complexes depend on the details of the particular glacier glacial landformsthermal erosion (ice-cored moraines and its subsidence due to ice melts), the basin area in the case of Korumdu lake has increased each year due to glacier recessionretreat. If theseis applyies to other short-lived glacier lakes in the Teskey Rangein this region, large-scale flooding events during their discharge may become more frequent increase in the future due to increasing temperature.

6 Conclusions

From our field d survey, we foundOur field survey found that Korumdu lake appeared and expanded from July to August and then drained over a period of 2–3 weeks. The lake formed when its outlet ice-tunnel closed, which we arguedwas was due to deposition of ice-debris mixture and ice during summer. The lake drainage was always Later, the draining process was relatively slow because the outlet ice- tunnel was small and the scale of discharge rate is related to the sizes of the outlet ice-tunnel and the lake volume. We argued that predicting drainage rates the scale of a drainage requires knowledgeknowing about the of the outlet ice-tunnel dimensions of the outlet ice-tunnel and the size of the lake basinand the lake's depression size. By combining water level data and UAV-derived DSMs from consecutive years, we were able to estimate daily lake discharge and Our research method of combination between water-levelwater level data and UAV DSMs could estimate the discharge and the approximate the smalltunnel -dimensions of the tunnelat much less than 8 m^2. Four lakes that appeared a month earlier (May–June) showed drainage rates were significantly higher compared to Kromudu lake.

Based on satellite images from 2013–2018, 160 short-lived glacial lakes were detected in the northern Teskey RangeDuring 2013–2018, satellite data showed this region to have 160 short-lived glacial lakes, many of which had a similar timing of appearance as Korumdu lake with average 27% forming in June, average 73% in July–September. This result shows the deposition–closure type is likely the main type for the short-lived glacial lakes in the northern Teskey Range. Four lakes that appeared a month earlier showed drainage rates which were significantly higher compared to the rest of the lakeshad large drainages, the only cases of large drainage in the study. HoweverNevertheless, with a warming climate, resulting in enlarging outlet ice-tunnels and lake basin sizes, also other short-lived glacial lakes of the northern Teskey Range might cause large flood eventsany short-lived glacial lake might cause large flooding if the outlet ice tunnel and basin size sufficiently enlarge. Glacial lake outburst floods (GLOFs) caused by moraine-dam failure, as frequently observed in the Himalayas or the Andes, rather rarely occur in the northern Teskey RangeThe glacial lake outburst floods (GLOFs) which caused by moraine-dam failure such as Himalaya and Andes are minor cases in this region. Although Sshort-lived glacial lakes in the northern Teskey Range rarely flood via moraine-dam failure, they are nevertheless can be a major flood -that form on ice-cored moraine complexes within the mountain permafrost zone through closure and opening of subsurface outlet ice-tunnels are a major hazard in the northern Teskey Rangelakes which caused by closure and opening of an outlet ice-tunnel in moraine complex are a major hazard in this region, because the short-lived lake exists on an ice-cored moraine complex within geomorphological and climate conditions of the mountain permafrost zone. Moreover, the Iwarming climate may result in n general, short-lived llarger outlet ice-tunnels and lake basin sizes that could cause large flood events. Therefore, short-lived lakes akes should be monitored using satellite data and field observations . Insights from monitoring short-lived glacial lakes in permafrost zones are useful to betterto better- understand their characteristics and behaviorbehaviour. Such monitoring may help , and therefore important for mitigateion of glacier-related hazards in permafrost zones in of high-mountain areas of Central AsiaThese new knowledges are useful to understand the phenomena and behavior of the short-lived lakes and consider glacier hazard mitigation in the mountain permafrost regions of Asian high mountains. A threat of the short-lived lakes increases for the residents since 2000s. This hazard case might be major in Asian high mountains in present.

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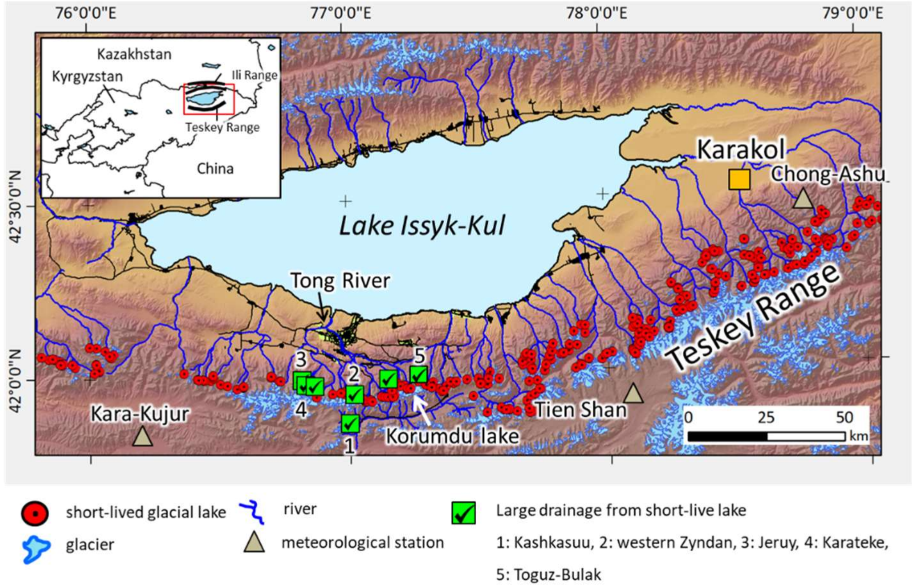
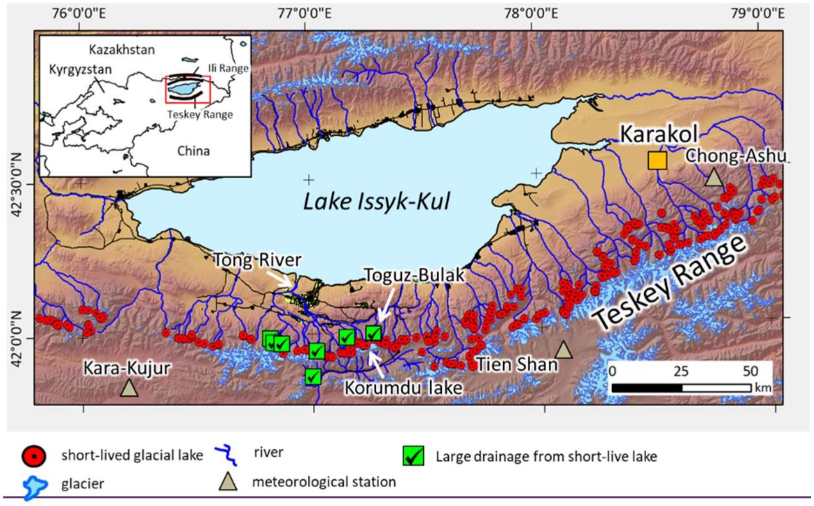

76°0'0"E
77°0'0"E
78°0'0"E
79°0'0"E
42°30'0"N
42°0'0"N
Kazakhstan
Kyrgyzstan
Ili Range
Teskey Range
China
Lake Issyk-Kul
Karakol
Chong-Ashu
Tong River
Teskey Range
Tien Shan
Korumdu lake
Kara-Kujur
0 25 50 km
short-lived glacial lake
river
Large drainage from short-live lake
glacier
meteorological station
1: Kashkasuu, 2: western Zyndan, 3: Jeruy, 4: Karateke,
5: Toguz-Bulak


76°0'0"E
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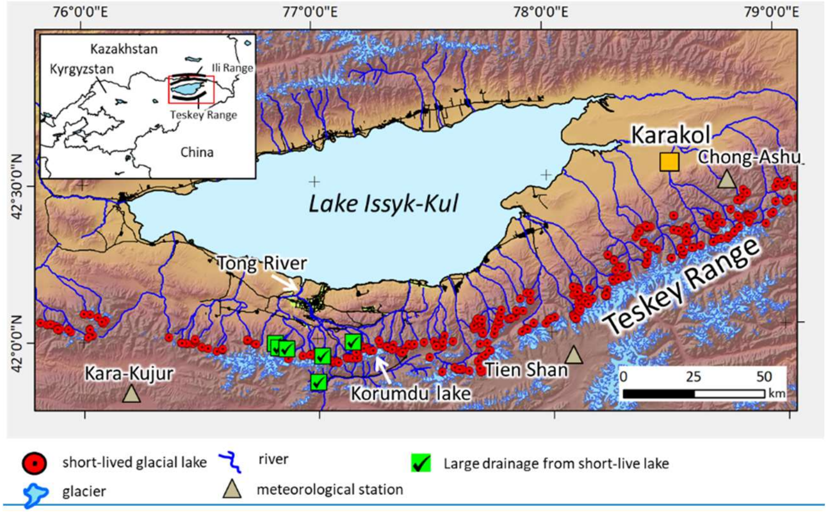
79°0'0"E
42°30'0"N
42°0'0"N
Kazakhstan
Kyrgyzstan
Ili Range
Teskey Range
China
Lake Issyk-Kul
Karakol
Chong-Ashu
Tong River
Toguz-Bulak
Teskey Range
Tien Shan
Korumdu lake
Kara-Kujur
0 25 50 km
short-lived glacial lake
river
Large drainage from short-live lake
glacier
meteorological station



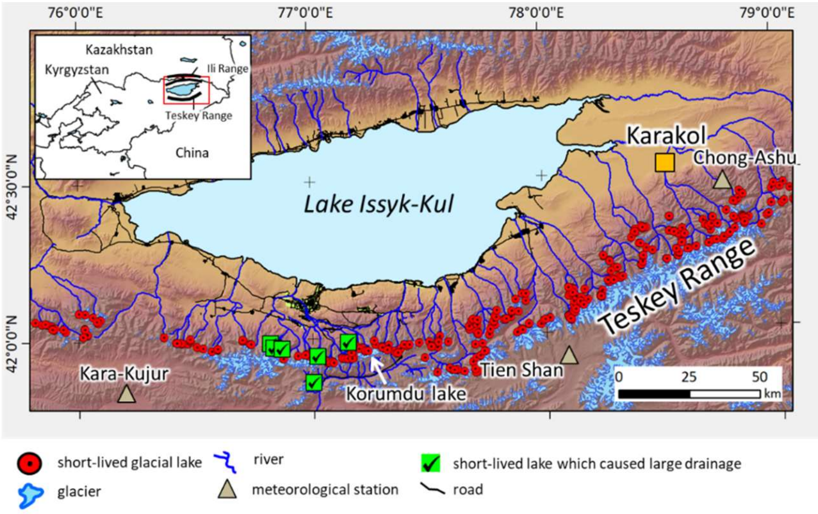


Figure 1: Study area in the northern part of the Teskey Range located on the south ~~shoreline~~ of Lake Issyk-Kul ~~Lake~~, Kyrgyz Republic. Red circles indicate locations of ~~are~~ short-lived glacial lakes that appeared in 2013–2018. Green squares with checks show ~~are~~ short-lived glacial lakes that have caused large drainage~~s~~ events since the 1970s. The shaded relief map was created using SRTM DEM.

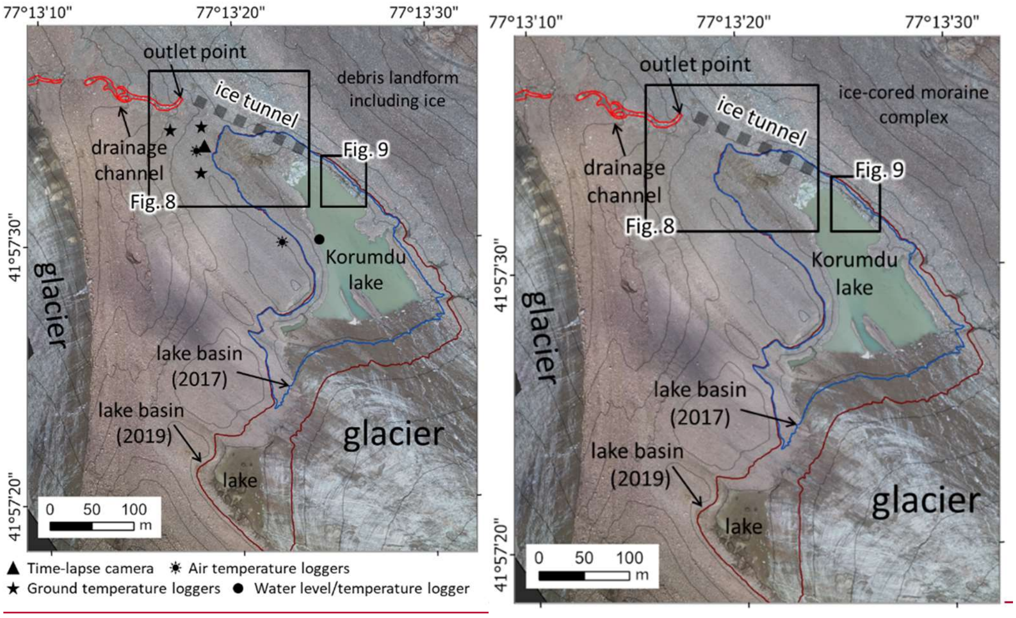


Figure 2: Overview ~~Geomorphological map~~ of the Korumdu glacier front. The location of the glacier is shown in Fig. 1. Orthoimages were acquired by our UAV imagery in 2019. Contour spacing is 10 m.

