

Supplementary Materials

Runoff Characteristics and Their Response to Meteorological Condition in the Yarlung Zangbo River Basin: Spatial Heterogeneity Due to the Glacier Coverage Difference

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Table S1. Description of input data used in setting up a SWAT model.

Data	Description	Resolution	Source
Topography	Digital elevation model	90 m	Geospatial Data Cloud (http://www.gscloud.cn/) (accessed on 9 July 2024)
Land use land cover	The Crop Data Layer	1 km	Resource and Environment Science and Data Center (https://www.resdc.cn/) (accessed on 9 July 2024)
Soil	Soil Survey Geographic database	1 km	Harmonized World Soil Database (HWSD) (https://www.fao.org/) (accessed on 9 July 2024)
Meteorological data	Maximum and minimum air temperature, precipitation, relative humidity, solar radiation, wind speed	Daily	Daily meteorological dataset of basic meteorological elements of China National Surface Weather Station (V3.0) (http://data.cma.cn/) (accessed on 9 July 2024)
Streamflow	Discharge	Monthly	Hydrologic station
Glacier	Glacier area	30 m	National Cryosphere Desert Data Center (http://www.ncdc.ac.cn/portal/) (accessed on 9 July 2024)

Table S2. Information on the subbasins controlled by each hydrological station.

Hydrological Stations	Subbasin Number	Controlled Subbasin Number	Controlled Watershed area (10 ⁴ km ²)
RKZ	128	128,132,140,145-147,149	1.42
LS	78	12-13,17-20,29-30,41-42,61,66-67,74,78	2.61
GZ	73	40,44-45,55-56,59-60,72-73	1.57
PL	50	5-6,9-11,14-16,23-24,34-36,38,48,50-52,65,69,76	2.66
LZ	122	1-4,7-8,21-22,25-27,32-33,53,57-58,62-63,70-71,81-82,92-93,115,121-122	5.07
NGS	104	28,31,37,39,43,46-47,49,64,68,75,77,83,85-86,89,94-101,103-104,106,117,120,133,144	4.72

YC	113	79,80,102,105,108-114,125,127,131,136,141-143,148	2.81
NX	91	90-91,116,118-119,123-124,126,129-130,134-135,137-139	2.37
DX	107	54,84,87-88,107	0.63

Table S3. The calibration and validation periods for runoff at each station. (2010) means that the runoff for 2010 is missing at the LS station.

Stations	Calibration Period	Validation Period
RKZ	2009-2010	2011-2012
LS	2009-2011(2010)	2012-2013
GZ	2003-2006	2007-2008
PL	2011-2014	2015-2016
LZ	2009-2011	2012-2013
NGS	2009-2011	2012-2013
YC	2003-2008	2009-2013
NX	2003-2009	2010-2014
DX	2003-2011	2012-2016

Table S4. Descriptions and initial ranges of the parameters used for the SWAT-glac model calibration. The fourth column indicates the type of modification to be made to the existing parameter value: "r" means multiplying the original value by the adjustment factor (add 1 to a given value in the range), and "v" means replacing the original value with a value in the range.

Parameter Name	Description	Initial Range	Adjustment	Hydrologic Process
CN2	Curve number for moisture condition II	[-0.3,0.3]	r	Surface runoff
FLOWFR	Fraction of available flow allowed to be used for irrigation	[0,1]	v	Irrigation
CANMX	Maximum canopy storage (mm H ₂ O)	[0,100]	v	Evapotranspiration
HRU_SLP	Average slope steepness (m/m)	[-0.5,0.5]	r	Topographic
SLSUBBSN	Average slope length (m)	[-0.5,0.5]	r	Topographic
ESCO	Soil evaporation compensation factor	[0.01,1]	v	Evaporation
LAT_TTIME	Lateral flow travel time (days)	[0,180]	v	Soil water
OV_N	Manning's "n" value for overland flow	[0.01,1]	r	Groundwater
EPCO	Plant uptake compensation factor	[0.01,1]	v	Evaporation
TIMP	Snow pack temperature lag factor	[0,1]	v	Snow
SFTMP	Snowfall temperature (°C)	[-10,10]	v	Snow
SMTMP	Snowmelt base temperature (°C)	[-10,10]	v	Snow
SMFMX	Maximum melt rate for snow during year (occurs on summer solstice) (mm/(°C · day))	[0,10]	v	Snow
SMFMN	Minimum Melt Rate for Snow during the Year (Occurs on Winter Solstice) (mm/°C /Day)	[0,10]	v	Snow
SNOCOV MX	Minimum snow water content that corresponds to 100% snow cover	[0,500]	v	Snow
SNO50COV	Snow water equivalent that corresponds to 50% snow cover	[0,0.9]	v	Snow
SURLAG	Surface Runoff Lag Coefficient	[0.05,24]	v	Snow
ALPHA_BF	Baseflow alpha factor for recession constant (days)	[0,1]	v	Groundwater

