Response to the anonymous reviewer 1# (RC1)

General comments:

This work intended to quantify streamflow and aquifer storage volume response to changes in glacier melt and frozen ground thaw at a branch of Lhasa River Basin on the southern TP. However, the work is mostly in a qualitative way and lacks of in-depth quantitative analysis. Therefore, the conclusions are not supported by solid analysis or materials.

Response: Many thanks for the reviews that we received with respect to our paper hess-2018-541 entitled "Quantifying streamflow and active groundwater storage in response to climate warming in an alpine catchment on the Tibetan Plateau". Those comments are all valuable and very helpful for revising and improving our paper. A major revision has been made and the manuscript has been thoroughly revised by adding more data and materials to support our conclusions solidly.

We have to say that the key factor limiting hydrological study of the TP is the availability of observations. Due to the harsh natural environmental conditions, many areas on the TP are not accessible, and in situ field measurement stations are difficult to establish and maintain (Cuo et al., 2015). Thus, in this study, we try to do a little quantitative work based on the present available data. For example, many studies show that the approach of recession flow analysis can be used for quantitative work. On the basis of Lyon et al. (2009) and Lin and Yeh. (2017), we further develop this approach by assuming nonlinearized outflow to estimate groundwater storage in autumn and early winter. Through recession flow analysis, we found that recession coefficient K and groundwater storage S in autumn and early winter increase significantly at the rates of about 7.70 ($mm^{0.79}d^{0.21}$)/10a and 19.32 mm/10a during the past 40 years.

We added some analysis and materials to confirm our conclusions.

(1) The conclusion "the increased streamflow is mainly fed by glacier meltwater". In the old version of the manuscript, we did not consider the contribution of permafrost degradation to streamflow. In the revised manuscript, we introduce the coverage of glaciers and frozen ground and the changes of hydro-meteorological data in four sub-catchments of the Lhasa River Basin to confirm this conclusion (Figure S1, S2 and S3; Table S1 and S2).

(2) The conclusion "the increase of air temperature act as a primary climatic factor for streamflow increase." In the old version of the manuscript, the conclusion is just simply based on similar increasing tendency between annual streamflow and annual air temperature, but without any further statistical analysis. In the revised manuscript, we introduce gray relational analysis between precipitation/temperature and streamflow at both annual and seasonal scales to further confirm this conclusion (Table S3).

(3) The conclusion "It is reasonable to attribute annual streamflow increase to the accelerated glacier retreat as the consequence of increasing annual air temperature." In the manuscript, we did not check if the retreat of the glacier volume can support the increase of the streamflow during the study period. In the revised manuscript, we quantify the increase rate of glacial meltwater and streamflow, and analyzed the relative area/volume glacial change at different size and elevation classes to confirm this conclusion (Figure S4 and S5).

(4) The conclusion "the increase of active groundwater storage in autumn and early winter is attributed to frozen ground degradation." In the revised manuscript, we quantify the degradation of frozen ground area extent according to the twice map of frozen ground on the

Tibetan Plateau to confirm this conclusion.

(5) We use the GRACE satellites assessing total groundwater storage changes at the catchment scale to validate the increase of groundwater storage S.

Moreover, most importantly, we can conveniently make a hypothesis that "some gradually connected underground pathways in the frozen ground driven by warming temperature have leaked huge amount of melt water from glaciers out of the Yangbajain Catchment through the fault zone. As air temperature significantly increased in autumn and winter, the degradation of frozen ground area extent manifested the increase of active layer thickness and the abundance of open vertical taliks particularly beneath fault zones, which result in the increase volume of meltwater from glaciers stored and percolating in the underground space.

The widespread distribution of hot springs and the rate of glacial volume reduction (9.46×10^7 m^3/a on average) and streamflow increase (0.33×10^7 m^3/a on average) provide the direct evidence that large amount of leakage is drained directly through the fault zone to downstream of the Yangbajain Catchment due to the great unbalance between the reduction of glacial volume and the increase of streamflow volume. Finally, isotopes results (unpublished results) also provide the evidence to confirm the subsurface leakage (private discussions with Prof. Hongbin Tan from Hohai University) (Figure S6). This also leads to the increase of groundwater storage in autumn and winter, which has been validated by the recession flow analysis and the GRACE satellites to assess total groundwater storage changes at the catchment scale (Figure S7).

In the following, we provide point-by-point response to each reviewer comment (blue texts are our responses, while black texts are original comments).

Once again, we appreciate the time you put in reading our manuscript, and the comments were valuable. My co-authors and I hope that we have adequately addressed all the review comments.

For instance, in Abstract, lines 29-30, the statement "It is believed that the increased streamflow is mainly fed by glacier meltwater, …". Firstly, there is no quantitative analysis to support this statement in the manuscript. Secondly, in research paper, every statement or conclusion must be supported by solid analysis. How can authors use words like "It is believed…"?

Response: Sorry for the uncertain conclusions. It is complex for underlying surface of the Yangbajain Catchment, including glaciers, frozen ground and fault zone, etc. According to the new map of permafrost distribution on the Tibetan Plateau (Zou et al., 2017), the coverages of permafrost and seasonally frozen ground in Lhasa, Pangdo and Tangga sub-catchments are comparable to that in the Yangbajain Catchment; but the coverage of glaciers in the three catchments is far lower than that in the Yangbajain Catchment according to the First Chinese Glacier Inventory (Mi et al., 2002) (Figure S1, Table S1).

The MK test showed that, in all four catchments, the annual mean air temperature had significant increases at the 1% significance level (Figure S2) while the annual precipitation showed non-significant trends (Table S2).The annual streamflow of the three Lhasa, Pangdo and Tangga Catchments all had non-significant trends, while the annual streamflow of Yangbajain Catchment showed an increasing trend at the 5% significance level with a mean rate of about 12.30 mm/10a during the period (Figure S3).

Ye et al. (1999) also stated that when glacier coverage is greater than 5%, glacier contribution to streamflow starts to show up. This indicates that, in the Yangbajain Catchment, the increased streamflow is mainly fed by glacier meltwater rather than frozen ground degradation.

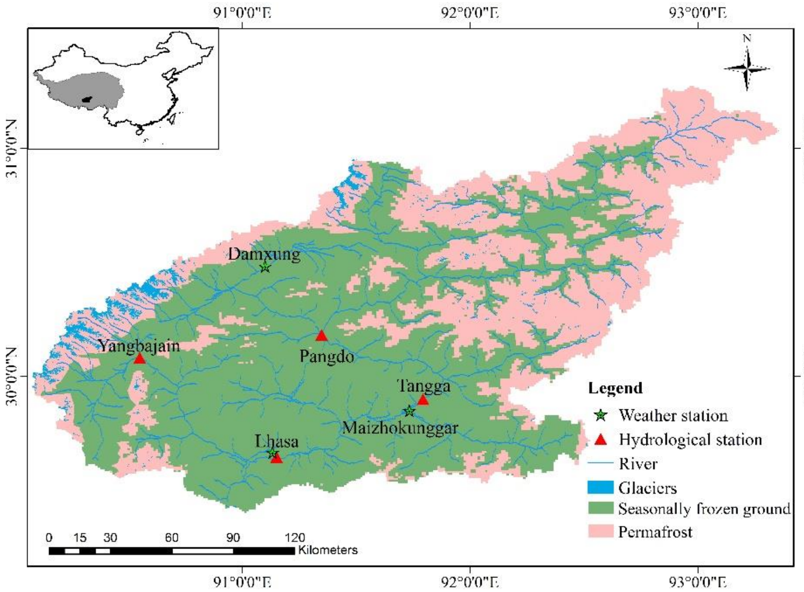


Figure S1. The distribution of glaciers and frozen ground in the Lhasa River Basin.

Table S1. The coverage of glaciers and frozen ground in four catchments of the Lhasa River Basin

Stations	Area (km^2)	Coverage (%)		
		Glaciers	Permafrost	Seasonally frozen ground
Lhasa	26233	1.3	37	63
Pangdo	16425	2.1	50	50
Tangga	20152	1.7	47	53
Yangbajain	2645	12.0	36	64

Table S2. Mann-Kendall trend test with trend-free pre-whitening of annual mean air temperature (°C), precipitation (mm) and streamflow (mm) in four catchments of the Lhasa River Basin

	Air temperature		Precipitation		Streamflow	
	Z_C	β (°C/a)	Z_C	β (mm/a)	Z_C	β (mm/a)
Lhasa	6.07**	0.028	1.16	1.581	1.09	1.420
Pangdo	6.19**	0.026	0.89	1.435	0.30	0.223
Tangga	7.35**	0.021	1.48	2.005	-0.62	-0.531
Yangbajain	4.48**	0.028	1.28	2.541	2.07*	1.230

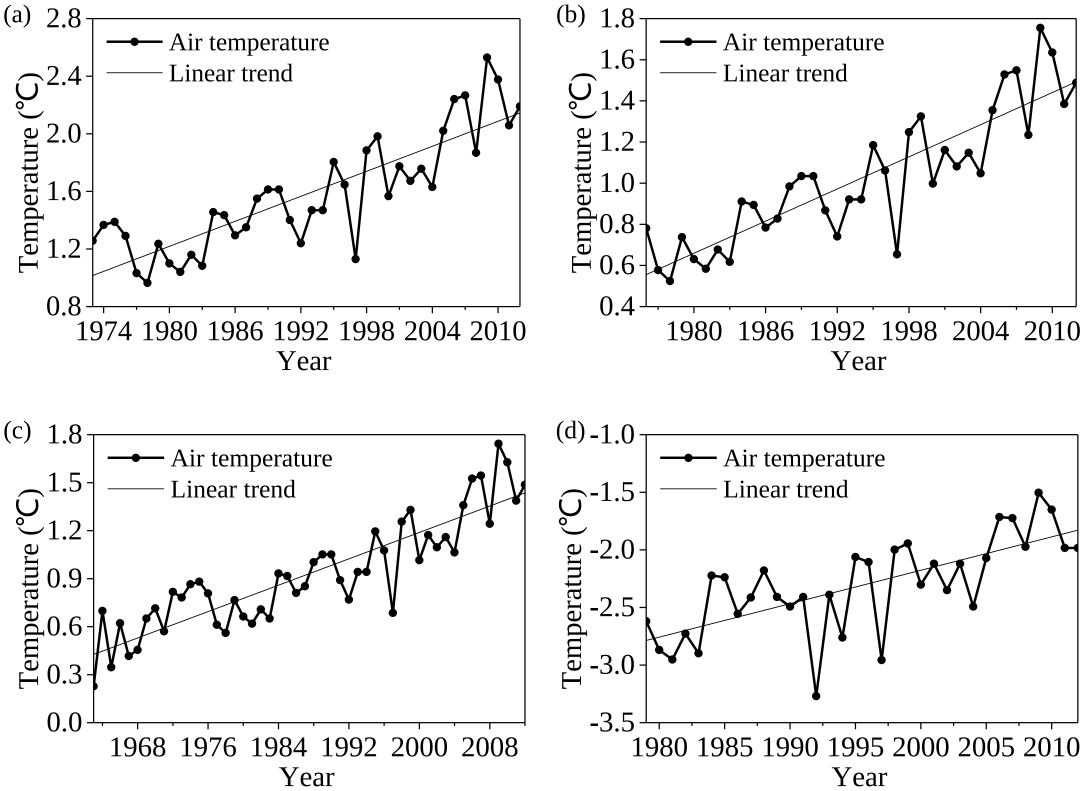


Figure S2. Variations of annual mean air temperature in four catchments of the Lhasa River Basin (a: Lhasa; b: Pangdo; c: Tangga; d: Yangbajain).