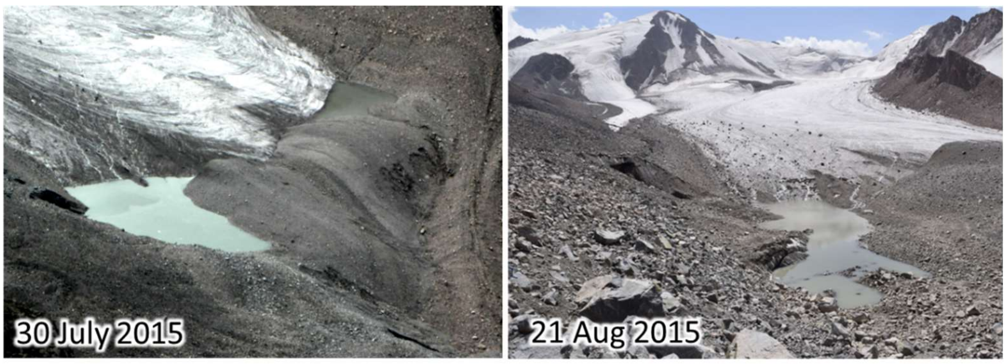
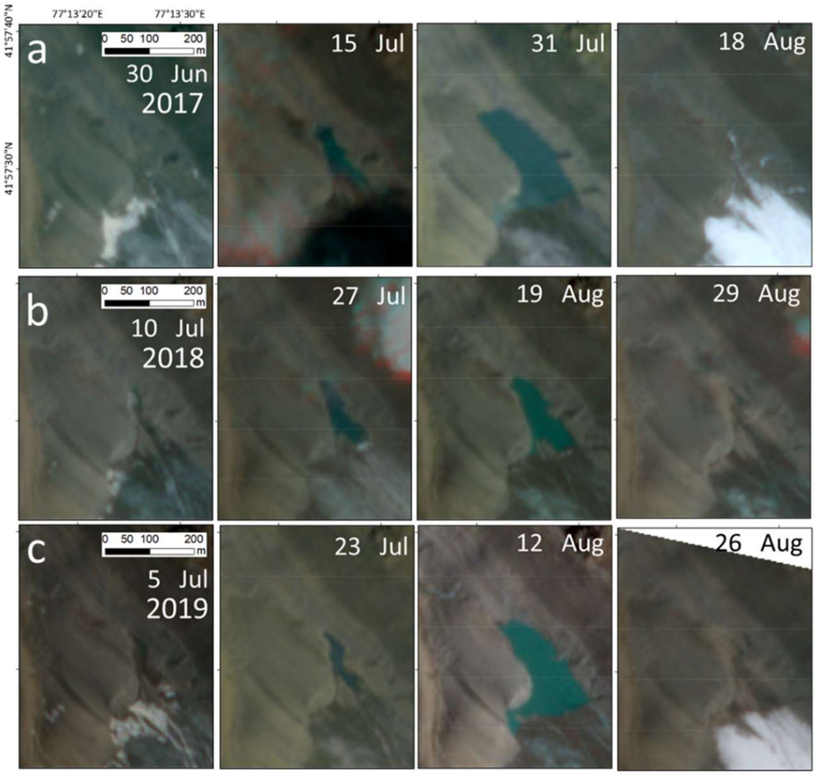


Figure 3: Korumdu glacial lake on 30 July 2015 (from a helicopter) and 21 August 2015 (from field observation). The width at the lake middle is about 85 m (left image) and 40 m (right).


77°13'20"E
77°13'30"E
41°57'40"N
41°57'30"N
a
0 50 100 200 m
30 Jun 2017
15 Jul
31 Jul
18 Aug
b
0 50 100 200 m
10 Jul 2018
27 Jul
19 Aug
29 Aug
c
0 50 100 200 m
5 Jul 2019
23 Jul
12 Aug
26 Aug

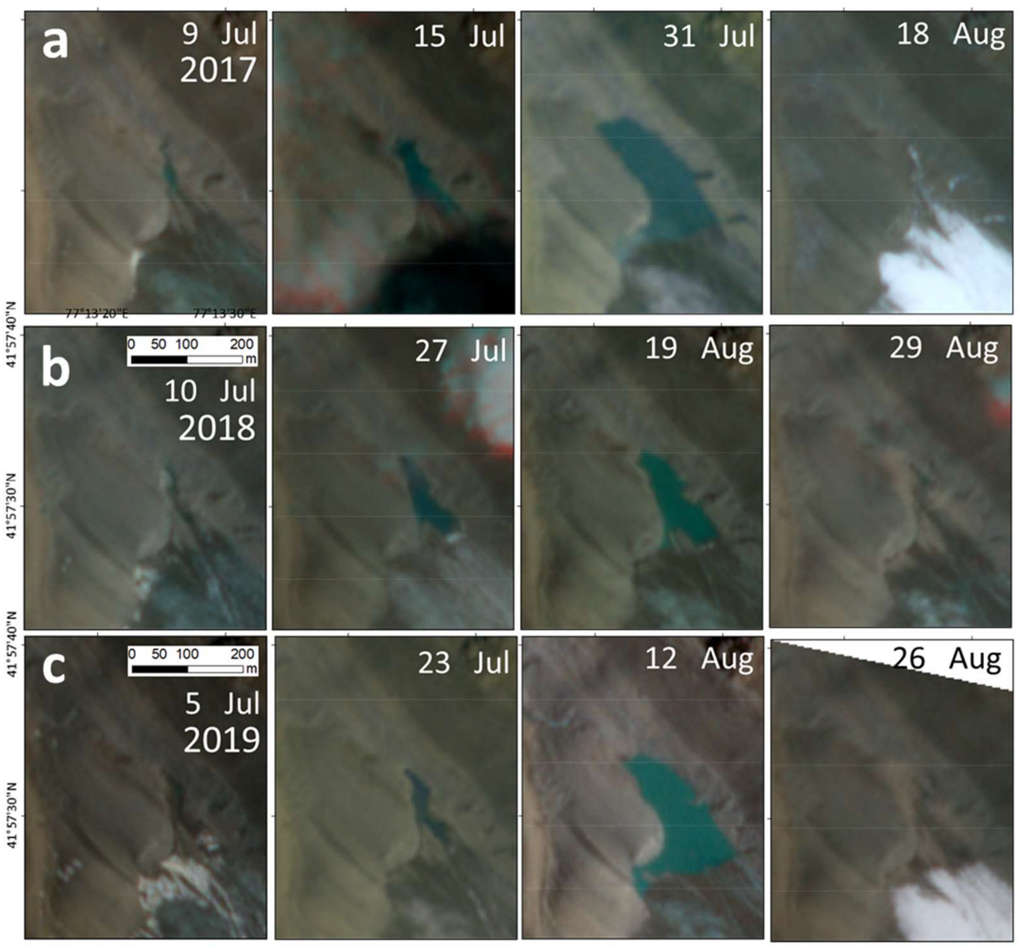


Figure 4: Time sequence of satellite images (PlanetScope) showing the evolution of the Korumdu lake in (a) 2017, (b) 2018, and (c) 2019area during 2017–2019. Scale in b) applies also to a) and c).

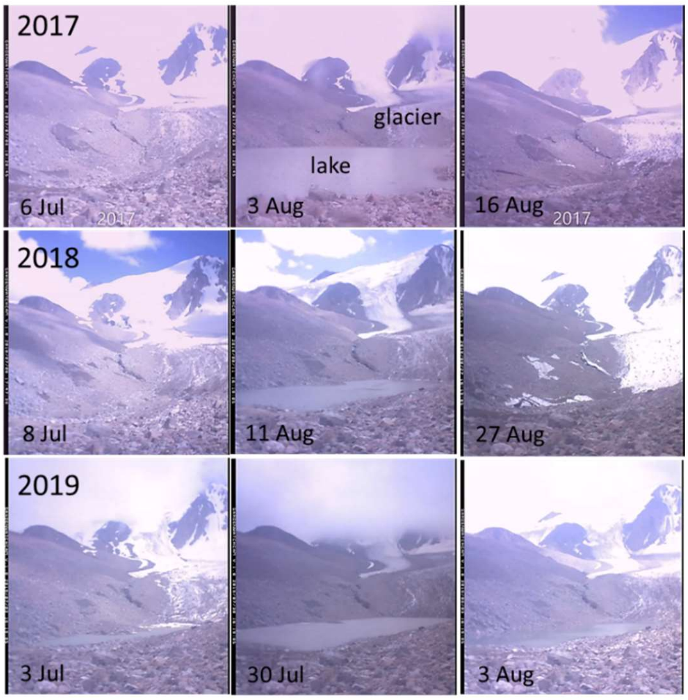
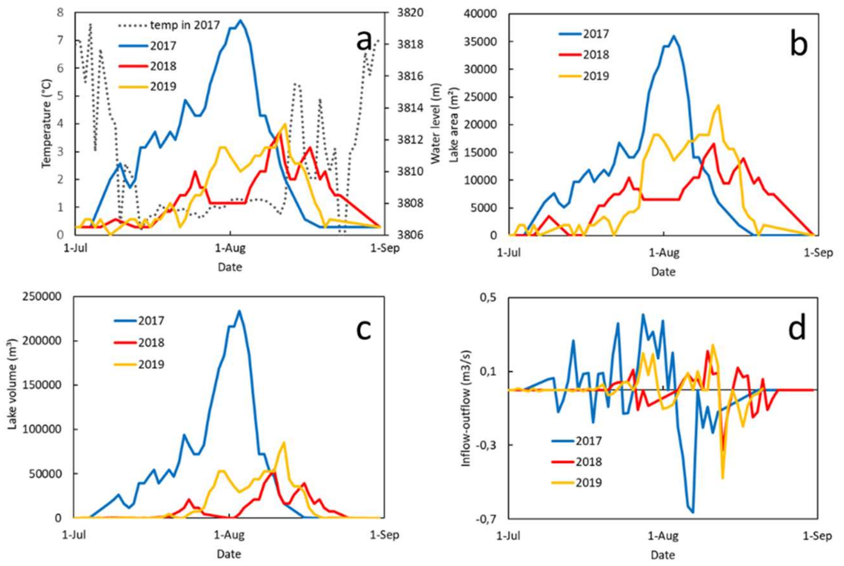
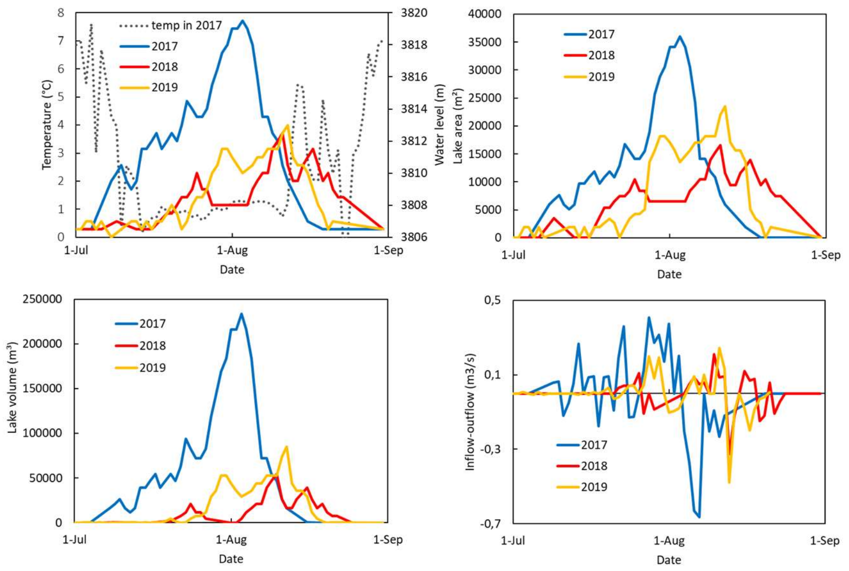


Figure 5: Evolution of Korumdu lake during 2017–2019 basedfrom on time-lapse camera images acquired in the fieldTime sequence of ground camera images of the Korumdu lake area during 2017–2019.


a
temp in 2017
2017
2018
2019
Temperature (°C)
Water level (m)
Date
1-Jul
1-Aug
1-Sep
b
Lake area (m²)
c
Lake volume (m³)
d
Inflow-outflow (m3/s)


temp in 2017
2017
2018
2019
Temperature (°C)
Water level (m)
Lake area (m²)
Lake volume (m³)
Inflow-outflow (m3/s)
Date
1-Jul
1-Aug
1-Sep

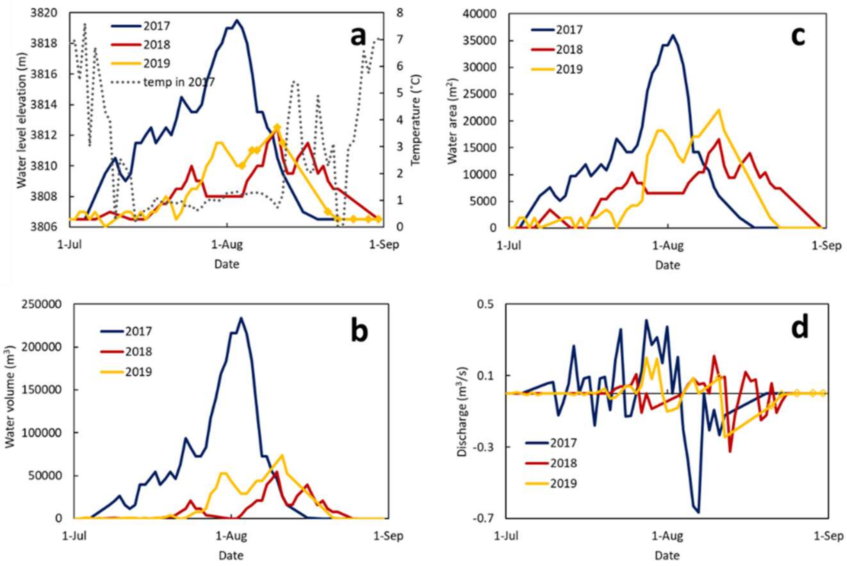
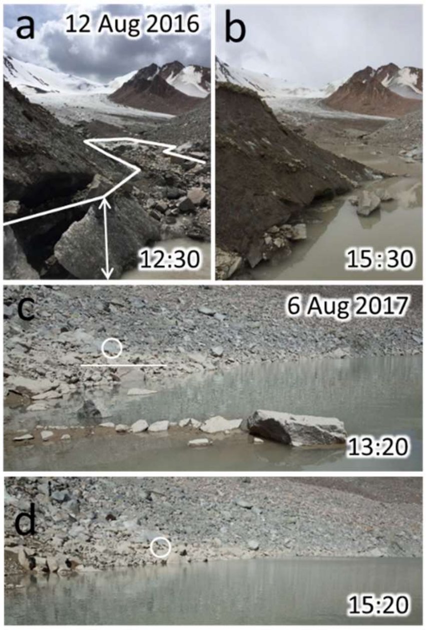
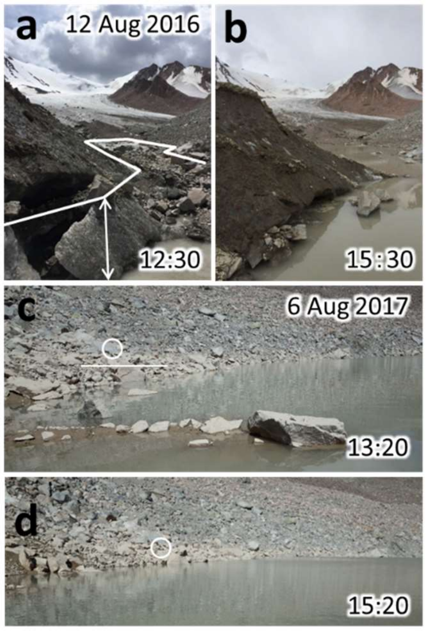


Figure 6: ~~Yearly Korumdu lake properties 2017–2019. (a)~~ Water levels of Korumdu lake in 2017–2019. (a) and air/water ~~level (left) and~~ temperature in 2017 ~~(right)~~. (b) Lake volume. (c) ~~Water~~ Lake surface area. (d) Inflow–outflow ~~discharge~~rate. ~~These d~~Data ~~derived from 2017 to 2019 are~~ based on ~~water level~~water level logger ~~(Hobo U20)~~ data, UAV-derived DSMs, time-lapse camera images, and PlanetScope satellite images.





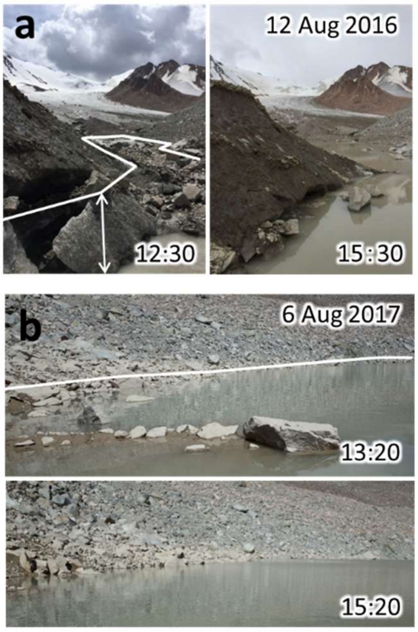
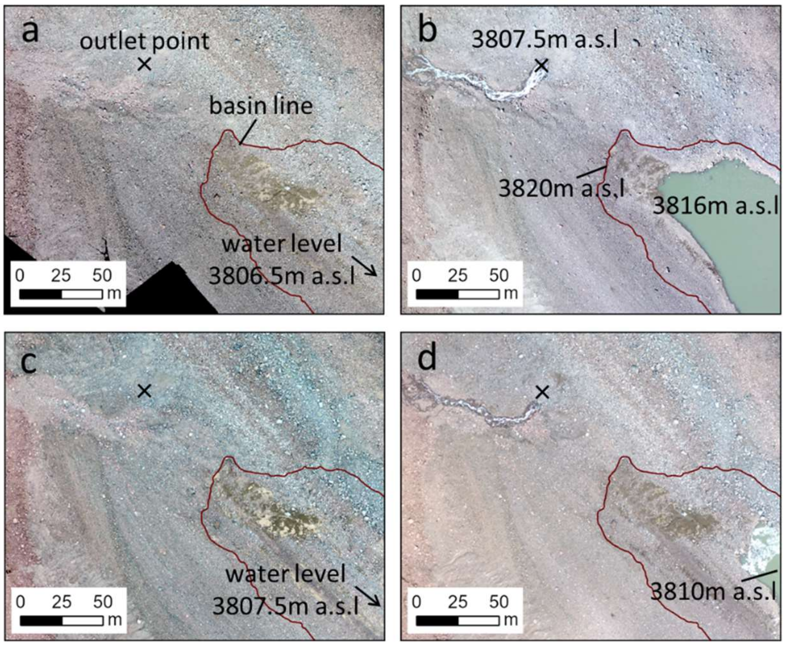
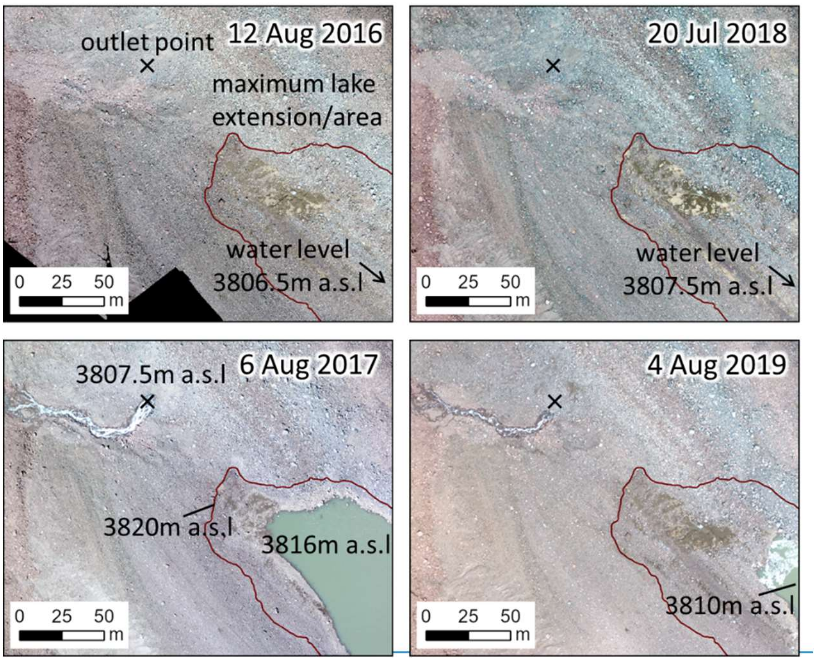


Figure 7: Two examples of a sudden small increase in water level of Korumdu lake. (a) On 12 August 2016. (b) Same as (a) except 3 hours later. (c) On 6 August 2017. (d) Same as (c) except 2 hours later. Images taken in the field.


a
outlet point
basin line
water level
3806.5m a.s.l
0 25 50 m
b
3807.5m a.s.l
3820m a.s.l
3816m a.s.l
0 25 50 m
c
water level
3807.5m a.s.l
0 25 50 m
d
3810m a.s.l
0 25 50 m


outlet point
12 Aug 2016
maximum lake
extension/area
water level
3806.5m a.s.l
0 25 50 m
20 Jul 2018
water level
3807.5m a.s.l
0 25 50 m
3807.5m a.s.l
6 Aug 2017
3820m a.s.l
3816m a.s.l
0 25 50 m
4 Aug 2019
3810m a.s.l
0 25 50 m

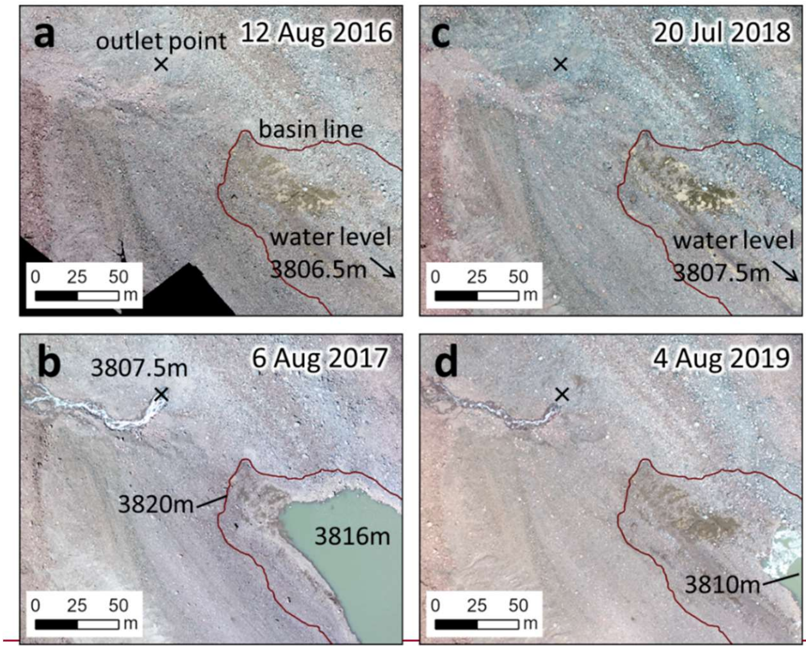
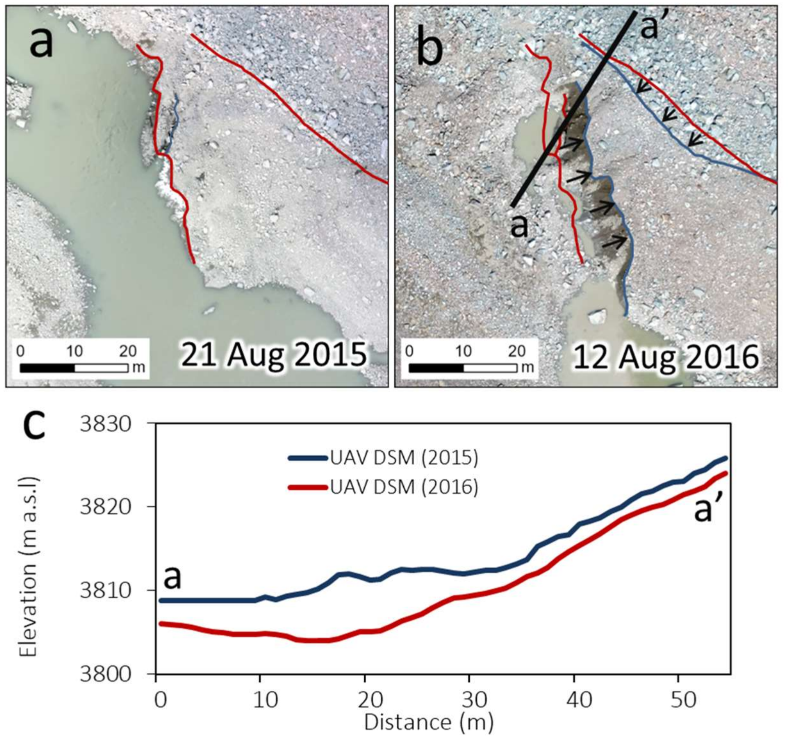
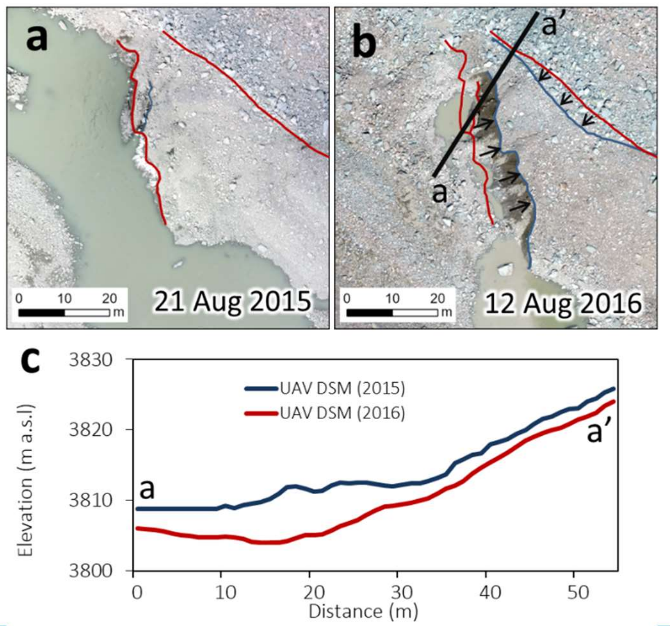


Figure 8: One-day drainage events -from Korumdu lake on the listed dates. (a) On 12 August 2016. (b) On 6 August 2017. (c) On 20 July 2018. (d) On 4 August 2019. (a) On 12 August. 2016. (b) On 6 August. 2017. (c) On 20 July. 2018. (d) On 4 August. 2019. OrthoiImages were acquired from are from our UAV surveysimagery.


a
b
a'
a
0 10 20 m
21 Aug 2015
0 10 20 m
12 Aug 2016
c
UAV DSM (2015)
UAV DSM (2016)
Elevation (m a.s.l)
Distance (m)
3830
3820
3810
3800
0 10 20 30 40 50


a
b
a'
a
0 10 20 m
21 Aug 2015
0 10 20 m
12 Aug 2016
c
UAV DSM (2015)
UAV DSM (2016)
Elevation (m a.s.l)
Distance (m)
3830
3820
3810
3800
0 10 20 30 40 50

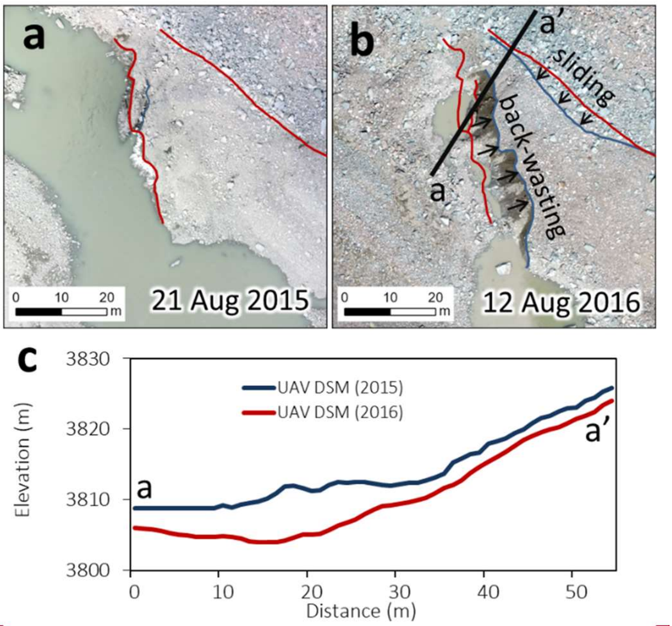
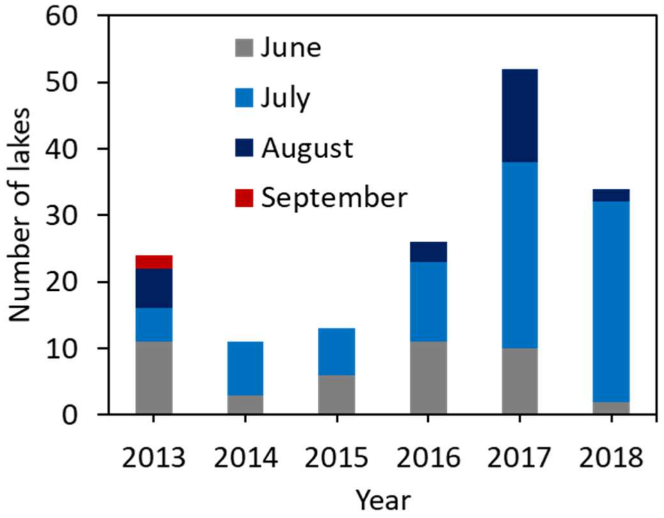


Figure 9: Surface features and elevation profiles of the debris--covered stagnant ice/dead ice landform at the entrance of the outlet ice-tunnel based on UAV ortho-images. (a) On 21 August. 2015. Left red line shows the position of the exposed ice edge line of the debris surface before the ice-cliff underwent backwasting and melting. Right red line shows the deposition line of boulders on the slope. (b) Same as (a) except 12 Aug.-ust 2016. The blue lines show the new positions of the respective surface features after one year. (c) Elevation profile of the surface along line a–a′ in (b).