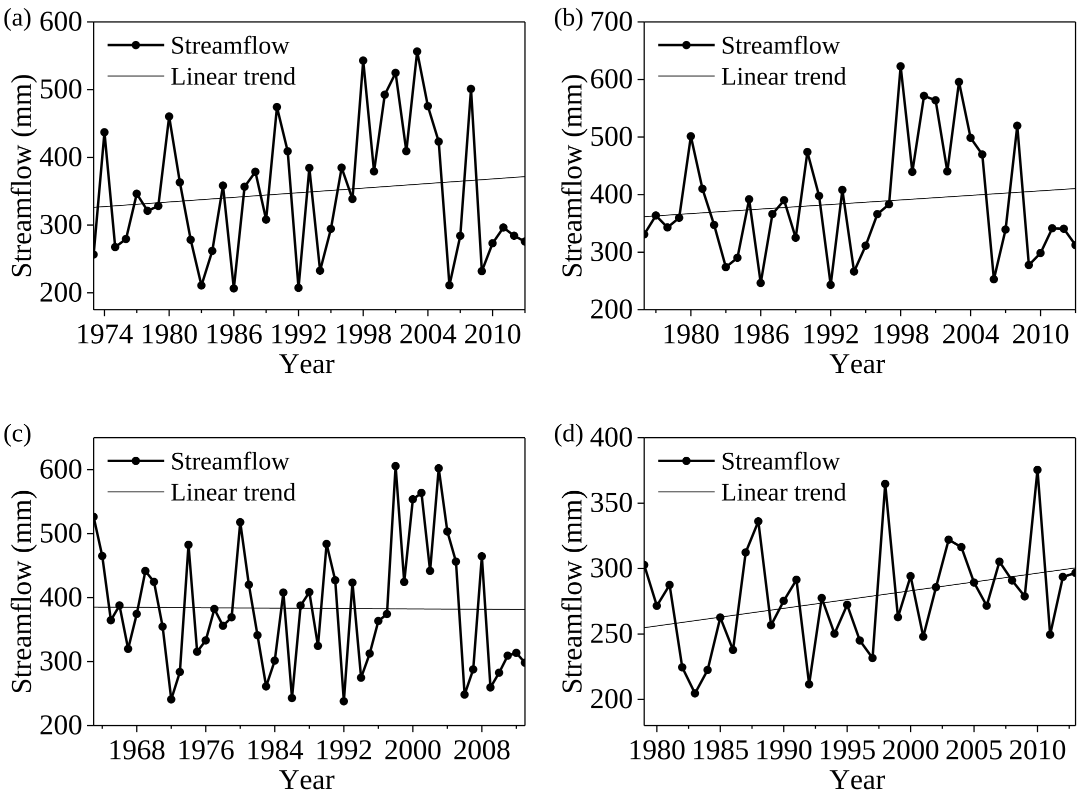


Figure S3. Variations of annual streamflow in four catchments of the Lhasa River Basin (a: Lhasa; b: Pangdo; c: Tangga; d: Yangbajain).

Furthermore, gray relational analysis (see the response of specific comments 2**)** is applied to the catchment with significant increasing annual streamflow to identify the major climatic factors for the streamflow. The result shows that the air temperature has the higher gray relational grade at annual scale (Table S3). This indicates that the air temperature acts as a primary factor for the increased streamflow. According to the Chinese Glacier Inventories, the reduction rate of glacial volume is 9.46×10^7 m^3/a on average during the past 50 years. Compared to the rate of streamflow increase of 0.33×10^7 m^3/a on average, the glacial meltwater is sufficient enough to meet the demand of increased streamflow volume. It is reasonable to attribute annual streamflow increase to the accelerated glacier retreat as the consequence of increasing annual air temperature. So we make it clearer that "It is concluded that the increased streamflow is mainly fed by glacier meltwater" in Abstract.

The same issues exist everywhere in the text, other examples are, the sentences in Lines 36-42 are mostly qualitative descriptions or deductions instead of solid conclusions. Sentence like "Thus, it is reasonable to attribute the increase of baseflow and the slowdown of baseflow recession process in autumn and early winter to the enlargement of groundwater storage capacity."

Response: Sorry for the uncertain conclusions. According to the twice map of frozen ground distribution on the TP (Li and Cheng, 1996; Zou et al., 2017), the areal extent of permafrost in the catchment has decreased by 442 km^2 (16%) over the past 22 years; the corresponding areal extent of seasonal frozen ground has increased by 449 km^2 (16%) with the degradation of permafrost. Our hypothesis is that increased groundwater storage S in autumn and early winter is associated with frozen ground degradation, which leads to the enlargement of groundwater storage capacity (Niu et al., 2016). The accelerated glacier retreat supplies large quantities of glacial meltwater as water source to recharge groundwater. Through recession flow analysis, we find that active groundwater storage in autumn and early winter increases significantly at a rate of about 19.32 mm/10a over the period 1979-2013. The increase of groundwater storage allows more groundwater discharge into streams as baseflow (Walvoord and Striegl, 2007; Lyon and Destouni, 2010) and lengthens the time scale of the baseflow recession indicated by recession coefficient K (Niu et al., 2016; Lin and Yeh, 2017). This leads to increased baseflow and slow baseflow recession in autumn and early winter. In the late winter and spring, the increase of baseflow can be explained by the delayed release of increased groundwater storage. So we make it clearer that "The increase of active groundwater storage is caused by frozen ground degradation, which lead to the enlargement of the storage capacity that can accommodate summer rainfall and increasing meltwater in the valley, which is slowly released into streams in subsequent seasons. Thus, the increase of baseflow and the slowdown of baseflow recession in autumn and early winter are attributed to the increase of groundwater storage." in Abstract.

Specific comments:

1. Section 2.3.2. Baseflow separation:

It is not clear to me, if the baseflow separation in Fig.4b and Fig.7 are calculated by equations (6)-(7)

Response: Yes, the baseflow separation in Fig.4b and Fig.7 are calculated by equations (6)-(7).

2. Section 3.1. Variation of annual streamflow and its components

The authors conclude that the changes of air temperature may act as a primary climatic factor for streamflow increase simply based on similar increasing tendency between annual streamflow and annual air temperature, but without any further statistical analysis. I would suggest at least a correlation analysis between precipitation/temperature and streamflow at both annual and seasonal scales.

Response: Thanks for the nice suggestions. We used gray relational analysis to investigate the main stress factors for the total streamflow and the baseflow. Gray relational analysis was originally proposed to detect the primary relationship among various factors and was developed to find the major climatic or hydrological factors that influenced an objective variable (Liu et al., 2005; Wang et al., 2013).

Suppose the time series of objective variable are designated as $\{X_0(t)\}$ (t is the time step and $t = 1, 2, . . . m$), for instance, the annual baseflow or streamflow series; and the time series of influence variable i are designated as $\{X_i(t)\}$ ($i = 1, 2, . . . n$; $t = 1, 2, . . . m$), for instance, the annual precipitation and air temperature time series. To remove the differences in the units and scales of $\{X_i(t)\}$, the variable time series are first normalized as

$$X_{n_i}(t) = \frac{X_i(t)}{\overline{X_i}}$$

$$\overline{X_i} = \frac{1}{m}\sum_{t=1}^{m} X_i(t)$$

where $Xn_i(t)$ is the normalized time series of the influence variable i. At the time step t, the gray relational coefficient is expressed as

$$\delta_{oi}(t) = \frac{\min_i\left(\min_t(\Delta_{oi}(t))\right) + \rho\max_i(\max_t((\Delta_{oi}(t)))}{\Delta_{oi}(t) + \rho\max_i(\max_t((\Delta_{oi}(t)))}$$

$$\Delta_{oi}(t) = \left|X_0(t) - X_{n_i}(t)\right|$$

where $\delta_{oi}(t)$ is the gray relational coefficient between $\{X_i(t)\}$ and $\{X_0(t)\}$ and ρ is an adjustable parameter and is assigned as 0.5 in this study (Wang et al., 2013). Finally, the gray relational grade is used to describe the average degree of correlation between $\{X_i(t)\}$ and $\{X_0(t)\}$ and is expressed as

$$G_{oi} = \frac{1}{m}\sum_{t=1}^{m} \delta_{oi}(t)$$

where G_{oi} is the gray relational grade between $\{X_i(t)\}$ and $\{X_0(t)\}$.The importance of each influence factor can therefore be determined by the order of the gray relational grade values. The influence factor with the largest G_{oi} is regarded as the main stress factor for the objective variable.

Table S3 shows the gray relational grades between the total streamflow and precipitation and air temperature and gray relational grades between the baseflow and these factors. The results show that the air temperature has the higher gray relational grades at both annual and seasonal scales. These results implied that the air temperature was the primary factor for the changes in baseflow and total streamflow in all seasons and the whole year. Therefore, the increase in baseflow and total streamflow in the Yangbajain Catchment was mainly caused by an increase in air temperature.