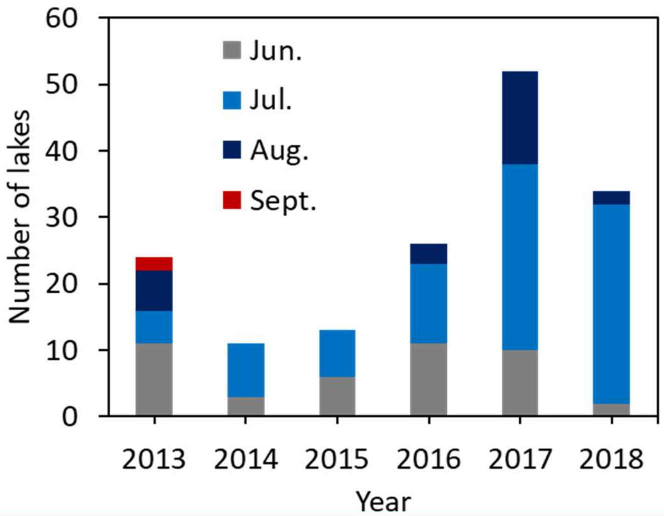


Figure 10: Total number of short-lived lakes in the months of June–September during 2013–2018 in the northern part of the Teskey Range derived by Landsat-7/8, Sentinel-2, and PlanetScope satellite images.

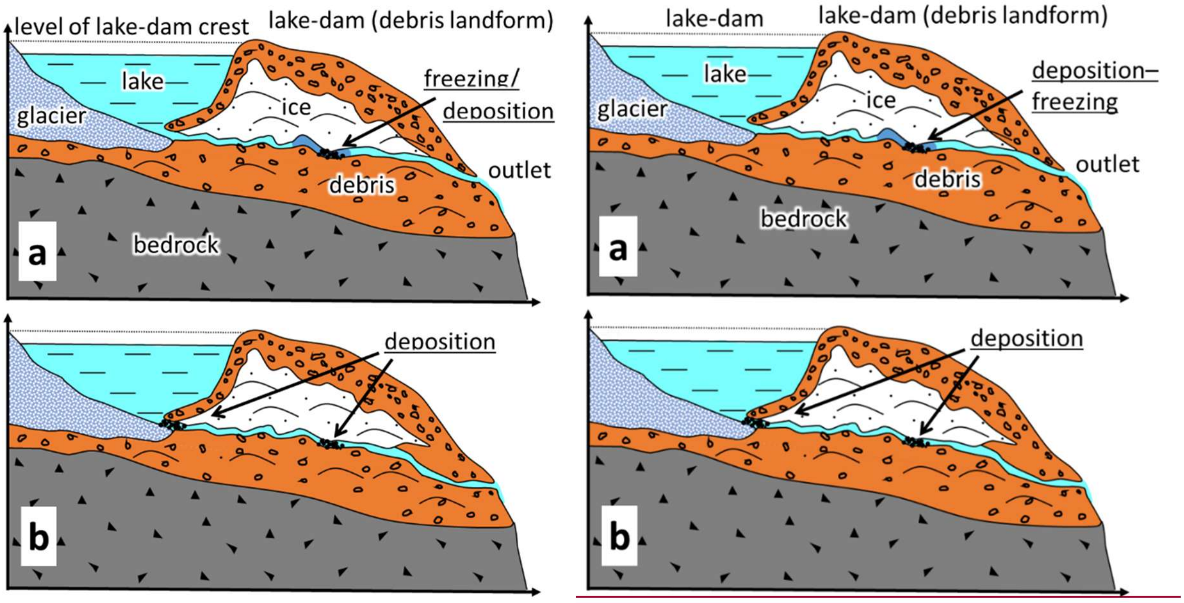
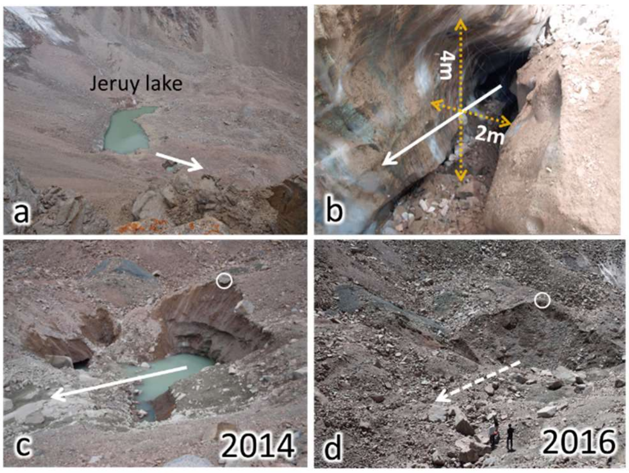
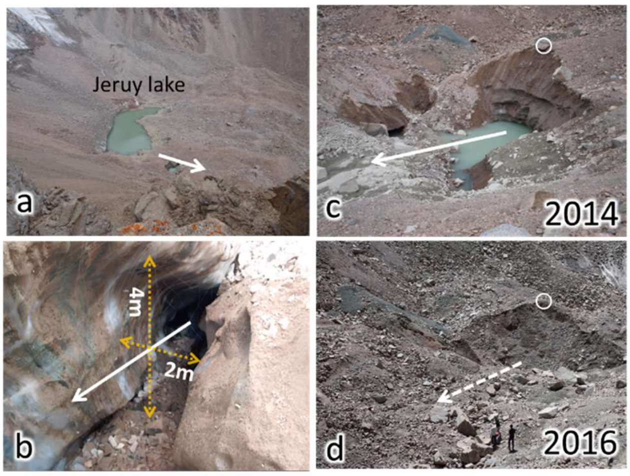


Figure 11: The two types of ice-tunnel closure occurring in the northern Teskey Range~~in the region~~. Sketches show cross-sections through a glacier, lake basin, and ice-cored moraine complex in the case of a short-lived lake (based on Popov, 1987). (a) Deposition–freezing type of closure in case of ~~that appears when~~ an outlet ice-tunnel being ~~is~~ blocked ~~due to the~~by freezing of storage water or deposition of debris and ice. Dark blue in the tunnel is frozen. (b) Deposition–closure type of closure in case of ~~that appears when~~ an outlet ice-tunnel ~~at the entrance or interior is~~being blocked ~~due to~~by deposition of debris and ice by thermal erosion (ice melt~~ing~~).





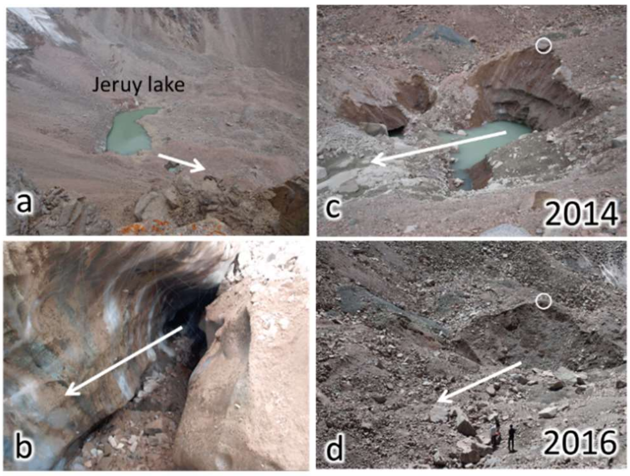


Figure 12: Basin and outlet ice-tunnel of Jeruy lake, which drained ~~in~~ on 15 August 2013. (a) Lake basin of Jeruy glacial lake on 9 August 2014. The ~~W~~white arrow shows the direction of lake drainage ~~flow~~. (b) Insight into the ~~O~~outlet ~~Ice~~ice-tunnel ~~for the drainage channel~~ on 9 Aug 2014. (c) The outlet ice-tunnel area on 9 August 2014. The ~~W~~white circles in (c) and (d) show~~s~~ the same location. (d) Same as (c) except on 9 August 2016.

Landsat-7 and 8				
ID	Satellite	Acquisition date	Resolution (m)	Used for...
1	Landsat-8/OLI	12.06.2013	15 (pan)	analysis short-lived glacial lakes
2	Landsat-8/OLI	19.06.2013	15 (pan)	analysis short-lived glacial lakes
3	Landsat-8/OLI	05.07.2013	15 (pan)	analysis short-lived glacial lakes
4	Landsat-8/OLI	28.07.2013	15 (pan)	analysis short-lived glacial lakes
5	Landsat-7 ETM+/SLC-off	29.07.2013	15 (pan)	analysis short-lived glacial lakes
6	Landsat-8/OLI	30.07.2013	15 (pan)	analysis short-lived glacial lakes
7	Landsat-8/OLI	06.08.2013	15 (pan)	analysis short-lived glacial lakes
8	Landsat-8/OLI	15.08.2013	15 (pan)	analysis short-lived glacial lakes
9	Landsat-8/OLI	29.08.2013	15 (pan)	analysis short-lived glacial lakes
10	Landsat-8/OLI	31.08.2013	15 (pan)	analysis short-lived glacial lakes
11	Landsat-8/OLI	01.09.2013	15 (pan)	analysis short-lived glacial lakes
12	Landsat-8/OLI	07.09.2013	15 (pan)	analysis short-lived glacial lakes
13	Landsat-7 ETM+/SLC-off	08.09.2013	15 (pan)	analysis short-lived glacial lakes
14	Landsat-8/OLI	23.09.2013	15 (pan)	analysis short-lived glacial lakes
15	Landsat-7 ETM+/SLC-off	24.09.2013	15 (pan)	analysis short-lived glacial lakes
16	Landsat-7 ETM+/SLC-off	01.10.2013	15 (pan)	analysis short-lived glacial lakes
17	Landsat-8/OLI	09.10.2013	15 (pan)	analysis short-lived glacial lakes
18	Landsat-7 ETM+/SLC-off	10.10.2013	15 (pan)	analysis short-lived glacial lakes
19	Landsat-8/OLI	05.05.2014	15 (pan)	analysis short-lived glacial lakes
20	Landsat-7 ETM+/SLC-off	29.05.2014	15 (pan)	analysis short-lived glacial lakes
21	Landsat-7 ETM+/SLC-off	14.06.2014	15 (pan)	analysis short-lived glacial lakes
22	Landsat-8/OLI	15.06.2014	15 (pan)	analysis short-lived glacial lakes
23	Landsat-8/OLI	27.06.2014	15 (pan)	analysis short-lived glacial lakes
24	Landsat-7 ETM+/SLC-off	30.06.2014	15 (pan)	analysis short-lived glacial lakes
25	Landsat-8/OLI	01.07.2014	15 (pan)	analysis short-lived glacial lakes
26	Landsat-8/OLI	08.07.2014	15 (pan)	analysis short-lived glacial lakes
27	Landsat-7 ETM+/SLC-off	09.07.2014	15 (pan)	analysis short-lived glacial lakes
28	Landsat-7 ETM+/SLC-off	16.07.2014	15 (pan)	analysis short-lived glacial lakes
29	Landsat-7 ETM+/SLC-off	25.07.2014	15 (pan)	analysis short-lived glacial lakes
30	Landsat-7 ETM+/SLC-off	01.08.2014	15 (pan)	analysis short-lived glacial lakes
31	Landsat-8/OLI	02.08.2014	15 (pan)	analysis short-lived glacial lakes
32	Landsat-7 ETM+/SLC-off	10.08.2014	15 (pan)	analysis short-lived glacial lakes
33	Landsat-8/OLI	25.08.2014	15 (pan)	analysis short-lived glacial lakes
34	Landsat-8/OLI	01.09.2014	15 (pan)	analysis short-lived glacial lakes
35	Landsat-7 ETM+/SLC-off	02.09.2014	15 (pan)	analysis short-lived glacial lakes
36	Landsat-8/OLI	03.09.2014	15 (pan)	analysis short-lived glacial lakes
37	Landsat-8/OLI	10.09.2014	15 (pan)	analysis short-lived glacial lakes
38	Landsat-7 ETM+/SLC-off	18.09.2014	15 (pan)	analysis short-lived glacial lakes
39	Landsat-8/OLI	19.09.2014	15 (pan)	analysis short-lived glacial lakes
40	Landsat-8/OLI	26.09.2014	15 (pan)	analysis short-lived glacial lakes
41	Landsat-7 ETM+/SLC-off	17.06.2015	15 (pan)	analysis short-lived glacial lakes
42	Landsat-8/OLI	18.06.2015	15 (pan)	analysis short-lived glacial lakes
43	Landsat-8/OLI	02.07.2015	15 (pan)	analysis short-lived glacial lakes
44	Landsat-7 ETM+/SLC-off	03.07.2015	15 (pan)	analysis short-lived glacial lakes
45	Landsat-8/OLI	04.07.2015	15 (pan)	analysis short-lived glacial lakes
46	Landsat-8/OLI	11.07.2015	15 (pan)	analysis short-lived glacial lakes
47	Landsat-7 ETM+/SLC-off	12.07.2015	15 (pan)	analysis short-lived glacial lakes
48	Landsat-8/OLI	18.07.2015	15 (pan)	analysis short-lived glacial lakes
49	Landsat-8/OLI	30.07.2015	15 (pan)	analysis short-lived glacial lakes
50	Landsat-8/OLI	12.08.2015	15 (pan)	analysis short-lived glacial lakes
51	Landsat-8/OLI	19.08.2015	15 (pan)	analysis short-lived glacial lakes
52	Landsat-7 ETM+/SLC-off	20.08.2015	15 (pan)	analysis short-lived glacial lakes
53	Landsat-8/OLI	21.08.2015	15 (pan)	analysis short-lived glacial lakes
54	Landsat-8/OLI	04.09.2015	15 (pan)	analysis short-lived glacial lakes
55	Landsat-7 ETM+/SLC-off	05.09.2015	15 (pan)	analysis short-lived glacial lakes
56	Landsat-8/OLI	06.09.2015	15 (pan)	analysis short-lived glacial lakes
57	Landsat-8/OLI	13.09.2015	15 (pan)	analysis short-lived glacial lakes
58	Landsat-8/OLI	29.09.2015	15 (pan)	analysis short-lived glacial lakes
59	Landsat-8/OLI	08.10.2015	15 (pan)	analysis short-lived glacial lakes
60	Landsat-7 ETM+/SLC-off	10.06.2016	15 (pan)	analysis short-lived glacial lakes

Sentinel-2				
ID	Satellite	Acquisition date	Resolution (m)	Used for...
1	Sentinel-2	10.06.2016	10	analysis short-lived glacial lakes
2	Sentinel-2	30.06.2016	10	analysis short-lived glacial lakes
3	Sentinel-2	17.07.2016	10	analysis short-lived glacial lakes
4	Sentinel-2	09.08.2016	10	analysis short-lived glacial lakes
5	Sentinel-2	29.08.2016	10	analysis short-lived glacial lakes
6	Sentinel-2	18.09.2016	10	analysis short-lived glacial lakes
7	Sentinel-2	08.10.2016	10	analysis short-lived glacial lakes
8	Sentinel-2	12.06.2017	10	analysis short-lived glacial lakes
9	Sentinel-2	12.06.2017	10	analysis short-lived glacial lakes
10	Sentinel-2	12.06.2017	10	analysis short-lived glacial lakes
11	Sentinel-2	12.06.2017	10	analysis short-lived glacial lakes
12	Sentinel-2	15.06.2017	10	analysis short-lived glacial lakes
13	Sentinel-2	17.06.2017	10	analysis short-lived glacial lakes
14	Sentinel-2	21.06.2017	10	analysis short-lived glacial lakes
15	Sentinel-2	30.06.2017	10	analysis short-lived glacial lakes
16	Sentinel-2	02.07.2017	10	analysis short-lived glacial lakes
17	Sentinel-2	07.07.2017	10	analysis short-lived glacial lakes
18	Sentinel-2	07.07.2017	10	analysis short-lived glacial lakes
19	Sentinel-2	07.07.2017	10	analysis short-lived glacial lakes
20	Sentinel-2	09.07.2017	10	analysis short-lived glacial lakes
21	Sentinel-2	20.07.2017	10	analysis short-lived glacial lakes
22	Sentinel-2	22.07.2017	10	analysis short-lived glacial lakes
23	Sentinel-2	27.07.2017	10	analysis short-lived glacial lakes
24	Sentinel-2	27.07.2017	10	analysis short-lived glacial lakes
25	Sentinel-2	27.07.2017	10	analysis short-lived glacial lakes
26	Sentinel-2	27.07.2017	10	analysis short-lived glacial lakes
27	Sentinel-2	27.07.2017	10	analysis short-lived glacial lakes
28	Sentinel-2	09.08.2017	10	analysis short-lived glacial lakes
29	Sentinel-2	14.08.2017	10	analysis short-lived glacial lakes
30	Sentinel-2	29.08.2017	10	analysis short-lived glacial lakes
31	Sentinel-2	29.08.2017	10	analysis short-lived glacial lakes
32	Sentinel-2	31.08.2017	10	analysis short-lived glacial lakes
33	Sentinel-2	31.08.2017	10	analysis short-lived glacial lakes
34	Sentinel-2	31.08.2017	10	analysis short-lived glacial lakes
35	Sentinel-2	31.08.2017	10	analysis short-lived glacial lakes
36	Sentinel-2	18.09.2017	10	analysis short-lived glacial lakes
37	Sentinel-2	20.09.2017	10	analysis short-lived glacial lakes
38	Sentinel-2	20.09.2017	10	analysis short-lived glacial lakes
39	Sentinel-2	20.09.2017	10	analysis short-lived glacial lakes
40	Sentinel-2	20.09.2017	10	analysis short-lived glacial lakes
41	Sentinel-2	23.09.2017	10	analysis short-lived glacial lakes
42	Sentinel-2	10.10.2017	10	analysis short-lived glacial lakes
43	Sentinel-2	10.06.2018	10	analysis short-lived glacial lakes
44	Sentinel-2	17.06.2018	10	analysis short-lived glacial lakes
45	Sentinel-2	22.06.2018	10	analysis short-lived glacial lakes
46	Sentinel-2	22.06.2018	10	analysis short-lived glacial lakes
47	Sentinel-2	27.06.2018	10	analysis short-lived glacial lakes
48	Sentinel-2	27.06.2018	10	analysis short-lived glacial lakes
49	Sentinel-2	27.06.2018	10	analysis short-lived glacial lakes
50	Sentinel-2	30.06.2018	10	analysis short-lived glacial lakes
51	Sentinel-2	07.07.2018	10	analysis short-lived glacial lakes
52	Sentinel-2	07.07.2018	10	analysis short-lived glacial lakes
53	Sentinel-2	07.07.2018	10	analysis short-lived glacial lakes
54	Sentinel-2	10.07.2018	10	analysis short-lived glacial lakes
55	Sentinel-2	22.07.2018	10	analysis short-lived glacial lakes
56	Sentinel-2	25.07.2018	10	analysis short-lived glacial lakes
57	Sentinel-2	25.07.2018	10	analysis short-lived glacial lakes
58	Sentinel-2	27.07.2018	10	analysis short-lived glacial lakes
59	Sentinel-2	27.07.2018	10	analysis short-lived glacial lakes
60	Sentinel-2	30.07.2018	10	analysis short-lived glacial lakes

PlanetScope				
ID	Satellite	Acquisition date	Resolution (m)	Used for...
1	Planet Scope	28.07.2013	3	analysis short-lived glacial lakes
2	Planet Scope	18.08.2013	3	analysis short-lived glacial lakes
3	Planet Scope	27.06.2014	3	analysis short-lived glacial lakes
4	Planet Scope	09.07.2017	3	analysis Korumdu lake
5	Planet Scope	15.07.2017	3	analysis Korumdu lake
6	Planet Scope	31.07.2017	3	analysis Korumdu lake
7	Planet Scope	18.08.2017	3	analysis Korumdu lake
8	Planet Scope	10.07.2018	3	analysis Korumdu lake
9	Planet Scope	27.07.2018	3	analysis Korumdu lake
10	Planet Scope	19.08.2018	3	analysis Korumdu lake
11	Planet Scope	23.08.2018	3	analysis Korumdu lake
12	Planet Scope	29.08.2018	3	analysis Korumdu lake
13	Planet Scope	30.08.2018	3	analysis Korumdu lake
14	Planet Scope	05.07.2019	3	analysis Korumdu lake
15	Planet Scope	23.07.2019	3	analysis Korumdu lake
16	Planet Scope	08.08.2019	3	analysis Korumdu lake
17	Planet Scope	12.08.2019	3	analysis Korumdu lake
18	Planet Scope	26.08.2019	3	analysis Korumdu lake

ALOS/AVNIR-2				
ID	Satellite	Acquisition date	Resolution (m)	Used for...
1	ALOS/AVNIR-2	17.09.2007	2.5	lake basin extraction

	Satellite	Acquisition	Resolution (m)	Used for…
1	Landsat-8/OLI	12.06.2013	15 (pan)	analysis short-lived glacial la
2	Landsat-8/OLI	19.06.2013	15 (pan)	analysis short-
3	Landsat-8/OLI	05.07.2013	15 (pan)	analysis short-
4	Landsat-8/OLI	28.07.2013	15 (pan)	analysis short-
5	Landsat-7 ETM+/SLC-off	29.07.2013	15 (pan)	analysis short-
6	Landsat-8/OLI	30.07.2013	15 (pan)	analysis short-
7	Landsat-8/OLI	06.08.2013	15 (pan)	analysis short-
8	Landsat-8/OLI	15.08.2013	15 (pan)	analysis short-
9	Landsat-8/OLI	29.08.2013	15 (pan)	analysis short-
10	Landsat-8/OLI	31.08.2013	15 (pan)	analysis short-
11	Landsat-8/OLI	01.09.2013	15 (pan)	analysis short-
12	Landsat-8/OLI	07.09.2013	15 (pan)	analysis short-
13	Landsat-7 ETM+/SLC-off	08.09.2013	15 (pan)	analysis short-
14	Landsat-8/OLI	23.09.2013	15 (pan)	analysis short-
15	Landsat-7 ETM+/SLC-off	24.09.2013	15 (pan)	analysis short-
16	Landsat-7 ETM+/SLC-off	01.10.2013	15 (pan)	analysis short-
17	Landsat-8/OLI	09.10.2013	15 (pan)	analysis short-
18	Landsat-7 ETM+/SLC-off	10.10.2013	15 (pan)	analysis short-
19	Landsat-8/OLI	05.05.2014	15 (pan)	analysis short-
20	Landsat-7 ETM+/SLC-off	29.05.2014	15 (pan)	analysis short-
21	Landsat-7 ETM+/SLC-off	14.06.2014	15 (pan)	analysis short-
22	Landsat-8/OLI	15.06.2014	15 (pan)	analysis short-
23	Landsat-8/OLI	27.06.2014	15 (pan)	analysis short-
24	Landsat-7 ETM+/SLC-off	30.06.2014	15 (pan)	analysis short-
25	Landsat-8/OLI	01.07.2014	15 (pan)	analysis short-
26	Landsat-8/OLI	08.07.2014	15 (pan)	analysis short-
27	Landsat-7 ETM+/SLC-off	09.07.2014	15 (pan)	analysis short-
28	Landsat-7 ETM+/SLC-off	16.07.2014	15 (pan)	analysis short-
29	Landsat-7 ETM+/SLC-off	25.07.2014	15 (pan)	analysis short-
30	Landsat-7 ETM+/SLC-off	01.08.2014	15 (pan)	analysis short-
31	Landsat-8/OLI	02.08.2014	15 (pan)	analysis short-
32	Landsat-7 ETM+/SLC-off	10.08.2014	15 (pan)	analysis short-
33	Landsat-8/OLI	25.08.2014	15 (pan)	analysis short-
34	Landsat-8/OLI	01.09.2014	15 (pan)	analysis short-
35	Landsat-7 ETM+/SLC-off	02.09.2014	15 (pan)	analysis short-
36	Landsat-8/OLI	03.09.2014	15 (pan)	analysis short-
37	Landsat-8/OLI	10.09.2014	15 (pan)	analysis short-
38	Landsat-7 ETM+/SLC-off	18.09.2014	15 (pan)	analysis short-
39	Landsat-8/OLI	19.09.2014	15 (pan)	analysis short-
40	Landsat-8/OLI	26.09.2014	15 (pan)	analysis short-
41	Landsat-7 ETM+/SLC-off	17.06.2015	15 (pan)	analysis short-
42	Landsat-8/OLI	18.06.2015	15 (pan)	analysis short-
43	Landsat-8/OLI	02.07.2015	15 (pan)	analysis short-
44	Landsat-7 ETM+/SLC-off	03.07.2015	15 (pan)	analysis short-
45	Landsat-8/OLI	04.07.2015	15 (pan)	analysis short-
46	Landsat-8/OLI	11.07.2015	15 (pan)	analysis short-
47	Landsat-7 ETM+/SLC-off	12.07.2015	15 (pan)	analysis short-
48	Landsat-8/OLI	18.07.2015	15 (pan)	analysis short-
49	Landsat-8/OLI	30.07.2015	15 (pan)	analysis short-
50	Landsat-8/OLI	12.08.2015	15 (pan)	analysis short-
51	Landsat-8/OLI	19.08.2015	15 (pan)	analysis short-
52	Landsat-7 ETM+/SLC-off	20.08.2015	15 (pan)	analysis short-
53	Landsat-8/OLI	21.08.2015	15 (pan)	analysis short-
54	Landsat-8/OLI	04.09.2015	15 (pan)	analysis short-
55	Landsat-7 ETM+/SLC-off	05.09.2015	15 (pan)	analysis short-
56	Landsat-8/OLI	06.09.2015	15 (pan)	analysis short-
57	Landsat-8/OLI	13.09.2015	15 (pan)	analysis short-
58	Landsat-8/OLI	29.09.2015	15 (pan)	analysis short-
59	Landsat-8/OLI	08.10.2015	15 (pan)	analysis short-
60	Landsat-7 ETM+/SLC-off	10.06.2016	15 (pan)	analysis short-
61	Landsat-8/OLI	11.06.2016	15 (pan)	analysis short-
62	Landsat-7 ETM+/SLC-off	26.06.2016	15 (pan)	analysis short-
63	Landsat-8/OLI	20.06.2016	15 (pan)	analysis short-
64	Landsat-7 ETM+/SLC-off	12.07.2016	15 (pan)	analysis short-
65	Landsat-8/OLI	13.07.2016	15 (pan)	analysis short-
66	Landsat-8/OLI	20.07.2016	15 (pan)	analysis short-
67	Landsat-7 ETM+/SLC-off	21.07.2016	15 (pan)	analysis short-
68	Landsat-8/OLI	22.07.2016	15 (pan)	analysis short-
69	Landsat-8/OLI	29.07.2016	15 (pan)	analysis short-
70	Landsat-7 ETM+/SLC-off	30.07.2016	15 (pan)	analysis short-
71	Landsat-8/OLI	29.07.2016	15 (pan)	analysis short-
72	Landsat-8/OLI	07.08.2016	15 (pan)	analysis short-
73	Landsat-7 ETM+/SLC-off	13.08.2016	15 (pan)	analysis short-
74	Landsat-8/OLI	14.08.2016	15 (pan)	analysis short-
75	Landsat-8/OLI	21.08.2016	15 (pan)	analysis short-
76	Landsat-7 ETM+/SLC-off	22.08.2016	15 (pan)	analysis short-
77	Landsat-8/OLI	23.08.2016	15 (pan)	analysis short-
78	Landsat-7 ETM+/SLC-off	07.09.2016	15 (pan)	analysis short-
79	Landsat-8/OLI	08.09.2016	15 (pan)	analysis short-