Table S3. Gray relational grades between the baseflow/streamflow and climate factors (precipitation and air temperature) in the Yangbajain Catchment at both annual and seasonal scales. Bold text shows the higher gray relational grade in each season.

`	Gray relational grades with the total streamflow		Gray relational grades with the baseflow	
	Precipitation	Air temperature	Precipitation	Air temperature
Spring	0.690	**0.778**	0.713	**0.789**
Summer	0.689	**0.784**	0.680	**0.776**
Autumn	0.653	**0.667**	0.648	**0.680**
Winter	0.742	**0.886**	0.748	**0.895**
Annual	0.675	**0.727**	0.665	**0.729**

The statement "…, it is reasonable to attribute annual streamflow increase to the accelerated glacier retreat as the consequence of increasing annual air temperature." (Lines 286-288) is also too arbitrary and lack of more analysis to support. One quick way to check is to see if the lost of the glacier mass can support the increase of the streamfow during the study period.

Response: Thanks for the nice suggestions. According to the glacier distribution of the twice Chinese Glacier Inventories (Figure S4), the retreat rate of glacial volume is 9.46×10^{7} m^{3}/a on average during the period 1960-2009. Compared to the rate of streamflow increase of 0.33×10^{7} m^{3}/a on average, the glacial meltwater is sufficient enough to meet the demand of increased streamflow volume.

The total glacial area and volume have decreased by 38.06 km^{2} (12.0%) and 0.47×10^{10} m^{3} (26.2%) respectively over the past 50 years. Furthermore, the relative area/volume change (the changes between 1960 and 2009) against the initial glacial area/volume (in 1960) at different size and elevation classes were analyzed (Figure S5 and S6).

Figure S5 indicated greater relative loss for larger glaciers (glaciers in the size classes≥3 km^{2}). There was also a large relative loss for glaciers in the size classes 1~2 km^{2}. Glaciers in the size classes 2~3 km^{2} and ＜1.0 km^{2} did not shrink but increased, considering that the increased glaciers on the two scales are caused by the shrinkage of larger glaciers (glaciers in the size classes 1~2 km^{2} and ≥3 km^{2}) into smaller glaciers.

Glaciers with lower median elevation (<5900 m) tended to lose relatively more area and volume than higher elevation (>5900 m) glaciers (Figure S6). The highest absolute loss occured between 5800 and 5900 m and the highest relative loss for glacier retreat occured elevations below 5600 m. The average minimum elevation of the glaciers rose about 100 m from 5571 to 5686 m (Figure S6).

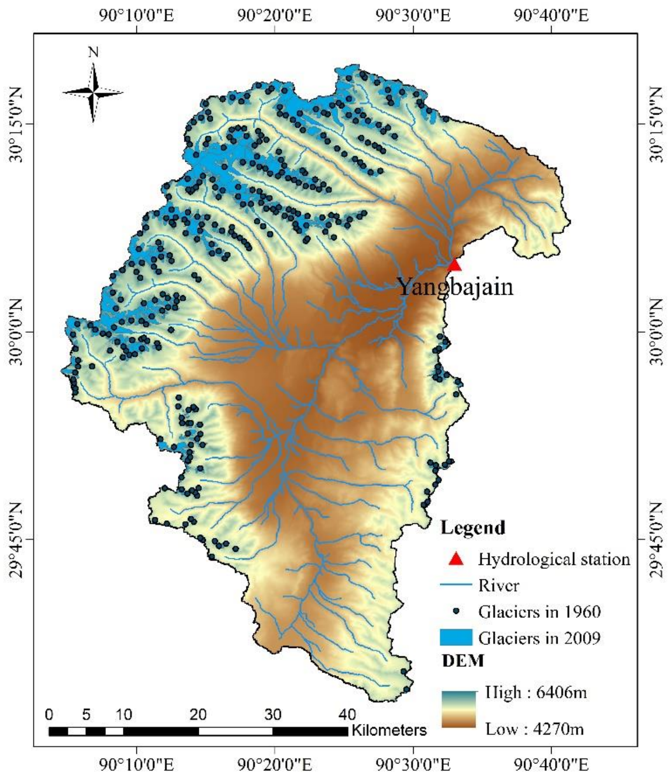


Figure S4. The distribution of glacier in 1960 and 2009 in the Yangbajain Catchment

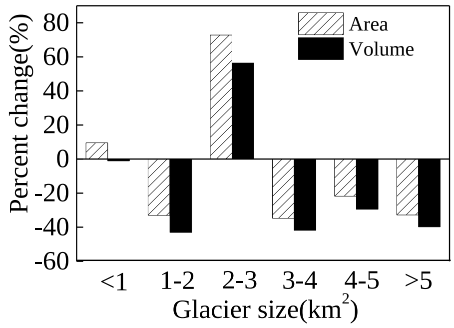
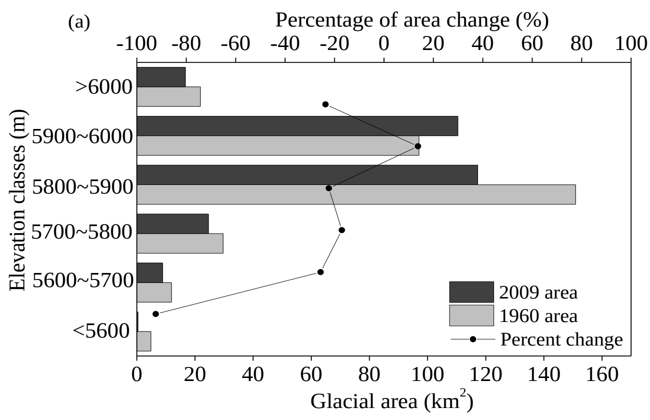


Figure S5. Analysis of the relative area and volume change against the initial glacial area and volume at different size classes in the catchment.



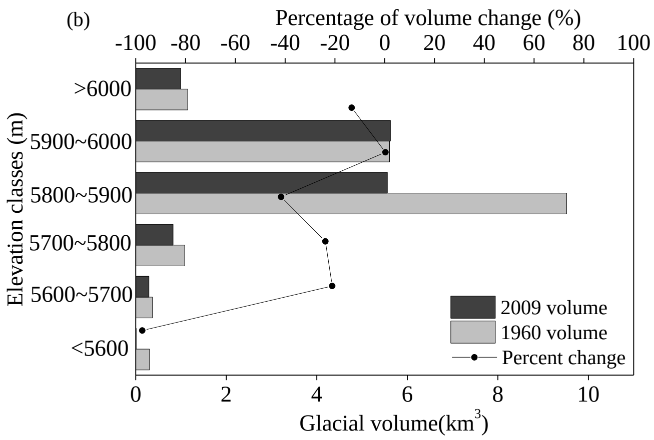


Figure S6. Analysis of the relative (a) area and (b) volume change against the initial glacial area and volume at different elevation classes in the catchment.

The above analysis indicates that the significant increasing air temperature induce the accelerated glacier retreat, which supplies adequate meltwater to streamflow. So we make it clear that "It is reasonable to attribute annual streamflow increase to the accelerated glacier retreat as the consequence of increasing annual air temperature." Detailed the information of the twice Chinese Glacier Inventories see the Appendix.

"It can be further concluded that streamflow is recharged by the increased meltwater from the accelerated glacier retreat which may be partly stored in soil and aquifers in the wide and flat valley (Figure 1b), and subsequently discharge into streams as baseflow." (Lines 300-303) These are all just deductions or hypothesis without validations.

Response: Sorry for the uncertain conclusions. As air temperature significantly increased in autumn and winter at the rate of 0.4°/10a, the degradation of frozen ground area extent manifested the corresponding increase of active layer thickness and the abundance of open vertical taliks, particularly beneath water bodies and fault zones, during the past two decades (Walvoord and Kurylyk, 2016). The thicker active layer and more open vertical taliks result in the shift in meltwater from accelerated glacier retreat to soil- and groundwater, and the movement of subsurface water. The rate of glacial volume reduction (9.46×10^7 m^3/a on average) and streamflow increase (0.33×10^7 m^3/a on average) provides a quantitative argument that the catchment water loss via glacial meltwater is significantly more than direct water increase via streamflow. Prof. Tan believed that a large-scale of stretching tensile active tectonic belt (deep fault) have been developed along nearly south-north orientation through Yangbajain Catchment during the Tibetan Plateau uplift and geological evolution (Figure S6). As a half graben system, the fault has a strongly active status to accommodate the east-west extension of the Tibetan Plateau by the ductile normal fault (Cogan et al., 1998), which provides the access for groundwater flow as manifested by the widespread distribution of hot springs (Jiang et al., 2016). These kinds of faults can be acted as good conduits, which the large quantity of glacial meltwater can vertically infiltrate and recharge groundwater through the conduits in the foreland of glaciers in southern slope of Nyainqêntanglha Mountains (private discussions with Prof. Hongbin Tan from Hohai University).

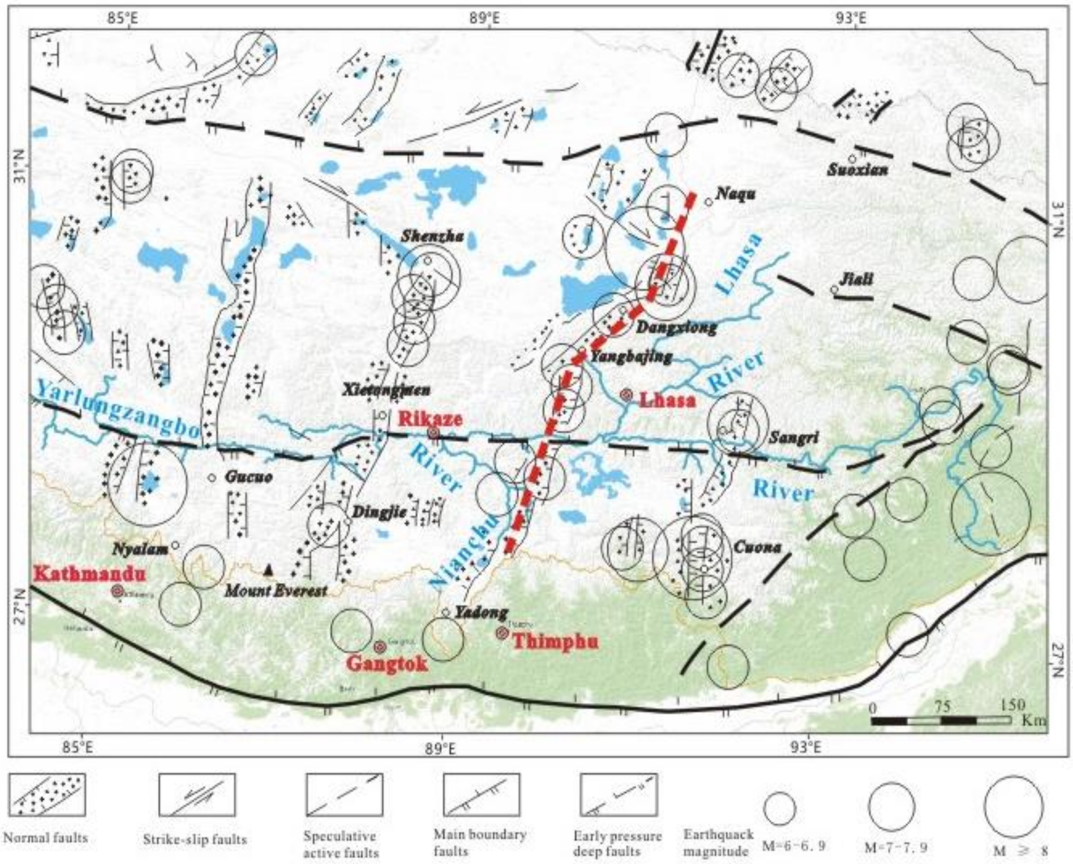


Figure S6. Stretching tensile active tectonic belt (deep fault) through the Yangbajain Catchment (Prof. Hongbin Tan from Hohai University)

In the catchment, the streamflow coefficient (*R/P*) is about 0.67 on average during the period 1979-2013. The annual evaporation increase (estimated to be around 0.16×10^{7} m^3/a) is considerably small comparing to the reduction rate of glacial volume (9.46×10^{7} m^3/a). The considerable water imbalance (estimated to be around 8.96×10^{7} m^3/a) provides the evidence that the subsurface leakage from the Yangbajain Catchment through the fault zone is likely. And isotopes results (unpublished results) also provide the evidence to confirm the subsurface leakage (private discussions with Prof. Hongbin Tan from Hohai University). Our results imply that more than 90% of glacial meltwater would be lost by subsurface leakage, with the consideration of a minor increase in streamflow and evaporation. Only less than 10% of glacial meltwater contributes to the increase in streamflow. This is consistent with the results of Prasch et al. (2013), which quantified glacier meltwater contributes to max. 11% of the streamflow in the Yangbajain Catchment.

According to the baseflow separation method described above, overall, the annual mean baseflow contributes about 59% of the annual mean streamflow in the catchment. The MK test shows that annual baseflow exhibits a significant increasing trend at the 1% level with a mean rate of about 10.95 mm/10a over the period 1979-2013. The trend is statistically nonsignificant for annual quickflow during the period. The increasing trends between the baseflow and streamflow are very close, indicating that the increase in baseflow is the main contributor to streamflow increase.

So we make it clear that “It can be further concluded that only less than 10% of glacial meltwater contributes to the increase in streamflow, which would be stored in aquifers in the valley, and subsequently discharge into streams as baseflow".

3. Section 4. Conclusions

"Moreover, the increase of active groundwater storage in autumn and early winter can partly be attributed to the enlargement of groundwater storage capacity by frozen ground degradation, which can provide storage spaces for increased glacial meltwater." (Lines 404-406). This statement is not supported by solid analysis or materials.

Response: Sorry for the uncertain conclusions. We quantified the degradation of frozen ground area extent which could manifest the corresponding increase of active layer thickness. The distribution and classification of frozen ground are collected from the map of frozen ground on the Tibetan Plateau (Li and Cheng, 1996) and a new map of permafrost distribution on the Tibetan Plateau (Zou et al., 2017). The areal extent of permafrost in the catchment has decreased by 442 km^2 (16%) over the past 22 years; the corresponding areal extent of seasonal frozen ground has increased by 449 km^2 (16%) with the degradation of permafrost. Our hypothesis is that increased groundwater storage S in autumn and early winter is associated with frozen ground degradation, which leads to the increase active layer thickness and the enlargement of groundwater storage capacity (Niu et al., 2016). According to the Chinese Glacier Inventories, the retreat rate of glacial volume is 9.46×10^7 m^3/a on average during the period 1960-2009 compared to the rate of streamflow increase of 0.33×10^7 m^3/a on average, which the glacial meltwater is sufficient enough to meet the demand of increased streamflow volume.

Through recession flow analysis, we find that active groundwater storage in autumn and early winter increases significantly at a rate of about 19.32 mm/10a over the period 1979-2013. The increase of groundwater storage allows more groundwater discharge into streams as baseflow (Walvoord and Striegl, 2007; Lyon and Destouni, 2010) and lengthens the time scale of the baseflow recession indicated by recession coefficient K (Niu et al., 2016; Lin and Yeh, 2017). This leads to increased baseflow and slow baseflow recession in autumn and early winter. So we make it clearer that "Moreover, the increase of active groundwater storage in autumn and early winter can be attributed to frozen ground degradation, which would enlarge groundwater storage capacity providing storage spaces for increased glacial meltwater. This can explain why baseflow volume increases and baseflow recession slows down in autumn and early winter."

In summary, this manuscript needs more solid quantitative analysis or materials to support the statements on the impacts of glacier or frozen ground degradation on streamflow changes. At least some statistical correlation analyses are needed, e.g., between P/T and streamfow/baseflow, and between P/T and groundwater storage S. Validations for S changes (e.g., well observations or other ways) would be appreciated.

Response: Thanks for your nice suggestions. We added gray relational analysis between precipitation/temperature and streamflow at both annual and seasonal scales (see the response of Specific comments 2). There is no well observations in the Yangbajain Catchment.

Remote sensing and earth observation technologies provide an important means of collecting groundwater-related data on a regional scale and to assess the state of the resource, which in turn allows for predictions of the possible responses of groundwater resources to climate change.

Satellite remote sensing has drawbacks, but it offers the advantages of global coverage, availability of data, metadata, error statistics, and the ability to provide meaningful spatial averages (Green et al., 2011). The most valuable remote sensing technology for groundwater investigations is high-precision satellite gravimetry, as enabled by the NASA/GFZ Gravity Recovery and Climate Experiment (GRACE)-a satellite gravimetry technology that may be used to assess groundwater storage changes (Green et al., 2011).

Since its launch in 2002, the GRACE satellites have been employed to detect tiny temporal changes in the gravity field of the Earth (Ramillien et al., 2008). Temporal changes in measured gravity are primarily caused by changes in total water (mass) storage (TWS), such as solid water in glaciers, liquid water in lakes/rivers, soil layer and subsurface of the continents. GRACE is being used to generate time series of terrestrial water variations (Tapley et al., 2004), which can be used to assess groundwater storage changes. For example, Rodell et al. (2007) developed time series of groundwater storage variations averaged over the Mississippi River basin and its four major sub-basins using in situ data, and used these to verify GRACE-based estimates in which snow water equivalent fields output from a sophisticated land surface model were used to isolate groundwater from the GRACE terrestrial water storage data.

Data

GRACE Data

For this study, terrestrial water storage (TWS) were anomalies relative to the 2004.01-2009.12 time-mean baseline based on the RL05 spherical harmonics from CSR (at 0.5° resolution), covering the period January 2003 to December 2015. The download data source is https://grace.jpl.nasa.gov/data/get-data/monthly-mass-grids-land/.

Soil Moisture and Snow Water Equivalent

The Global Land Data Assimilation System (GLDAS) provides global, high-resolution, near-real-time land surface states (e.g., soil moisture and snow water equivalent) and fluxes by integrating satellite- and ground-based observations (Rodell et al., 2004). GLDAS drives four land surface models: Mosaic, Noah, the Community Land Model, and the Variable Infiltration Capacity (VIC). In this study, the monthly Soil Moisture (SM) and Snow Water Equivalent (SWE) was based on the Noah model (at 0.25° resolution) from the period January 2003 to December 2015. The download data source is https://hydro1.gesdisc.eosdis.nasa.gov/data/GLDAS/GLDAS_NOAH025_M.2.1/.

Method

The non-negligible sources of terrestrial water storage mass variability in the valley of the Yangbajain Catchment were assumed herein to be groundwater, soil moisture, and snow. Due to no glacier coverage in the valley of the catchment, glacier ice (ICE) can be neglected. Thus, given GRACE-based estimates of terrestrial water storage (TWS) and numerically modeled soil moisture (SM) and snow water equivalent (SWE), groundwater storage (GWS) were computed as

$$\mathrm{GWS} = \mathrm{TWS} - (\mathrm{SWE} + \mathrm{SM})$$

Results

Figures S7 display the groundwater estimates during the autumn and early winter for the valley of the catchment. The MK test shows that the groundwater storage estimated from GRACE has a significant increasing trend at the rate of 8.47 mm/a. The correlation coefficient between GRACE results and the determination of active groundwater storage based on recession flow analysis is 0.67, which shows that the results of recession flow analysis is reliable.

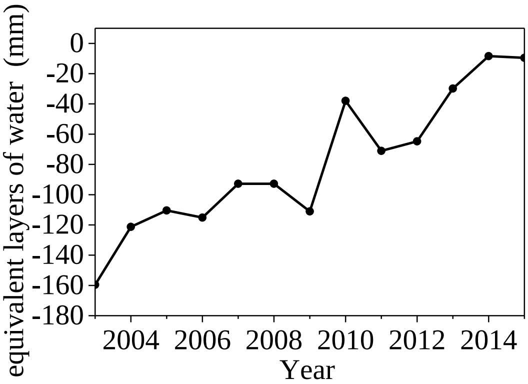


Figure S7. Groundwater storage estimated from GRACE during the autumn and early winter (from September to December), presented as equivalent layers of water (mm) averaged over the valley of the Yangbajain Catchment.