Sentinel-2

	Satellite	Acquisition d	Resolutio	Used for…
1	Sentinel-2	10.06.2016	10	analysis sh
2	Sentinel-2	30.06.2016	10	analysis sh
3	Sentinel-2	17.07.2016	10	analysis sh
4	Sentinel-2	09.08.2016	10	analysis sh
5	Sentinel-2	29.08.2016	10	analysis sh
6	Sentinel-2	18.09.2016	10	analysis sh
7	Sentinel-2	08.10.2016	10	analysis sh
8	Sentinel-2	12.06.2017	10	analysis sh
9	Sentinel-2	12.06.2017	10	analysis sh
10	Sentinel-2	12.06.2017	10	analysis sh
11	Sentinel-2	12.06.2017	10	analysis sh
12	Sentinel-2	15.06.2017	10	analysis sh
13	Sentinel-2	17.06.2017	10	analysis sh
14	Sentinel-2	21.06.2017	10	analysis sh
15	Sentinel-2	30.06.2017	10	analysis sh
16	Sentinel-2	02.07.2017	10	analysis sh
17	Sentinel-2	07.07.2017	10	analysis sh
18	Sentinel-2	07.07.2017	10	analysis sh
19	Sentinel-2	07.07.2017	10	analysis short-lived glacial lakes
20	Sentinel-2	09.07.2017	10	analysis short-lived g
21	Sentinel-2	20.07.2017	10	analysis short-lived g
22	Sentinel-2	22.07.2017	10	analysis sh
23	Sentinel-2	27.07.2017	10	analysis short-lived glacial lakes
24	Sentinel-2	27.07.2017	10	analysis short-lived glacial lakes
25	Sentinel-2	27.07.2017	10	analysis short-lived glacial lakes
26	Sentinel-2	27.07.2017	10	analysis short-lived glacial lakes
27	Sentinel-2	27.07.2017	10	analysis short-lived glacial lakes
28	Sentinel-2	09.08.2017	10	analysis short-lived glacial lakes
29	Sentinel-2	14.08.2017	10	analysis short-lived glacial lakes
30	Sentinel-2	29.08.2017	10	analysis short-lived glacial lakes
31	Sentinel-2	29.08.2017	10	analysis short-lived glacial lakes
32	Sentinel-2	31.08.2017	10	analysis short-lived glacial lakes
33	Sentinel-2	31.08.2017	10	analysis short-lived glacial lakes
34	Sentinel-2	31.08.2017	10	analysis short-lived glacial lakes
35	Sentinel-2	31.08.2017	10	analysis short-lived glacial lakes
36	Sentinel-2	18.09.2017	10	analysis short-lived glacial lakes
37	Sentinel-2	20.09.2017	10	analysis short-lived glacial lakes
38	Sentinel-2	20.09.2017	10	analysis short-lived glacial lakes
39	Sentinel-2	20.09.2017	10	analysis short-lived glacial lakes
40	Sentinel-2	20.09.2017	10	analysis short-lived glacial lakes
41	Sentinel-2	23.09.2017	10	analysis short-lived glacial lakes
42	Sentinel-2	10.10.2017	10	analysis short-lived glacial lakes
43	Sentinel-2	10.06.2018	10	analysis short-lived glacial lakes
44	Sentinel-2	17.06.2018	10	analysis short-lived glacial lakes
45	Sentinel-2	22.06.2018	10	analysis short-lived glacial lakes
46	Sentinel-2	22.06.2018	10	analysis short-lived glacial lakes
47	Sentinel-2	27.06.2018	10	analysis short-lived glacial lakes
48	Sentinel-2	27.06.2018	10	analysis short-lived glacial lakes
49	Sentinel-2	27.06.2018	10	analysis short-lived glacial lakes
50	Sentinel-2	30.06.2018	10	analysis short-lived glacial lakes
51	Sentinel-2	07.07.2018	10	analysis short-lived glacial lakes
52	Sentinel-2	07.07.2018	10	analysis short-lived glacial lakes
53	Sentinel-2	07.07.2018	10	analysis short-lived glacial lakes
54	Sentinel-2	10.07.2018	10	analysis short-lived glacial lakes
55	Sentinel-2	22.07.2018	10	analysis short-lived glacial lakes
56	Sentinel-2	25.07.2018	10	analysis short-lived glacial lakes
57	Sentinel-2	25.07.2018	10	analysis short-lived glacial lakes
58	Sentinel-2	27.07.2018	10	analysis short-lived glacial lakes
59	Sentinel-2	27.07.2018	10	analysis short-lived glacial lakes
60	Sentinel-2	30.07.2018	10	analysis short-lived glacial lakes
61	Sentinel-2	30.07.2018	10	analysis short-lived glacial lakes
62	Sentinel-2	01.08.2018	10	analysis short-lived glacial lakes
63	Sentinel-2	01.08.2018	10	analysis short-lived glacial lakes
64	Sentinel-2	01.08.2018	10	analysis short-lived glacial lakes
65	Sentinel-2	01.08.2018	10	analysis short-lived glacial lakes
66	Sentinel-2	01.08.2018	10	analysis short-lived glacial lakes
67	Sentinel-2	04.08.2018	10	analysis short-lived glacial lakes
68	Sentinel-2	04.08.2018	10	analysis short-lived glacial lakes
69	Sentinel-2	04.08.2018	10	analysis short-lived glacial lakes
70	Sentinel-2	09.08.2018	10	analysis short-lived glacial lakes
71	Sentinel-2	11.08.2018	10	analysis short-lived glacial lakes
72	Sentinel-2	11.08.2018	10	analysis short-lived glacial lakes
73	Sentinel-2	11.08.2018	10	analysis short-lived glacial lakes
74	Sentinel-2	11.08.2018	10	analysis short-lived glacial lakes
75	Sentinel-2	14.08.2018	10	analysis short-lived glacial lakes
76	Sentinel-2	14.08.2018	10	analysis short-lived glacial lakes
77	Sentinel-2	14.08.2018	10	analysis short-lived glacial lakes
78	Sentinel-2	16.08.2018	10	analysis short-lived glacial lakes

PlanetScope

	Satellite	Acquisition	Resolutio	Used for…
1	Planet Scope	28.07.2013	3	analysis sho
2	Planet Scope	18.08.2013	3	analysis sho
3	Planet Scope	27.06.2014	3	analysis sho
4	Planet Scope	09.07.2017	3	analysis Kor
5	Planet Scope	15.07.2017	3	analysis Kor
6	Planet Scope	31.07.2017	3	analysis Kor
7	Planet Scope	18.08.2017	3	analysis Kor
8	Planet Scope	10.07.2018	3	analysis Kor
9	Planet Scope	27.07.2018	3	analysis Kor
10	Planet Scope	19.08.2018	3	analysis Kor
11	Planet Scope	23.08.2018	3	analysis Kor
12	Planet Scope	29.08.2018	3	analysis Kor
13	Planet Scope	30.08.2018	3	analysis Kor
14	Planet Scope	05.07.2019	3	analysis Kor
15	Planet Scope	23.07.2019	3	analysis Kor
16	Planet Scope	08.08.2019	3	analysis Kor
17	Planet Scope	12.08.2019	3	analysis Kor
18	Planet Scope	26.08.2019	3	analysis Kor

ALOS/AVNIR-2

	Satellite	Acquisition	Resolutio	Used for…
1	ALOS/AVNIR	17.09.2007	2.5	lake basin e

61	Landsat-8/OLI	11.06.2016	15 (pan)	analysis short-lived glacial lakes	61	Sentinel-2	30.07.2018	10	analysis short-lived glacial lakes
62	Landsat-7 ETM+/SLC-off	26.06.2016	15 (pan)	analysis short-lived glacial lakes	62	Sentinel-2	01.08.2018	10	analysis short-lived glacial lakes
63	Landsat-8/OLI	20.06.2016	15 (pan)	analysis short-lived glacial lakes	63	Sentinel-2	01.08.2018	10	analysis short-lived glacial lakes
64	Landsat-7 ETM+/SLC-off	12.07.2016	15 (pan)	analysis short-lived glacial lakes	64	Sentinel-2	01.08.2018	10	analysis short-lived glacial lakes
65	Landsat-8/OLI	13.07.2016	15 (pan)	analysis short-lived glacial lakes	65	Sentinel-2	01.08.2018	10	analysis short-lived glacial lakes
66	Landsat-8/OLI	20.07.2016	15 (pan)	analysis short-lived glacial lakes	66	Sentinel-2	01.08.2018	10	analysis short-lived glacial lakes
67	Landsat-7 ETM+/SLC-off	21.07.2016	15 (pan)	analysis short-lived glacial lakes	67	Sentinel-2	04.08.2018	10	analysis short-lived glacial lakes
68	Landsat-8/OLI	22.07.2016	15 (pan)	analysis short-lived glacial lakes	68	Sentinel-2	04.08.2018	10	analysis short-lived glacial lakes
69	Landsat-8/OLI	29.07.2016	15 (pan)	analysis short-lived glacial lakes	69	Sentinel-2	04.08.2018	10	analysis short-lived glacial lakes
70	Landsat-7 ETM+/SLC-off	30.07.2016	15 (pan)	analysis short-lived glacial lakes	70	Sentinel-2	09.08.2018	10	analysis short-lived glacial lakes
71	Landsat-8/OLI	29.07.2016	15 (pan)	analysis short-lived glacial lakes	71	Sentinel-2	11.08.2018	10	analysis short-lived glacial lakes
72	Landsat-8/OLI	07.08.2016	15 (pan)	analysis short-lived glacial lakes	72	Sentinel-2	11.08.2018	10	analysis short-lived glacial lakes
73	Landsat-7 ETM+/SLC-off	13.08.2016	15 (pan)	analysis short-lived glacial lakes	73	Sentinel-2	11.08.2018	10	analysis short-lived glacial lakes
74	Landsat-8/OLI	14.08.2016	15 (pan)	analysis short-lived glacial lakes	74	Sentinel-2	11.08.2018	10	analysis short-lived glacial lakes
75	Landsat-8/OLI	21.08.2016	15 (pan)	analysis short-lived glacial lakes	75	Sentinel-2	14.08.2018	10	analysis short-lived glacial lakes
76	Landsat-7 ETM+/SLC-off	22.08.2016	15 (pan)	analysis short-lived glacial lakes	76	Sentinel-2	14.08.2018	10	analysis short-lived glacial lakes
77	Landsat-8/OLI	23.08.2016	15 (pan)	analysis short-lived glacial lakes	77	Sentinel-2	14.08.2018	10	analysis short-lived glacial lakes
78	Landsat-7 ETM+/SLC-off	07.09.2016	15 (pan)	analysis short-lived glacial lakes	78	Sentinel-2	16.08.2018	10	analysis short-lived glacial lakes
79	Landsat-8/OLI	08.09.2016	15 (pan)	analysis short-lived glacial lakes	79	Sentinel-2	16.08.2018	10	analysis short-lived glacial lakes
80	Landsat-7 ETM+/SLC-off	14.09.2016	15 (pan)	analysis short-lived glacial lakes	80	Sentinel-2	16.08.2018	10	analysis short-lived glacial lakes
81	Landsat-8/OLI	15.09.2016	15 (pan)	analysis short-lived glacial lakes	81	Sentinel-2	16.08.2018	10	analysis short-lived glacial lakes
82	Landsat-8/OLI	22.09.2016	15 (pan)	analysis short-lived glacial lakes	82	Sentinel-2	20.08.2018	10	analysis short-lived glacial lakes
83	Landsat-7 ETM+/SLC-off	23.09.2016	15 (pan)	analysis short-lived glacial lakes	83	Sentinel-2	29.08.2018	10	analysis short-lived glacial lakes
84	Landsat-8/OLI	24.09.2016	15 (pan)	analysis short-lived glacial lakes	84	Sentinel-2	31.08.2018	10	analysis short-lived glacial lakes
85	Landsat-8/OLI	14.06.2017	15 (pan)	analysis short-lived glacial lakes	85	Sentinel-2	31.08.2018	10	analysis short-lived glacial lakes
86	Landsat-8/OLI	30.06.2017	15 (pan)	analysis short-lived glacial lakes	86	Sentinel-2	31.08.2018	10	analysis short-lived glacial lakes
87	Landsat-8/OLI	01.07.2017	15 (pan)	analysis short-lived glacial lakes	87	Sentinel-2	31.08.2018	10	analysis short-lived glacial lakes
88	Landsat-8/OLI	07.07.2017	15 (pan)	analysis short-lived glacial lakes	88	Sentinel-2	03.09.2018	10	analysis short-lived glacial lakes
89	Landsat-8/OLI	09.07.2017	15 (pan)	analysis short-lived glacial lakes	89	Sentinel-2	05.09.2018	10	analysis short-lived glacial lakes
90	Landsat-8/OLI	16.07.2017	15 (pan)	analysis short-lived glacial lakes	90	Sentinel-2	05.09.2018	10	analysis short-lived glacial lakes
91	Landsat-8/OLI	25.07.2017	15 (pan)	analysis short-lived glacial lakes	91	Sentinel-2	05.09.2018	10	analysis short-lived glacial lakes
92	Landsat-8/OLI	25.07.2017	15 (pan)	analysis short-lived glacial lakes	92	Sentinel-2	08.09.2018	10	analysis short-lived glacial lakes
93	Landsat-8/OLI	01.08.2017	15 (pan)	analysis short-lived glacial lakes	93	Sentinel-2	08.09.2018	10	analysis short-lived glacial lakes
94	Landsat-8/OLI	08.08.2017	15 (pan)	analysis short-lived glacial lakes	94	Sentinel-2	13.09.2018	10	analysis short-lived glacial lakes
95	Landsat-8/OLI	10.08.2017	15 (pan)	analysis short-lived glacial lakes	95	Sentinel-2	30.09.2018	10	analysis short-lived glacial lakes
96	Landsat-8/OLI	26.08.2017	15 (pan)	analysis short-lived glacial lakes	96	Sentinel-2	30.09.2018	10	analysis short-lived glacial lakes
97	Landsat-8/OLI	02.09.2017	15 (pan)	analysis short-lived glacial lakes	97	Sentinel-2	27.06.2019	10	analysis short-lived glacial lakes
98	Landsat-7 ETM+/SLC-off	17.09.2017	15 (pan)	analysis short-lived glacial lakes	98	Sentinel-2	27.06.2019	10	analysis short-lived glacial lakes
99	Landsat-8/OLI	11.10.2017	15 (pan)	analysis short-lived glacial lakes	99	Sentinel-2	27.06.2019	10	analysis short-lived glacial lakes
100	Landsat-8/OLI	25.06.2018	15 (pan)	analysis short-lived glacial lakes	100	Sentinel-2	30.06.2019	10	analysis short-lived glacial lakes
101	Landsat-8/OLI	10.07.2018	15 (pan)	analysis short-lived glacial lakes	101	Sentinel-2	05.07.2019	10	analysis short-lived glacial lakes
102	Landsat-8/OLI	19.07.2018	15 (pan)	analysis short-lived glacial lakes	102	Sentinel-2	12.07.2019	10	analysis short-lived glacial lakes
103	Landsat-8/OLI	19.07.2018	15 (pan)	analysis short-lived glacial lakes	103	Sentinel-2	15.07.2019	10	analysis short-lived glacial lakes
104	Landsat-8/OLI	05.09.2019	15 (pan)	analysis short-lived glacial lakes	104	Sentinel-2	30.07.2019	10	analysis short-lived glacial lakes
105	Landsat-8/OLI	07.08.2019	15 (pan)	analysis short-lived glacial lakes	105	Sentinel-2	01.08.2019	10	analysis short-lived glacial lakes
					106	Sentinel-2	04.08.2019	10	analysis short-lived glacial lakes
					107	Sentinel-2	04.08.2019	10	analysis short-lived glacial lakes
					108	Sentinel-2	09.08.2019	10	analysis short-lived glacial lakes
					109	Sentinel-2	11.08.2019	10	analysis short-lived glacial lakes
					110	Sentinel-2	11.08.2019	10	analysis short-lived glacial lakes
					111	Sentinel-2	11.08.2019	10	analysis short-lived glacial lakes
					112	Sentinel-2	11.08.2019	10	analysis short-lived glacial lakes
					113	Sentinel-2	29.08.2019	10	analysis short-lived glacial lakes
					114	Sentinel-2	29.08.2019	10	analysis short-lived glacial lakes
					115	Sentinel-2	31.08.2019	10	analysis short-lived glacial lakes
					116	Sentinel-2	31.08.2019	10	analysis short-lived glacial lakes
					117	Sentinel-2	31.08.2019	10	analysis short-lived glacial lakes
					118	Sentinel-2	03.09.2019	10	analysis short-lived glacial lakes
					119	Sentinel-2	03.09.2019	10	analysis short-lived glacial lakes
					120	Sentinel-2	23.09.2019	10	analysis short-lived glacial lakes
					121	Sentinel-2	23.09.2019	10	analysis short-lived glacial lakes
					122	Sentinel-2	25.09.2019	10	analysis short-lived glacial lakes
					123	Sentinel-2	25.09.2019	10	analysis short-lived glacial lakes
					124	Sentinel-2	25.09.2019	10	analysis short-lived glacial lakes

79	Landsat-8/OLI	08.09.2016	15 (pan)	analysis short-	78	Sentinel-2	16.08.2018	10	analysis short-lived glacial lakes
80	Landsat-7 ETM+/SLC-off	14.09.2016	15 (pan)	analysis short-	79	Sentinel-2	16.08.2018	10	analysis short-lived glacial lakes
81	Landsat-8/OLI	15.09.2016	15 (pan)	analysis short-	80	Sentinel-2	16.08.2018	10	analysis short-lived glacial lakes
82	Landsat-8/OLI	22.09.2016	15 (pan)	analysis short-	81	Sentinel-2	16.08.2018	10	analysis short-lived glacial lakes
83	Landsat-7 ETM+/SLC-off	23.09.2016	15 (pan)	analysis short-	82	Sentinel-2	20.08.2018	10	analysis short-lived glacial lakes
84	Landsat-8/OLI	24.09.2016	15 (pan)	analysis short-	83	Sentinel-2	29.08.2018	10	analysis short-lived glacial lakes
85	Landsat-8/OLI	14.06.2017	15 (pan)	analysis short-	84	Sentinel-2	31.08.2018	10	analysis short-lived glacial lakes
86	Landsat-8/OLI	30.06.2017	15 (pan)	analysis short-	85	Sentinel-2	31.08.2018	10	analysis short-lived glacial lakes
87	Landsat-8/OLI	01.07.2017	15 (pan)	analysis short-	86	Sentinel-2	31.08.2018	10	analysis short-lived glacial lakes
88	Landsat-8/OLI	07.07.2017	15 (pan)	analysis short-	87	Sentinel-2	31.08.2018	10	analysis short-lived glacial lakes
89	Landsat-8/OLI	09.07.2017	15 (pan)	analysis short-	88	Sentinel-2	03.09.2018	10	analysis short-lived glacial lakes
90	Landsat-8/OLI	16.07.2017	15 (pan)	analysis short-	89	Sentinel-2	05.09.2018	10	analysis short-lived glacial lakes
91	Landsat-8/OLI	25.07.2017	15 (pan)	analysis short-	90	Sentinel-2	05.09.2018	10	analysis short-lived glacial lakes
92	Landsat-8/OLI	25.07.2017	15 (pan)	analysis short-	91	Sentinel-2	05.09.2018	10	analysis short-lived glacial lakes
93	Landsat-8/OLI	01.08.2017	15 (pan)	analysis short-	92	Sentinel-2	08.09.2018	10	analysis short-lived glacial lakes
94	Landsat-8/OLI	08.08.2017	15 (pan)	analysis short-	93	Sentinel-2	08.09.2018	10	analysis short-lived glacial lakes
95	Landsat-8/OLI	10.08.2017	15 (pan)	analysis short-	94	Sentinel-2	13.09.2018	10	analysis short-lived glacial lakes
96	Landsat-8/OLI	26.08.2017	15 (pan)	analysis short-	95	Sentinel-2	30.09.2018	10	analysis short-lived glacial lakes
97	Landsat-8/OLI	02.09.2017	15 (pan)	analysis short-	96	Sentinel-2	30.09.2018	10	analysis short-lived glacial lakes
98	Landsat-7 ETM+/SLC-off	17.09.2017	15 (pan)	analysis short-	97	Sentinel-2	27.06.2019	10	analysis short-lived glacial lakes
99	Landsat-8/OLI	11.10.2017	15 (pan)	analysis short-	98	Sentinel-2	27.06.2019	10	analysis short-lived glacial lakes
100	Landsat-8/OLI	25.06.2018	15 (pan)	analysis short-	99	Sentinel-2	27.06.2019	10	analysis short-lived glacial lakes
101	Landsat-8/OLI	10.07.2018	15 (pan)	analysis short-	100	Sentinel-2	30.06.2019	10	analysis short-lived glacial lakes
102	Landsat-8/OLI	19.07.2018	15 (pan)	analysis short-	101	Sentinel-2	05.07.2019	10	analysis short-lived glacial lakes
103	Landsat-8/OLI	19.07.2018	15 (pan)	analysis short-	102	Sentinel-2	12.07.2019	10	analysis short-lived glacial lakes
104	Landsat-8/OLI	05.09.2019	15 (pan)	analysis short-	103	Sentinel-2	15.07.2019	10	analysis short-lived glacial lakes
105	Landsat-8/OLI	07.08.2019	15 (pan)	analysis short-	104	Sentinel-2	30.07.2019	10	analysis short-lived glacial lakes
					105	Sentinel-2	01.08.2019	10	analysis short-lived glacial lakes
					106	Sentinel-2	04.08.2019	10	analysis short-lived glacial lakes
					107	Sentinel-2	04.08.2019	10	analysis short-lived glacial lakes
					108	Sentinel-2	09.08.2019	10	analysis short-lived glacial lakes
					109	Sentinel-2	11.08.2019	10	analysis short-lived glacial lakes
					110	Sentinel-2	11.08.2019	10	analysis short-lived glacial lakes
					111	Sentinel-2	11.08.2019	10	analysis short-lived glacial lakes
					112	Sentinel-2	11.08.2019	10	analysis short-lived glacial lakes
					113	Sentinel-2	29.08.2019	10	analysis short-lived glacial lakes
					114	Sentinel-2	29.08.2019	10	analysis short-lived glacial lakes
					115	Sentinel-2	31.08.2019	10	analysis short-lived glacial lakes
					116	Sentinel-2	31.08.2019	10	analysis short-lived glacial lakes
					117	Sentinel-2	31.08.2019	10	analysis short-lived glacial lakes
					118	Sentinel-2	03.09.2019	10	analysis short-lived glacial lakes
					119	Sentinel-2	03.09.2019	10	analysis short-lived glacial lakes
					120	Sentinel-2	23.09.2019	10	analysis short-lived glacial lakes
					121	Sentinel-2	23.09.2019	10	analysis short-lived glacial lakes
					122	Sentinel-2	25.09.2019	10	analysis short-lived glacial lakes
					123	Sentinel-2	25.09.2019	10	analysis short-lived glacial lakes
					124	Sentinel-2	25.09.2019	10	analysis short-lived glacial lakes

Supplemental Table 1: All list of sSatellite images source datesTable 1. List of used satellite images for study

Landsat-7 and 8

ID	Satellite	Acquisition date	Resolution (m)	Lake
1	Landsat-8/OLI	12-Jun-13	15 (pan)	other short-lived glacial lakes
2	Landsat-8/OLI	19-Jun-13	15 (pan)	other short-lived glacial lakes
3	Landsat-8/OLI	5-Jul-13	15 (pan)	other short-lived glacial lakes
4	Landsat-8/OLI	28-Jul-13	15 (pan)	other short-lived glacial lakes
5	Landsat-7 ETM+/SLC-off	29-Jul-13	15 (pan)	other short-lived glacial lakes
6	Landsat-8/OLI	30-Jul-13	15 (pan)	other short-lived glacial lakes
7	Landsat-8/OLI	6-Aug-13	15 (pan)	other short-lived glacial lakes
8	Landsat-8/OLI	15-Aug-13	15 (pan)	other short-lived glacial lakes
9	Landsat-8/OLI	29-Aug-13	15 (pan)	other short-lived glacial lakes
10	Landsat-8/OLI	31-Aug-13	15 (pan)	other short-lived glacial lakes
11	Landsat-8/OLI	1-Sep-13	15 (pan)	other short-lived glacial lakes
12	Landsat-8/OLI	7-Sep-13	15 (pan)	other short-lived glacial lakes
13	Landsat-7 ETM+/SLC-off	8-Sep-13	15 (pan)	other short-lived glacial lakes
14	Landsat-8/OLI	23-Sep-13	15 (pan)	other short-lived glacial lakes
15	Landsat-7 ETM+/SLC-off	24-Sep-13	15 (pan)	other short-lived glacial lakes
16	Landsat-7 ETM+/SLC-off	1-Oct-13	15 (pan)	other short-lived glacial lakes
17	Landsat-8/OLI	9-Oct-13	15 (pan)	other short-lived glacial lakes
18	Landsat-7 ETM+/SLC-off	10-Oct-13	15 (pan)	other short-lived glacial lakes
19	Landsat-8/OLI	5-May-14	15 (pan)	other short-lived glacial lakes
20	Landsat-7 ETM+/SLC-off	29-May-14	15 (pan)	other short-lived glacial lakes
21	Landsat-7 ETM+/SLC-off	14-Jun-14	15 (pan)	other short-lived glacial lakes
22	Landsat-8/OLI	15-Jun-14	15 (pan)	other short-lived glacial lakes
23	Landsat-8/OLI	27-Jun-14	15 (pan)	other short-lived glacial lakes
24	Landsat-7 ETM+/SLC-off	30-Jun-14	15 (pan)	other short-lived glacial lakes
25	Landsat-8/OLI	1-Jul-14	15 (pan)	other short-lived glacial lakes
26	Landsat-8/OLI	8-Jul-14	15 (pan)	other short-lived glacial lakes
27	Landsat-7 ETM+/SLC-off	9-Jul-14	15 (pan)	other short-lived glacial lakes
28	Landsat-7 ETM+/SLC-off	16-Jul-14	15 (pan)	other short-lived glacial lakes
29	Landsat-7 ETM+/SLC-off	25-Jul-14	15 (pan)	other short-lived glacial lakes
30	Landsat-7 ETM+/SLC-off	1-Aug-14	15 (pan)	other short-lived glacial lakes
31	Landsat-8/OLI	2-Aug-14	15 (pan)	other short-lived glacial lakes
32	Landsat-7 ETM+/SLC-off	10-Aug-14	15 (pan)	other short-lived glacial lakes
33	Landsat-8/OLI	25-Aug-14	15 (pan)	other short-lived glacial lakes
34	Landsat-8/OLI	1-Sep-14	15 (pan)	other short-lived glacial lakes
35	Landsat-7 ETM+/SLC-off	2-Sep-14	15 (pan)	other short-lived glacial lakes
36	Landsat-8/OLI	3-Sep-14	15 (pan)	other short-lived glacial lakes
37	Landsat-8/OLI	10-Sep-14	15 (pan)	other short-lived glacial lakes
38	Landsat-7 ETM+/SLC-off	18-Sep-14	15 (pan)	other short-lived glacial lakes
39	Landsat-8/OLI	19-Sep-14	15 (pan)	other short-lived glacial lakes
40	Landsat-8/OLI	26-Sep-14	15 (pan)	other short-lived glacial lakes
41	Landsat-7 ETM+/SLC-off	17-Jun-15	15 (pan)	other short-lived glacial lakes
42	Landsat-8/OLI	18-Jun-15	15 (pan)	other short-lived glacial lakes
43	Landsat-8/OLI	2-Jul-15	15 (pan)	other short-lived glacial lakes
44	Landsat-7 ETM+/SLC-off	3-Jul-15	15 (pan)	other short-lived glacial lakes
45	Landsat-8/OLI	4-Jul-15	15 (pan)	other short-lived glacial lakes
46	Landsat-8/OLI	11-Jul-15	15 (pan)	other short-lived glacial lakes
47	Landsat-7 ETM+/SLC-off	12-Jul-15	15 (pan)	other short-lived glacial lakes
48	Landsat-8/OLI	18-Jul-15	15 (pan)	other short-lived glacial lakes
49	Landsat-8/OLI	30-Jul-15	15 (pan)	other short-lived glacial lakes
50	Landsat-8/OLI	12-Aug-15	15 (pan)	other short-lived glacial lakes
51	Landsat-8/OLI	19-Aug-15	15 (pan)	other short-lived glacial lakes
52	Landsat-7 ETM+/SLC-off	20-Aug-15	15 (pan)	other short-lived glacial lakes
53	Landsat-8/OLI	21-Aug-15	15 (pan)	other short-lived glacial lakes
54	Landsat-8/OLI	4-Sep-15	15 (pan)	other short-lived glacial lakes
55	Landsat-7 ETM+/SLC-off	5-Sep-15	15 (pan)	other short-lived glacial lakes
56	Landsat-8/OLI	6-Sep-15	15 (pan)	other short-lived glacial lakes
57	Landsat-8/OLI	13-Sep-15	15 (pan)	other short-lived glacial lakes
58	Landsat-8/OLI	29-Sep-15	15 (pan)	other short-lived glacial lakes
59	Landsat-8/OLI	8-Oct-15	15 (pan)	other short-lived glacial lakes
60	Landsat-7 ETM+/SLC-off	10-Jun-16	15 (pan)	other short-lived glacial lakes
61	Landsat-8/OLI	11-Jun-16	15 (pan)	other short-lived glacial lakes
62	Landsat-7 ETM+/SLC-off	26-Jun-16	15 (pan)	other short-lived glacial lakes
63	Landsat-8/OLI	20-Jun-16	15 (pan)	other short-lived glacial lakes
64	Landsat-7 ETM+/SLC-off	12-Jul-16	15 (pan)	other short-lived glacial lakes
65	Landsat-8/OLI	13-Jul-16	15 (pan)	other short-lived glacial lakes
66	Landsat-8/OLI	20-Jul-16	15 (pan)	other short-lived glacial lakes
67	Landsat-7 ETM+/SLC-off	21-Jul-16	15 (pan)	other short-lived glacial lakes
68	Landsat-8/OLI	22-Jul-16	15 (pan)	other short-lived glacial lakes
69	Landsat-8/OLI	29-Jul-16	15 (pan)	other short-lived glacial lakes
70	Landsat-7 ETM+/SLC-off	30-Jul-16	15 (pan)	other short-lived glacial lakes
71	Landsat-8/OLI	29-Jul-16	15 (pan)	other short-lived glacial lakes
72	Landsat-8/OLI	7-Aug-16	15 (pan)	other short-lived glacial lakes
73	Landsat-7 ETM+/SLC-off	13-Aug-16	15 (pan)	other short-lived glacial lakes
74	Landsat-8/OLI	14-Aug-16	15 (pan)	other short-lived glacial lakes
75	Landsat-8/OLI	21-Aug-16	15 (pan)	other short-lived glacial lakes
76	Landsat-7 ETM+/SLC-off	22-Aug-16	15 (pan)	other short-lived glacial lakes
77	Landsat-8/OLI	23-Aug-16	15 (pan)	other short-lived glacial lakes
78	Landsat-7 ETM+/SLC-off	7-Sep-16	15 (pan)	other short-lived glacial lakes
79	Landsat-8/OLI	8-Sep-16	15 (pan)	other short-lived glacial lakes
80	Landsat-7 ETM+/SLC-off	14-Sep-16	15 (pan)	other short-lived glacial lakes
81	Landsat-8/OLI	15-Sep-16	15 (pan)	other short-lived glacial lakes
82	Landsat-8/OLI	22-Sep-16	15 (pan)	other short-lived glacial lakes
83	Landsat-7 ETM+/SLC-off	23-Sep-16	15 (pan)	other short-lived glacial lakes
84	Landsat-8/OLI	24-Sep-16	15 (pan)	other short-lived glacial lakes
85	Landsat-8/OLI	14-Jun-17	15 (pan)	other short-lived glacial lakes
86	Landsat-8/OLI	30-Jun-17	15 (pan)	other short-lived glacial lakes
87	Landsat-8/OLI	1-Jul-17	15 (pan)	other short-lived glacial lakes
88	Landsat-8/OLI	7-Jul-17	15 (pan)	other short-lived glacial lakes
89	Landsat-8/OLI	9-Jul-17	15 (pan)	other short-lived glacial lakes
90	Landsat-8/OLI	16-Jul-17	15 (pan)	other short-lived glacial lakes
91	Landsat-8/OLI	25-Jul-17	15 (pan)	other short-lived glacial lakes
92	Landsat-8/OLI	25-Jul-17	15 (pan)	other short-lived glacial lakes
93	Landsat-8/OLI	1-Aug-17	15 (pan)	other short-lived glacial lakes
94	Landsat-8/OLI	8-Aug-17	15 (pan)	other short-lived glacial lakes
95	Landsat-8/OLI	10-Aug-17	15 (pan)	other short-lived glacial lakes
96	Landsat-8/OLI	26-Aug-17	15 (pan)	other short-lived glacial lakes
97	Landsat-8/OLI	2-Sep-17	15 (pan)	other short-lived glacial lakes
98	Landsat-7 ETM+/SLC-off	17-Sep-17	15 (pan)	other short-lived glacial lakes
99	Landsat-8/OLI	11-Oct-17	15 (pan)	other short-lived glacial lakes
100	Landsat-8/OLI	25-Jun-18	15 (pan)	other short-lived glacial lakes
101	Landsat-8/OLI	10-Jul-18	15 (pan)	other short-lived glacial lakes
102	Landsat-8/OLI	19-Jul-18	15 (pan)	other short-lived glacial lakes
103	Landsat-8/OLI	19-Jul-18	15 (pan)	other short-lived glacial lakes
104	Landsat-8/OLI	5-Sep-19	15 (pan)	other short-lived glacial lakes
105	Landsat-8/OLI	7-Aug-19	15 (pan)	other short-lived glacial lakes