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Appendix

Table S4. The distribution, area and volume of glaciers in 1960 in the Yangbajain Catchment (Mi et al., 2002)

No	Glacial name	Longitude	Latitude	Area (km^2)	Volume (km^3)	Mean Elevation(m)	No	Glacial name	Longitude	Latitude	Area (km^2)	Volume (km^3)	Mean Elevation(m)
1		90.492	29.570	0.4	0.0092	5646	161		90.261	30.129	0.6	0.0204	5760
2		90.489	29.591	0.11	0.0014	5640	162		90.211	30.129	0.4	0.0092	5903
3		90.257	29.730	0.7	0.0252	5617	163		90.245	30.129	0.5	0.016	5933
4		90.286	29.739	0.5	0.016	5692	164		90.358	30.130	0.4	0.0092	5869
5		90.266	29.742	0.13	0.0018	5650	165		90.228	30.131	0.3	0.006	5963
6		90.275	29.745	0.8	0.0304	5650	166		90.209	30.132	0.07	0.0007	5975
7		90.261	29.748	0.5	0.016	5630	167		90.410	30.132	0.18	0.0029	5900
8		90.246	29.750	0.16	0.0024	5590	168		90.312	30.133	0.07	0.0007	5758
9		90.243	29.752	0.11	0.0014	5600	169		90.224	30.135	0.3	0.006	5995
10		90.225	29.769	0.07	0.0007	5620	170		90.424	30.135	1.6	0.08	5903
11		90.203	29.769	0.4	0.0092	5679	171		90.203	30.137	1.2	0.054	5881
12		90.236	29.772	0.09	0.0011	5660	172		90.353	30.137	0.5	0.016	5825
13		90.189	29.773	0.5	0.016	5575	173		90.178	30.137	0.9	0.036	5901
14		90.232	29.775	0.13	0.0018	5630	174		90.214	30.138	0.3	0.006	6028
15		90.513	29.792	0.11	0.0014	5610	175		90.390	30.138	0.9	0.036	5736
16		90.517	29.796	0.11	0.0014	5670	176		90.251	30.138	0.9	0.036	5780
17		90.240	29.803	0.17	0.0026	5650	177		90.435	30.139	0.7	0.0252	5779
18		90.228	29.805	0.12	0.0016	5747	178		90.240	30.139	1.4	0.0672	5865
19		90.237	29.807	0.05	0.0005	5804	179		90.407	30.139	0.4	0.0092	5649
20		90.517	29.808	0.05	0.0005	5660	180		90.373	30.139	1.5	0.0735	5800
21		90.233	29.809	0.6	0.0204	5677	181		90.345	30.140	0.5	0.016	5825

22		90.221	29.811	1	0.042	5702	182		90.401	30.140	0.4	0.0092	5641
23		90.201	29.812	0.4	0.0092	5733	183		90.361	30.142	0.5	0.016	5767
24		90.241	29.812	0.13	0.0018	5670	184		90.191	30.143	2.1	0.1155	5866
25		90.527	29.816	0.03	0.0002	5640	185		90.441	30.143	0.5	0.016	5738
26		90.531	29.822	0.05	0.0005	5645	186		90.228	30.144	1.6	0.08	5865
27		90.221	29.825	0.7	0.0252	5706	187		90.334	30.145	0.5	0.016	5900
28		90.527	29.833	0.05	0.0005	5683	188		90.356	30.145	0.4	0.0092	5775
29		90.243	29.836	1	0.042	5700	189		90.209	30.147	3.1	0.1953	5841
30		90.527	29.840	0.7	0.0252	5655	190		90.350	30.148	0.17	0.0026	5917
31		90.538	29.840	0.5	0.016	5640	191		90.331	30.148	0.05	0.0005	5934
32		90.521	29.843	0.2	0.0034	5650	192		90.323	30.148	0.6	0.0204	5907
33		90.543	29.844	0.3	0.006	5669	193		90.338	30.150	1.6	0.08	5854
34		90.229	29.845	1.2	0.054	5790	194		90.295	30.154	0.8	0.0304	5840
35		90.228	29.845	0.3	0.006	5749	195		90.304	30.154	3.58	0.2399	5850
36		90.231	29.849	0.13	0.0018	5770	196		90.317	30.155	0.5	0.016	5915
37		90.231	29.855	1.5	0.0735	5825	197		90.327	30.161	0.6	0.0204	5830
38		90.212	29.861	3.4	0.221	5805	198		90.265	30.162	0.07	0.0007	5910
39		90.232	29.864	0.4	0.0092	5770	199		90.205	30.163	0.4	0.0092	5820
40		90.246	29.864	0.8	0.0304	5730	200		90.289	30.163	0.5	0.016	6034
41		90.195	29.871	0.08	0.0009	5580	201		90.319	30.163	1.1	0.0473	5830
42		90.240	29.871	0.9	0.036	5791	202		90.232	30.169	0.05	0.0005	5940
43		90.244	29.877	0.4	0.0092	5790	203		90.315	30.169	0.5	0.016	5850
44		90.228	29.878	1.5	0.0735	5779	204		90.270	30.170	1.7	0.0867	5906
45		90.243	29.889	0.32	0.0067	5690	205		90.306	30.171	0.7	0.0252	5868
46		90.222	29.890	0.18	0.0029	5867	206		90.398	30.171	0.7	0.0252	5885

47		90.229	29.890	0.13	0.0018	5780	207		90.234	30.171	0.08	0.0009	5990
48		90.232	29.890	1.2	0.054	5745	208		90.229	30.171	0.2	0.0034	5890
49		90.221	29.897	0.4	0.0092	5749	209		90.386	30.172	0.5	0.016	5990
50		90.229	29.906	0.7	0.0252	5685	210		90.238	30.174	0.5	0.016	5900
51		90.238	29.907	0.25	0.0045	5718	211		90.261	30.174	1.7	0.0867	5908
52		90.235	29.910	0.08	0.0009	5700	212		90.289	30.174	3.5	0.231	5887
53		90.217	29.910	0.16	0.0024	5715	213		90.379	30.174	0.3	0.006	6073
54		90.218	29.921	0.05	0.0005	5725	214		90.203	30.175	1.7	0.0867	5821
55		90.552	29.925	0.11	0.0014	5630	215		90.370	30.176	0.7	0.0252	5962
56		90.093	29.927	0.3	0.006	5820	216		90.392	30.177	1	0.042	5940
57		90.093	29.932	0.28	0.0053	5800	217		90.362	30.180	0.7	0.0252	5893
58		90.091	29.939	0.13	0.0018	5897	218		90.242	30.180	0.8	0.0304	5900
59		90.554	29.940	0.9	0.036	5739	219		90.356	30.183	0.3	0.006	5983
60		90.090	29.943	0.19	0.003	5780	220		90.258	30.183	0.5	0.016	5920
61		90.532	29.943	0.19	0.003	5860	221		90.382	30.183	1.7	0.0867	5953
62		90.527	29.945	0.23	0.0041	5860	222	Lengqing	90.228	30.184	3.6	0.2412	5875
63		90.540	29.948	0.77	0.0293	5830	223		90.349	30.185	0.4	0.0092	5953
64	Pagele	90.093	29.951	2.05	0.1128	5835	224		90.337	30.188	0.17	0.0026	5886
65		90.530	29.952	1.1	0.0473	5709	225		90.246	30.188	2.9	0.1798	5872
66		90.530	29.958	0.4	0.0092	5770	226		90.328	30.191	0.2	0.0034	5940
67		90.096	29.958	0.21	0.0036	5813	227		90.370	30.191	0.09	0.0011	5938
68		90.113	29.959	0.04	0.0003	5850	228		90.342	30.192	4.3	0.3053	5938
69		90.096	29.966	1.7	0.0867	5690	229		90.449	30.192	1.4	0.0672	5757
70		90.150	29.969	0.13	0.0018	5761	230		90.460	30.194	0.18	0.0029	5867
71		90.158	29.972	1.4	0.0672	5900	231		90.367	30.194	1.4	0.0672	5840

72		90.165	29.973	0.3	0.006	5843	232		90.322	30.197	0.3	0.006	6122
73		90.154	29.977	0.5	0.016	5980	233		90.272	30.199	14.69	1.5865	5882
74		90.526	29.977	0.08	0.0009	5780	234		90.315	30.199	0.9	0.036	6064
75		90.135	29.977	0.11	0.0014	5770	235		90.440	30.200	0.22	0.0037	5788
76		90.093	29.980	0.3	0.006	5910	236		90.345	30.200	0.1	0.0012	5958
77		90.173	29.980	2.1	0.1155	5903	237		90.307	30.203	0.7	0.0252	5960
78		90.531	29.980	0.3	0.006	5760	238		90.436	30.204	0.3	0.006	5800
79		90.193	29.981	0.4	0.0092	5857	239	Guila	90.295	30.204	0.9	0.036	5970
80		90.151	29.982	0.14	0.002	5900	240		90.341	30.207	1.4	0.0672	5888
81		90.191	29.986	0.23	0.0041	5790	241		90.430	30.208	0.5	0.016	5730
82		90.539	29.988	0.96	0.0394	5748	242	Lisheng	90.311	30.211	4.4	0.3168	5924
83		90.144	29.988	1.95	0.1053	5850	243	Guren	90.239	30.213	5.6	0.4356	5830
84		90.180	29.989	0.6	0.0204	5790	244		90.417	30.214	0.19	0.003	5860
85		90.161	29.990	1.5	0.0735	5940	245		90.338	30.217	0.4	0.0092	5802
86		90.172	29.991	0.3	0.006	5815	246		90.464	30.218	0.23	0.0041	5690
87		90.176	29.993	0.07	0.0007	5720	247		90.408	30.221	0.4	0.0092	5898
88		90.532	29.994	0.28	0.0053	5730	248		90.459	30.221	0.13	0.0018	5766
89		90.090	29.997	1.7	0.0867	5924	249		90.272	30.222	4.5	0.324	5909
90		90.133	29.997	0.5	0.016	5880	250		90.309	30.224	1.2	0.054	6092
91		90.126	29.998	0.6	0.0204	5890	251		90.454	30.224	0.07	0.0007	5885
92		90.208	30.002	0.29	0.0058	5820	252		90.231	30.226	0.3	0.006	5900
93		90.117	30.003	1.7	0.0867	5925	253		90.250	30.226	0.6	0.0204	5880
94	Jiagezong	90.139	30.005	6.1	0.488	5893	254		90.445	30.228	0.8	0.0304	5800
95		90.111	30.008	1.5	0.0735	5935	255		90.315	30.229	0.8	0.0304	5945
96		90.178	30.009	0.08	0.0009	6013	256		90.397	30.229	0.4	0.0092	5980