Sentinel-2

ID	Satellite	Acquisition date	Resolution (m)	Lake
1	Sentinel-2	10-Jun-16	10	other short-lived glacial lakes
2	Sentinel-2	30-Jun-16	10	other short-lived glacial lakes
3	Sentinel-2	17-Jul-16	10	other short-lived glacial lakes
4	Sentinel-2	9-Aug-16	10	other short-lived glacial lakes
5	Sentinel-2	29-Aug-16	10	other short-lived glacial lakes
6	Sentinel-2	18-Sep-16	10	other short-lived glacial lakes
7	Sentinel-2	8-Oct-16	10	other short-lived glacial lakes
8	Sentinel-2	12-Jun-17	10	other short-lived glacial lakes
9	Sentinel-2	12-Jun-17	10	other short-lived glacial lakes
10	Sentinel-2	12-Jun-17	10	other short-lived glacial lakes
11	Sentinel-2	12-Jun-17	10	other short-lived glacial lakes
12	Sentinel-2	15-Jun-17	10	other short-lived glacial lakes
13	Sentinel-2	17-Jun-17	10	other short-lived glacial lakes
14	Sentinel-2	21-Jun-17	10	other short-lived glacial lakes
15	Sentinel-2	30-Jun-17	10	other short-lived glacial lakes
16	Sentinel-2	2-Jul-17	10	other short-lived glacial lakes
17	Sentinel-2	7-Jul-17	10	other short-lived glacial lakes
18	Sentinel-2	7-Jul-17	10	other short-lived glacial lakes
19	Sentinel-2	7-Jul-17	10	other short-lived glacial lakes
20	Sentinel-2	9-Jul-17	10	other short-lived glacial lakes
21	Sentinel-2	20-Jul-17	10	other short-lived glacial lakes
22	Sentinel-2	22-Jul-17	10	other short-lived glacial lakes
23	Sentinel-2	27-Jul-17	10	other short-lived glacial lakes
24	Sentinel-2	27-Jul-17	10	other short-lived glacial lakes
25	Sentinel-2	27-Jul-17	10	other short-lived glacial lakes
26	Sentinel-2	27-Jul-17	10	other short-lived glacial lakes
27	Sentinel-2	27-Jul-17	10	other short-lived glacial lakes
28	Sentinel-2	9-Aug-17	10	other short-lived glacial lakes
29	Sentinel-2	14-Aug-17	10	other short-lived glacial lakes
30	Sentinel-2	29-Aug-17	10	other short-lived glacial lakes
31	Sentinel-2	29-Aug-17	10	other short-lived glacial lakes
32	Sentinel-2	31-Aug-17	10	other short-lived glacial lakes
33	Sentinel-2	31-Aug-17	10	other short-lived glacial lakes
34	Sentinel-2	31-Aug-17	10	other short-lived glacial lakes
35	Sentinel-2	31-Aug-17	10	other short-lived glacial lakes
36	Sentinel-2	18-Sep-17	10	other short-lived glacial lakes
37	Sentinel-2	20-Sep-17	10	other short-lived glacial lakes
38	Sentinel-2	20-Sep-17	10	other short-lived glacial lakes
39	Sentinel-2	20-Sep-17	10	other short-lived glacial lakes
40	Sentinel-2	20-Sep-17	10	other short-lived glacial lakes
41	Sentinel-2	23-Sep-17	10	other short-lived glacial lakes
42	Sentinel-2	10-Oct-17	10	other short-lived glacial lakes
43	Sentinel-2	10-Jun-18	10	other short-lived glacial lakes
44	Sentinel-2	17-Jun-18	10	other short-lived glacial lakes
45	Sentinel-2	22-Jun-18	10	other short-lived glacial lakes
46	Sentinel-2	22-Jun-18	10	other short-lived glacial lakes
47	Sentinel-2	27-Jun-18	10	other short-lived glacial lakes
48	Sentinel-2	27-Jun-18	10	other short-lived glacial lakes
49	Sentinel-2	27-Jun-18	10	other short-lived glacial lakes
50	Sentinel-2	30-Jun-18	10	other short-lived glacial lakes
51	Sentinel-2	7-Jul-18	10	other short-lived glacial lakes
52	Sentinel-2	7-Jul-18	10	other short-lived glacial lakes
53	Sentinel-2	7-Jul-18	10	other short-lived glacial lakes
54	Sentinel-2	10-Jul-18	10	other short-lived glacial lakes
55	Sentinel-2	22-Jul-18	10	other short-lived glacial lakes
56	Sentinel-2	25-Jul-18	10	other short-lived glacial lakes
57	Sentinel-2	25-Jul-18	10	other short-lived glacial lakes
58	Sentinel-2	27-Jul-18	10	other short-lived glacial lakes
59	Sentinel-2	27-Jul-18	10	other short-lived glacial lakes
60	Sentinel-2	30-Jul-18	10	other short-lived glacial lakes
61	Sentinel-2	30-Jul-18	10	other short-lived glacial lakes
62	Sentinel-2	1-Aug-18	10	other short-lived glacial lakes
63	Sentinel-2	1-Aug-18	10	other short-lived glacial lakes
64	Sentinel-2	1-Aug-18	10	other short-lived glacial lakes
65	Sentinel-2	1-Aug-18	10	other short-lived glacial lakes
66	Sentinel-2	1-Aug-18	10	other short-lived glacial lakes
67	Sentinel-2	4-Aug-18	10	other short-lived glacial lakes
68	Sentinel-2	4-Aug-18	10	other short-lived glacial lakes
69	Sentinel-2	4-Aug-18	10	other short-lived glacial lakes
70	Sentinel-2	9-Aug-18	10	other short-lived glacial lakes
71	Sentinel-2	11-Aug-18	10	other short-lived glacial lakes
72	Sentinel-2	11-Aug-18	10	other short-lived glacial lakes
73	Sentinel-2	11-Aug-18	10	other short-lived glacial lakes
74	Sentinel-2	11-Aug-18	10	other short-lived glacial lakes
75	Sentinel-2	14-Aug-18	10	other short-lived glacial lakes
76	Sentinel-2	14-Aug-18	10	other short-lived glacial lakes
77	Sentinel-2	14-Aug-18	10	other short-lived glacial lakes
78	Sentinel-2	16-Aug-18	10	other short-lived glacial lakes
79	Sentinel-2	16-Aug-18	10	other short-lived glacial lakes
80	Sentinel-2	16-Aug-18	10	other short-lived glacial lakes
81	Sentinel-2	16-Aug-18	10	other short-lived glacial lakes
82	Sentinel-2	20-Aug-18	10	other short-lived glacial lakes
83	Sentinel-2	29-Aug-18	10	other short-lived glacial lakes
84	Sentinel-2	31-Aug-18	10	other short-lived glacial lakes
85	Sentinel-2	31-Aug-18	10	other short-lived glacial lakes
86	Sentinel-2	31-Aug-18	10	other short-lived glacial lakes
87	Sentinel-2	31-Aug-18	10	other short-lived glacial lakes
88	Sentinel-2	3-Sep-18	10	other short-lived glacial lakes
89	Sentinel-2	5-Sep-18	10	other short-lived glacial lakes
90	Sentinel-2	5-Sep-18	10	other short-lived glacial lakes
91	Sentinel-2	5-Sep-18	10	other short-lived glacial lakes
92	Sentinel-2	8-Sep-18	10	other short-lived glacial lakes
93	Sentinel-2	8-Sep-18	10	other short-lived glacial lakes
94	Sentinel-2	13-Sep-18	10	other short-lived glacial lakes
95	Sentinel-2	30-Sep-18	10	other short-lived glacial lakes
96	Sentinel-2	30-Sep-18	10	other short-lived glacial lakes
97	Sentinel-2	27-Jun-19	10	other short-lived glacial lakes
98	Sentinel-2	27-Jun-19	10	other short-lived glacial lakes
99	Sentinel-2	27-Jun-19	10	other short-lived glacial lakes
100	Sentinel-2	30-Jun-19	10	other short-lived glacial lakes
101	Sentinel-2	5-Jul-19	10	other short-lived glacial lakes
102	Sentinel-2	12-Jul-19	10	other short-lived glacial lakes
103	Sentinel-2	15-Jul-19	10	other short-lived glacial lakes
104	Sentinel-2	30-Jul-19	10	other short-lived glacial lakes
105	Sentinel-2	1-Aug-19	10	other short-lived glacial lakes
106	Sentinel-2	4-Aug-19	10	other short-lived glacial lakes
107	Sentinel-2	4-Aug-19	10	other short-lived glacial lakes
108	Sentinel-2	9-Aug-19	10	other short-lived glacial lakes
109	Sentinel-2	11-Aug-19	10	other short-lived glacial lakes
110	Sentinel-2	11-Aug-19	10	other short-lived glacial lakes
111	Sentinel-2	11-Aug-19	10	other short-lived glacial lakes
112	Sentinel-2	11-Aug-19	10	other short-lived glacial lakes
113	Sentinel-2	29-Aug-19	10	other short-lived glacial lakes
114	Sentinel-2	29-Aug-19	10	other short-lived glacial lakes
115	Sentinel-2	31-Aug-19	10	other short-lived glacial lakes
116	Sentinel-2	31-Aug-19	10	other short-lived glacial lakes
117	Sentinel-2	31-Aug-19	10	other short-lived glacial lakes
118	Sentinel-2	3-Sep-19	10	other short-lived glacial lakes
119	Sentinel-2	3-Sep-19	10	other short-lived glacial lakes
120	Sentinel-2	23-Sep-19	10	other short-lived glacial lakes
121	Sentinel-2	23-Sep-19	10	other short-lived glacial lakes
122	Sentinel-2	25-Sep-19	10	other short-lived glacial lakes
123	Sentinel-2	25-Sep-19	10	other short-lived glacial lakes
124	Sentinel-2	25-Sep-19	10	other short-lived glacial lakes

PlanetScope

ID	Satellite	Acquisition date	Resolution (m)	lake basin extraction
1	Planet Scope	28-Jul-13	3	analysis short-lived glacial lakes
2	Planet Scope	18-Aug-13	3	analysis short-lived glacial lakes
3	Planet Scope	27-Jun-14	3	analysis short-lived glacial lakes
4	Planet Scope	30-Jun-17	3	Korumdu lake
5	Planet Scope	15-Jul-17	3	Korumdu lake
6	Planet Scope	31-Jul-17	3	Korumdu lake
7	Planet Scope	18-Aug-17	3	Korumdu lake
8	Planet Scope	10-Jul-18	3	Korumdu lake
9	Planet Scope	27-Jul-18	3	Korumdu lake
10	Planet Scope	19-Aug-18	3	Korumdu lake
11	Planet Scope	23-Aug-18	3	Korumdu lake
12	Planet Scope	29-Aug-18	3	Korumdu lake
13	Planet Scope	30-Aug-18	3	Korumdu lake
14	Planet Scope	5-Jul-19	3	Korumdu lake
15	Planet Scope	23-Jul-19	3	Korumdu lake
16	Planet Scope	8-Aug-19	3	Korumdu lake
17	Planet Scope	12-Aug-19	3	Korumdu lake
18	Planet Scope	26-Aug-19	3	Korumdu lake

ALOS/AVNIR-2

ID	Satellite	Acquisition date	Resolution (m)	Used for…
1	ALOS/AVNIR-2	2007/9/17	2.5	lake basin extraction