97	Gaerbu	90.095	30.009	3.5	0.231	5850	257		90.283	30.230	0.23	0.0041	6008
98		90.149	30.012	0.04	0.0003	6173	258		90.323	30.231	0.2	0.0034	5800
99		90.172	30.013	1.1	0.0473	5922	259		90.228	30.232	0.5	0.016	5890
100		90.160	30.014	1.2	0.054	6013	260		90.253	30.232	0.3	0.006	5845
101		90.185	30.019	3	0.189	5886	261		90.438	30.233	0.27	0.0051	5845
102		90.198	30.026	1.7	0.0867	5873	262		90.279	30.235	0.04	0.0003	6050
103	Ninong	90.142	30.028	6.9	0.5796	5894	263		90.478	30.235	0.7	0.0252	5773
104		90.213	30.029	1	0.042	5850	264		90.299	30.236	3.6	0.2412	5942
105		90.204	30.030	0.1	0.0012	5980	265		90.317	30.236	0.4	0.0092	5881
106		90.176	30.034	0.6	0.0204	5879	266		90.392	30.236	1	0.042	5868
107		90.215	30.037	0.9	0.036	5868	267		90.464	30.241	0.12	0.0016	5992
108		90.189	30.038	1.3	0.0598	5873	268		90.313	30.241	0.21	0.0036	5835
109		90.147	30.039	0.1	0.0012	6085	269		90.367	30.243	0.07	0.0007	5970
110		90.222	30.041	0.14	0.002	5828	270		90.281	30.243	1	0.042	6901
111		90.204	30.041	0.8	0.0304	5875	271		90.296	30.245	0.04	0.0003	5840
112		90.215	30.044	0.16	0.0024	5828	272		90.229	30.245	0.4	0.0092	5850
113		90.198	30.045	0.14	0.002	5877	273		90.289	30.245	0.13	0.0018	5800
114		90.138	30.047	3.08	0.194	5960	274		90.470	30.246	0.6	0.0304	5885
115		90.241	30.063	0.14	0.002	5770	275		90.458	30.249	1.8	0.0936	5829
116		90.171	30.065	0.4	0.0092	5922	276		90.361	30.249	0.3	0.006	5944
117		90.138	30.067	1.6	0.08	5932	277		90.236	30.252	0.7	0.0252	5853
118		90.236	30.068	0.28	0.0053	5758	278		90.431	30.254	0.3	0.006	6025
119		90.166	30.072	0.18	0.0029	6011	279		90.446	30.254	1.6	0.08	5895
120		90.193	30.073	0.6	0.0204	5874	280		90.355	30.255	0.4	0.0092	5970
121		90.150	30.074	0.9	0.036	5960	281		90.540	30.256	0.6	0.0204	5820

122		90.187	30.078	0.22	0.0037	5976	282		90.255	30.256	0.08	0.0009	5850
123		90.161	30.082	1.3	0.0598	5976	283		90.244	30.258	1.7	0.0867	5840
124		90.173	30.083	1.6	0.08	5953	284		90.440	30.260	0.9	0.036	5848
125		90.209	30.085	0.3	0.006	5875	285		90.346	30.261	0.8	0.0304	5980
126		90.188	30.087	1.2	0.054	5940	286		90.422	30.261	1.7	0.0867	5939
127		90.273	30.088	0.4	0.0092	5839	287		90.397	30.262	0.3	0.006	6012
128		90.196	30.090	0.9	0.036	6003	288		90.339	30.262	0.2	0.0034	6000
129		90.207	30.092	0.7	0.0252	5820	289	Boda	90.363	30.263	9.7	0.9118	5892
130		90.276	30.093	0.2	0.0034	5725	290		90.392	30.264	0.09	0.0011	6104
131		90.257	30.095	0.6	0.0204	5883	291		90.253	30.264	0.5	0.016	5820
132		90.266	30.097	1.3	0.0598	5802	292		90.433	30.266	1.3	0.0598	5909
133	Dongnong	90.169	30.099	5.84	0.4614	5874	293		90.519	30.266	2.8	0.1708	5803
134		90.196	30.100	1.53	0.075	5883	294		90.383	30.268	2.4	0.1392	6108
135		90.302	30.101	0.09	0.0011	5680	295		90.339	30.270	2.1	0.1155	5958
136		90.300	30.105	0.05	0.0005	5700	296		90.414	30.272	0.3	0.006	5989
137		90.257	30.106	1.6	0.08	5847	297		90.510	30.273	0.7	0.0252	6000
138		90.193	30.108	0.15	0.0023	6000	298	Qingga	90.403	30.273	6.7	0.5561	5953
139		90.296	30.109	0.05	0.0005	5660	299	Bilie	90.250	30.275	1.4	0.0672	5855
140		90.371	30.109	0.13	0.0018	5828	300		90.410	30.275	0.12	0.0016	5928
141		90.240	30.112	0.4	0.0092	5967	301		90.473	30.275	0.4	0.0092	5980
142		90.373	30.112	0.3	0.006	5653	302		90.507	30.277	0.38	0.0084	6150
143		90.291	30.113	0.3	0.006	5740	303		90.293	30.277	0.6	0.0204	5800
144		90.404	30.114	0.7	0.0252	5602	304		90.270	30.280	0.2	0.0034	5910
145		90.285	30.116	0.09	0.0011	5780	305		90.423	30.280	3.53	0.233	5949
146		90.328	30.118	0.11	0.0014	5735	306		90.471	30.282	0.4	0.0092	5980

147		90.171	30.118	0.6	0.0204	5963	307		90.282	30.282	2.4	0.1392	5859
148		90.226	30.119	0.2	0.0034	5952	308		90.300	30.284	2.1	0.1155	5878
149		90.281	30.120	0.6	0.0204	5769	309		90.504	30.286	2	0.108	6010
150		90.394	30.121	0.3	0.006	5735	310		90.487	30.288	5.69	0.4438	6062
151		90.363	30.122	0.22	0.0037	5790	311		90.325	30.289	0.05	0.0005	5884
152		90.243	30.122	4.1	0.287	5436	312		90.345	30.290	5.8	0.4582	5954
153		90.270	30.122	0.9	0.036	5788	313		90.469	30.291	2.4	0.1392	6000
154		90.359	30.125	0.25	0.0045	5890	314		90.329	30.293	0.13	0.0018	5965
155		90.178	30.125	0.9	0.036	5863	315		90.314	30.297	1.9	0.1007	5939
156		90.281	30.126	0.06	0.0006	5760	316		90.457	30.300	1.8	0.0936	5918
157		90.319	30.127	0.14	0.002	5753	317		90.422	30.305	8.18	0.728	5950
158		90.421	30.128	0.7	0.0252	5800	318	Langbu	90.442	30.306	0.6	0.0204	5853
159		90.371	30.128	3.5	0.231	5811	319		90.439	30.310	0.9	0.036	5995
160		90.398	30.129	2.3	0.1311	5733							

Table S5. The distribution, area and volume of glaciers in 2009 in the Yangbajain Catchment
(See the Second China Glacier Inventory http://westdc.westgis.ac.cn/)

No	Glacial name	Longitude	Latitude	Area (km^2)	Volume (km^3)	Mean Elevation(m)	No	Glacial name	Longitude	Latitude	Area (km^2)	Volume (km^3)	Mean Elevation(m)
1		90.082	29.939	0.31	0.0073	5810	213		90.285	29.738	0.01	0.0001	5849
2		90.083	29.934	0.34	0.0083	5872	214		90.286	30.243	0.05	0.0005	5947
3		90.183	29.769	0.01	0.0001	5667	215		90.287	30.245	0.03	0.0002	5907
4		90.183	29.801	0.03	0.0003	5719	216		90.288	30.161	0.26	0.0056	6006
5		90.197	29.858	0.02	0.0001	5866	217		90.288	30.175	2.95	0.1615	5923

6		90.209	29.812	0.21	0.0041	5643	218		90.288	30.112	0.03	0.0003	5817
7		90.210	29.851	1.15	0.0442	5772	219		90.289	30.239	1.18	0.0460	5950
8		90.252	29.730	0.03	0.0002	5675	220		90.290	30.243	0.02	0.0001	5858
9		90.480	29.556	0.10	0.0014	5678	221		90.291	30.110	0.02	0.0002	5802
10		90.087	29.971	0.03	0.0003	5834	222		90.293	30.277	0.48	0.0135	5839
11	Pagele	90.087	29.952	1.06	0.0398	5666	223		90.293	30.154	0.66	0.0207	5953
12	Pagele	90.088	29.947	0.02	0.0002	5830	224		90.294	30.206	0.76	0.0252	5980
13		90.088	29.996	1.26	0.0502	5956	225		90.295	30.244	0.02	0.0002	5868
14		90.089	29.986	0.02	0.0002	6026	226		90.295	30.108	0.05	0.0006	5749
15		90.090	29.939	0.10	0.0015	5921	227		90.299	30.284	1.32	0.0537	5815
16		90.091	29.933	0.03	0.0003	5793	228		90.299	30.232	1.68	0.0745	5952
17	Gaerbu	90.092	30.011	2.75	0.1470	5906	229		90.300	30.146	0.18	0.0034	5858
18		90.092	29.980	0.19	0.0038	5895	230		90.300	30.100	0.01	0.0001	5746
19		90.092	29.927	0.15	0.0027	5807	231		90.301	30.157	2.13	0.1029	5862
20		90.093	29.987	0.22	0.0045	5919	232		90.304	30.171	0.66	0.0205	5906
21		90.093	29.966	1.32	0.0536	5744	233		90.304	30.203	0.96	0.0343	5986
22		90.095	29.958	0.17	0.0032	5792	234		90.306	30.223	0.88	0.0306	6025
23		90.108	30.006	0.74	0.0241	5927	235		90.306	30.163	0.02	0.0001	6041
24		90.112	29.958	0.03	0.0002	5797	236		90.308	30.159	0.28	0.0063	5914
25		90.116	30.004	1.84	0.0842	5934	237	Lisheng	90.310	30.210	2.79	0.1493	5957
26		90.125	29.999	0.44	0.0117	5916	238		90.312	30.231	0.15	0.0026	5976
27		90.131	30.052	0.39	0.0100	5940	239		90.312	30.242	0.12	0.0019	5828
28		90.132	29.997	0.57	0.0168	5897	240		90.313	30.167	0.66	0.0207	5878
29		90.133	29.976	0.07	0.0009	5900	241		90.313	30.236	0.11	0.0018	5833
30	Jiagezong	90.133	30.011	5.07	0.3403	5852	242		90.314	30.226	0.14	0.0024	5878

31		90.137	30.048	0.66	0.0205	5837	243		90.314	30.199	0.77	0.0255	5965
32		90.137	30.068	1.31	0.0528	5975	244		90.314	30.296	1.58	0.0685	5929
33		90.138	29.991	0.34	0.0084	5836	245		90.315	30.155	0.32	0.0076	5881
34	Ninong	90.142	30.030	6.30	0.4585	5951	246		90.317	30.234	0.01	0.0001	5942
35		90.147	30.039	0.09	0.0014	6037	247		90.317	30.126	0.10	0.0016	5749
36		90.147	30.043	0.27	0.0061	5855	248		90.320	30.164	0.55	0.0159	5841
37	Jiagezong	90.147	29.995	0.18	0.0035	5956	249		90.320	30.197	0.34	0.0082	6028
38		90.148	30.012	0.04	0.0004	6224	250		90.321	30.232	0.08	0.0010	5833
39		90.148	29.987	0.93	0.0332	5870	251		90.322	30.149	0.49	0.0139	5912
40		90.148	30.076	0.76	0.0251	5984	252		90.323	30.159	0.41	0.0107	5880
41		90.149	29.973	0.06	0.0008	5882	253		90.324	30.289	0.01	0.0001	5934
42		90.149	29.982	0.03	0.0003	5812	254		90.325	30.115	0.01	0.0001	5873
43		90.150	29.970	0.03	0.0003	5923	255		90.326	30.192	0.14	0.0026	5968
44		90.152	29.977	0.19	0.0038	5905	256	Lisheng	90.327	30.208	0.70	0.0223	5927
45		90.155	29.991	0.28	0.0064	5860	257		90.328	30.293	0.07	0.0010	5963
46		90.157	29.972	1.16	0.0449	5915	258		90.328	30.160	0.21	0.0043	5817
47		90.158	30.082	0.86	0.0296	5972	259		90.331	30.148	0.13	0.0021	5972
48		90.160	30.015	0.93	0.0330	5907	260		90.334	30.145	0.33	0.0078	5873
49		90.161	30.115	0.06	0.0008	6059	261		90.334	30.187	0.13	0.0023	5995
50		90.162	29.985	0.43	0.0116	5973	262		90.336	30.209	0.19	0.0037	5921
51		90.164	29.973	0.10	0.0016	5781	263		90.336	30.299	1.40	0.0577	5945
52		90.165	30.070	0.04	0.0004	5967	264		90.337	30.151	0.81	0.0273	5865
53		90.165	29.991	0.02	0.0002	5792	265		90.337	30.206	0.96	0.0343	5946
54		90.166	30.097	4.33	0.2739	5917	266		90.338	30.271	1.23	0.0488	5943
55		90.169	30.065	0.21	0.0042	5822	267		90.338	30.219	0.35	0.0086	5900

56		90.170	30.118	0.46	0.0124	5917	268		90.339	30.193	3.59	0.2119	5946
57		90.171	30.014	0.85	0.0292	5912	269		90.342	30.147	0.35	0.0088	5843
58		90.171	30.084	1.17	0.0455	5924	270		90.344	30.140	0.39	0.0099	5847
59		90.171	29.989	0.15	0.0026	5968	271		90.344	30.260	0.59	0.0177	6027
60		90.172	29.979	1.71	0.0764	5868	272		90.347	30.289	2.29	0.1139	5937
61		90.173	30.033	0.67	0.0212	5891	273		90.348	30.297	0.69	0.0218	5936
62		90.174	29.992	0.04	0.0005	5856	274		90.348	30.185	0.23	0.0047	5907
63		90.175	30.130	0.21	0.0042	5873	275		90.349	30.148	0.12	0.0020	5845
64		90.177	30.124	0.37	0.0093	5846	276		90.352	30.136	0.47	0.0128	5856
65		90.177	30.136	0.80	0.0267	5923	277		90.353	30.145	0.27	0.0061	5813
66		90.178	30.018	0.11	0.0018	6008	278		90.355	30.183	0.07	0.0010	5872
67		90.179	29.987	0.29	0.0065	5811	279		90.356	30.191	0.27	0.0060	5999
68		90.179	30.015	0.10	0.0015	5936	280		90.357	30.130	0.34	0.0083	5926
69		90.183	30.088	1.00	0.0365	5970	281		90.358	30.125	0.20	0.0041	5863
70		90.183	30.017	2.14	0.1036	5900	282		90.359	30.250	0.31	0.0072	5994
71		90.183	30.101	0.25	0.0054	5963	283		90.360	30.181	0.57	0.0170	5920
72		90.184	30.079	0.25	0.0056	5972	284		90.360	30.142	0.33	0.0080	5834
73		90.186	30.036	0.87	0.0303	5883	285	Boda	90.361	30.264	9.37	0.7912	6013
74		90.187	29.772	0.04	0.0005	5579	286		90.362	30.121	0.11	0.0017	5843
75		90.190	29.984	0.09	0.0014	5878	287		90.365	30.195	1.09	0.0413	5819
76		90.190	30.142	2.11	0.1021	5896	288		90.366	30.181	0.06	0.0007	6100
77		90.191	30.106	0.10	0.0015	6022	289		90.368	30.243	0.03	0.0003	6027
78		90.192	29.982	0.46	0.0125	5849	290		90.368	30.176	0.38	0.0098	5888
79		90.192	30.071	0.41	0.0107	5929	291		90.369	30.138	0.69	0.0219	5851
80		90.192	30.092	1.24	0.0491	5983	292		90.369	30.109	0.12	0.0019	5841

81		90.193	30.101	0.94	0.0336	5884	293	Boda	90.370	30.246	0.21	0.0042	6012
82		90.194	30.036	0.27	0.0059	5966	294		90.370	30.112	0.13	0.0021	5717
83		90.195	30.024	1.21	0.0477	5859	295		90.371	30.127	2.50	0.1283	5856
84		90.197	30.045	0.13	0.0022	5877	296		90.373	30.192	0.06	0.0008	5919
85		90.197	29.813	0.06	0.0007	5751	297		90.378	30.184	1.15	0.0445	5886
86		90.198	29.864	0.97	0.0351	5686	298		90.379	30.176	0.06	0.0007	6139
87		90.199	30.018	0.13	0.0023	5837	299	Boda	90.379	30.242	1.25	0.0497	5908
88		90.200	29.810	0.07	0.0010	5693	300		90.384	30.128	0.32	0.0077	5860
89		90.201	30.031	0.02	0.0002	6023	301		90.384	30.172	0.24	0.0051	6014
90		90.201	30.100	0.03	0.0003	5943	302		90.385	30.263	0.69	0.0219	5900
91		90.202	30.093	0.52	0.0149	5870	303		90.387	30.183	0.07	0.0010	5776
92		90.202	30.175	1.53	0.0657	5845	304		90.388	30.137	0.65	0.0203	5742
93		90.202	30.039	0.76	0.0251	5855	305		90.389	30.177	0.15	0.0027	5817
94		90.203	30.135	0.89	0.0311	5891	306		90.390	30.236	0.64	0.0199	5878
95		90.203	30.030	0.07	0.0009	6004	307		90.390	30.171	0.02	0.0002	6109
96		90.203	30.089	0.12	0.0019	5984	308		90.391	30.264	0.11	0.0016	6079
97		90.204	30.086	0.03	0.0003	6039	309		90.391	30.130	0.38	0.0095	5830
98		90.205	30.164	0.29	0.0067	5840	310		90.393	30.120	0.12	0.0019	5740
99		90.205	30.002	0.05	0.0006	5826	311		90.395	30.131	0.37	0.0093	5725
100		90.205	29.768	0.08	0.0010	5781	312		90.396	30.233	0.24	0.0050	5995
101		90.208	30.131	0.08	0.0011	5990	313		90.396	30.263	0.25	0.0055	6001
102		90.208	30.084	0.04	0.0005	5885	314		90.397	30.140	0.03	0.0003	5728
103		90.208	30.000	0.05	0.0007	5875	315	Qingga	90.397	30.273	5.91	0.4202	5879
104		90.208	30.147	2.93	0.1599	5860	316		90.398	30.170	0.36	0.0089	5753
105		90.210	30.130	0.38	0.0097	5933	317		90.399	30.113	0.07	0.0010	5726

106		90.212	30.029	0.74	0.0240	5908	318		90.400	30.139	0.14	0.0025	5701
107		90.212	30.038	0.52	0.0150	5906	319		90.401	30.134	0.27	0.0060	5809
108		90.214	30.044	0.09	0.0013	5852	320		90.405	30.222	0.08	0.0012	5961
109		90.215	29.862	1.56	0.0670	5774	321		90.410	30.275	0.11	0.0018	5940
110		90.216	29.910	0.05	0.0006	5743	322		90.411	30.218	0.05	0.0005	5810
111		90.217	30.136	0.10	0.0015	6008	323		90.412	30.305	0.06	0.0008	5965
112		90.219	29.920	0.02	0.0002	5809	324		90.413	30.272	0.21	0.0043	5977
113		90.220	29.890	0.14	0.0023	5883	325		90.414	30.133	0.07	0.0010	6038
114		90.220	29.896	0.27	0.0059	5717	326		90.415	30.297	1.93	0.0903	5906
115		90.220	29.809	0.63	0.0192	5682	327		90.416	30.303	0.05	0.0006	5882
116		90.220	29.823	0.37	0.0091	5703	328		90.416	30.213	0.17	0.0032	5846
117		90.221	29.873	0.27	0.0060	5833	329		90.418	30.283	2.97	0.1633	5872
118		90.222	30.134	0.16	0.0031	5931	330		90.419	30.127	0.48	0.0134	5740
119		90.223	29.905	0.04	0.0004	5795	331		90.419	30.134	0.11	0.0017	5776
120		90.223	30.189	0.06	0.0007	5990	332		90.420	30.131	0.13	0.0022	5686
121		90.224	29.767	0.01	0.0001	5704	333		90.420	30.263	0.85	0.0290	6014
122		90.226	29.804	0.03	0.0002	5813	334		90.422	30.310	3.40	0.1965	5932
123		90.226	30.131	0.27	0.0061	5969	335		90.423	30.138	0.37	0.0093	5884
124		90.226	30.120	0.03	0.0003	6062	336		90.425	30.207	0.17	0.0032	5865
125		90.227	30.142	1.41	0.0585	5853	337		90.425	30.258	0.58	0.0174	5946
126	Lengqing	90.227	30.184	3.10	0.1727	5886	338		90.430	30.289	0.18	0.0034	5858
127		90.227	29.845	0.63	0.0194	5708	339		90.430	30.254	0.16	0.0028	5884
128		90.227	30.232	0.20	0.0041	5878	340		90.430	30.205	0.11	0.0017	5756
129		90.228	30.228	0.05	0.0006	6003	341		90.431	30.140	0.42	0.0110	5746
130		90.228	30.171	0.21	0.0043	5953	342		90.433	30.251	0.06	0.0008	6111

131		90.228	29.898	0.07	0.0009	5783	343		90.433	30.266	0.45	0.0121	5909
132		90.229	29.891	0.07	0.0010	5698	344		90.434	30.310	0.30	0.0068	5889
133		90.229	29.835	0.27	0.0060	5726	345		90.435	30.201	0.19	0.0036	5867
134		90.229	29.855	0.90	0.0315	5727	346		90.435	30.234	0.22	0.0045	5899
135		90.229	29.905	0.25	0.0054	5687	347		90.437	30.144	0.18	0.0034	5688
136		90.229	30.245	0.30	0.0070	5838	348		90.438	30.230	0.16	0.0029	5885
137		90.229	30.226	0.20	0.0041	5919	349		90.438	30.267	0.28	0.0065	5834
138		90.230	29.849	0.11	0.0017	5790	350		90.438	30.260	0.45	0.0122	5940
139		90.230	29.808	0.27	0.0059	5705	351		90.439	30.140	0.06	0.0008	5803
140		90.230	30.169	0.05	0.0006	5930	352	Langbu	90.441	30.308	0.66	0.0207	5938
141		90.231	29.878	0.79	0.0262	5783	353		90.443	30.254	0.99	0.0359	5852
142		90.231	29.888	0.52	0.0149	5739	354		90.445	30.228	0.17	0.0032	5749
143		90.231	29.863	0.28	0.0063	5752	355		90.447	30.193	1.33	0.0542	5784
144		90.231	29.773	0.02	0.0002	5747	356		90.450	30.226	0.04	0.0004	5928
145		90.232	30.140	0.12	0.0021	5918	357		90.451	30.306	0.61	0.0185	5960
146		90.233	30.252	0.55	0.0160	5810	358		90.452	30.225	0.04	0.0004	5938
147		90.233	29.851	0.02	0.0002	5836	359		90.453	30.250	1.22	0.0479	5819
148		90.234	29.909	0.02	0.0002	5757	360		90.458	30.221	0.09	0.0013	5807
149		90.234	30.067	0.12	0.0019	5726	361		90.458	30.301	0.73	0.0238	5958
150		90.235	29.905	0.11	0.0018	5819	362		90.462	30.192	0.11	0.0018	5829
151		90.235	29.810	0.17	0.0032	5713	363		90.463	30.217	0.09	0.0014	5674
152	Guren	90.236	30.214	5.02	0.3351	5871	364		90.464	30.241	0.02	0.0001	6005
153		90.236	30.174	0.44	0.0120	5902	365		90.466	30.294	1.84	0.0844	5919
154		90.236	29.806	0.03	0.0003	5784	366		90.467	30.246	0.21	0.0044	5803
155		90.237	30.177	0.19	0.0037	5974	367		90.469	30.282	0.14	0.0024	5925

156		90.237	30.139	0.96	0.0345	5854	368		90.470	30.250	0.03	0.0003	5881
157		90.238	29.871	0.39	0.0099	5762	369		90.473	30.275	0.40	0.0103	5936
158		90.238	30.111	0.18	0.0034	5892	370		90.478	30.234	0.53	0.0153	5802
159		90.239	29.831	0.08	0.0011	5766	371		90.479	30.283	0.13	0.0023	5900
160		90.240	30.063	0.03	0.0003	5772	372		90.481	30.277	0.73	0.0236	5913
161		90.240	30.181	0.46	0.0127	5914	373		90.484	30.290	2.94	0.1609	5930
162		90.241	29.876	0.10	0.0016	5708	374		90.490	29.566	0.08	0.0011	5706
163		90.242	29.811	0.02	0.0001	5767	375		90.494	29.570	0.05	0.0006	5702
164		90.242	30.121	3.13	0.1751	5852	376		90.500	30.292	0.46	0.0126	6014
165		90.242	29.888	0.24	0.0052	5743	377		90.503	30.292	0.04	0.0005	6048
166		90.242	30.258	1.40	0.0581	5835	378		90.506	30.278	0.31	0.0073	6108
167		90.243	29.834	0.58	0.0171	5684	379		90.508	30.287	0.71	0.0228	5960
168		90.244	30.130	0.41	0.0108	5914	380		90.510	30.273	0.41	0.0108	6052
169		90.245	30.138	0.18	0.0034	5878	381		90.512	29.791	0.04	0.0004	5668
170		90.246	30.190	2.49	0.1279	5918	382		90.516	29.794	0.05	0.0006	5781
171		90.247	30.113	0.24	0.0051	5864	383		90.519	29.841	0.05	0.0005	5743
172		90.247	29.864	0.46	0.0125	5749	384		90.519	30.269	2.56	0.1328	5829
173	Lilie	90.249	30.274	1.12	0.0424	5826	385		90.526	29.839	0.49	0.0138	5695
174	Guren	90.250	30.220	0.15	0.0028	5921	386		90.527	29.945	0.15	0.0027	5857
175		90.250	30.226	0.36	0.0089	5887	387		90.529	29.951	1.01	0.0371	5892
176		90.250	30.138	0.38	0.0095	5771	388		90.529	29.958	0.35	0.0085	5797
177		90.251	30.264	0.41	0.0106	5827	389		90.530	29.978	0.09	0.0014	5893
178		90.252	30.232	0.07	0.0009	5948	390		90.530	29.834	0.03	0.0003	5735
179		90.254	30.257	0.05	0.0006	5858	391		90.532	29.942	0.11	0.0017	5755
180		90.255	30.094	0.29	0.0066	5845	392		90.533	29.995	0.12	0.0019	5741

181		90.256	30.105	1.30	0.0521	5851	393		90.534	29.979	0.06	0.0008	6026
182		90.256	29.729	0.13	0.0021	5652	394		90.535	30.254	0.11	0.0017	5902
183		90.256	30.189	0.21	0.0042	5997	395		90.537	29.839	0.24	0.0051	5667
184		90.258	29.729	0.01	0.0001	5587	396		90.537	29.944	0.14	0.0024	5716
185		90.259	30.185	0.44	0.0118	5924	397		90.537	29.996	0.15	0.0026	5749
186		90.260	30.166	0.14	0.0023	5875	398		90.537	29.986	0.74	0.0243	5795
187		90.260	29.748	0.32	0.0075	5595	399		90.538	29.961	2.16	0.1054	5686
188		90.261	30.174	0.85	0.0293	5969	400		90.538	30.256	0.31	0.0074	5711
189		90.261	30.128	0.49	0.0135	5805	401		90.539	29.950	0.12	0.0019	5869
190	Guila	90.264	30.208	13.12	1.2571	5924	402		90.542	29.836	0.08	0.0011	5770
191		90.265	30.097	1.20	0.0467	5817	403		90.543	29.843	0.25	0.0056	5681
192		90.266	30.162	0.05	0.0006	5913	404		90.543	29.952	0.12	0.0019	5946
193		90.266	30.123	0.16	0.0029	5821	405		90.543	29.856	0.11	0.0017	5705
194		90.268	29.742	0.15	0.0027	5687	406		90.547	29.839	0.24	0.0052	5694
195		90.268	30.220	3.57	0.2097	5928	407		90.550	29.945	0.06	0.0008	5694
196		90.269	30.281	0.11	0.0017	5942	408		90.552	29.939	0.55	0.0160	5682
197		90.270	30.171	1.33	0.0541	5981	409		90.446	30.323	3.74	0.2237	5867
198		90.271	29.745	0.07	0.0009	5684	410		90.469	30.315	4.50	0.2891	5904
199		90.271	30.088	0.15	0.0027	5780	411		90.516	30.295	2.10	0.1013	5898
200		90.271	30.120	0.28	0.0062	5784	412		90.527	30.274	4.70	0.3066	5900
201		90.274	29.744	0.13	0.0022	5687	413		90.363	30.297	1.00	0.0367	5854
202		90.275	30.093	0.15	0.0026	5741	414		90.387	30.293	5.72	0.4011	5868
203		90.277	30.240	0.30	0.0069	5854	415		90.101	30.021	2.65	0.1392	5850
204		90.279	30.125	0.02	0.0002	5790	416		90.115	30.053	1.29	0.0517	6037
205		90.280	30.119	0.28	0.0063	5809	417		90.202	30.160	0.11	0.0019	5926

206		90.280	30.167	0.22	0.0046	5979	418		90.205	30.185	1.47	0.0618	5771
207		90.281	30.230	0.12	0.0020	5915	419		90.217	30.194	2.64	0.1390	5874
208		90.281	30.283	2.12	0.1026	5848	420		90.220	30.226	0.85	0.0293	5899
209		90.282	30.241	0.10	0.0015	5945	421		90.267	30.291	2.57	0.1335	5780
210		90.283	30.114	0.04	0.0004	5826	422		90.293	30.295	1.78	0.0804	5790
211		90.284	30.245	0.05	0.0006	5879	423		90.321	30.309	3.86	0.2338	5825
212		90.284	29.739	0.07	0.0009	5820							