GWQMN	Threshold depth of water in the shallow aquifer required for return flow to occur (mm)	[0,5000]	v	Groundwater
RCHRG_DP	Deep aquifer percolation fraction	[0,1]	v	Groundwater
GW_REVAP	Groundwater re-evaporation coefficient	[0.02,0.2]	v	Groundwater
REVAPMN	Threshold depth for exchange with deep aquifer	[0,500]	v	Groundwater
GW_DELAY	Groundwater delay time (days)	[0,500]	v	Groundwater
GWHT	Initial groundwater height (m)	[0,25]	v	Groundwater
DEEPST	Initial depth of water in shallow aquifer (mm H ₂ O)	[0,50000]	v	Groundwater
SOL_BD()	Moist bulk density (mg/ m ³)	[-0.5,0.5]	r	Soil water
SOL_AWC()	Available water capacity of the soil layer (mm H ₂ O/mm Soil)	[-0.5,0.5]	r	Soil water
SOL_K()	Saturated hydraulic conductivity (mm/hr)	[-1,1]	r	Surface runoff
CH_K2	Effective hydraulic conductivity in main channel alluvium (mm/ hr)	[0,500]	v	Routing
CH_N2	Manning's "n" value for the main channel	[0,0.3]	v	Routing
ALPHA_BNK	Baseflow alpha factor for bank	[0,1]	v	Groundwater
TLAPS	Temperature lapse rate (°C /km)	[-10,0]	v	Evapotranspiration
PLAPS	Precipitation lapse rate (mm/km)	[0,100]	v	Snow
CH_S1	Average slope of tributary	[0.0001,1]	v	Surface runoff
b _{gmlt6}	Glacier melt degree-day factor on June 21 (mm°C ⁻¹ day ⁻¹)	[0,6.7]	v	Glacier
b _{gmlt12}	Glacier melt degree-day factor on December 21 (mm°C ⁻¹ day ⁻¹)	[0,6.7]	v	Glacier
S _{gmlt6}	Glacier sublimation factor on June 21 (mm°C ⁻¹ day ⁻¹)	[0,1]	v	Glacier
S _{gmlt12}	Glacier sublimation factor on December 21 (mm°C ⁻¹ day ⁻¹)	[0,1]	v	Glacier
T _{gmlt}	Glacier melt base temperature (°C)	[0,5]	v	Glacier
β ₀	Basal turnover rate of snow to ice	[0.001,0.006]	v	Glacier

Table S5. Statistical results of temperature (°C), precipitation (P), and simulated river discharge (R) at nine stations in the YZRB. Parentheses in the Stations column denote the meteorological station near the hydrological station, such as the meteorological station near the RKZ hydrological station which is the Rikaze station.

Stations	Variable	Annual	Spring	Summer	Autumn	Winter
RKZ (Rikaze)	T _{max} (°C)	15.9	16.3	22.2	16.3	8.6
	T _{min} (°C)	-0.2	0.8	9.5	-0.5	-10.7
	P(mm)	417.3	29.3	331.3	56.3	0.4
	R(mm)	3.9	0.2	1.8	1.5	0.4
LS (Lasa)	T _{max} (°C)	17.1	17.1	23.5	17.6	10.1
	T _{min} (°C)	3.5	3.8	11.7	3.8	-5.4
	P(mm)	466.8	44.8	355.8	62.9	3.3
	R(mm)	32.7	4.4	18.0	8.2	2.1
GZ	T _{max} (°C)	17.0	17.2	22.6	17.6	10.6

(Linzhi)	T _{min} (°C)	4.7	4.6	12.1	5.2	-3.3
	P(mm)	688.6	153.5	365.1	162.5	7.5
	R(mm)	73.5	13.7	38.6	18.2	3.0
PL	T _{max} (°C)	16.8	16.1	23.4	17.4	10.2
(Bomi)	T _{min} (°C)	4.7	4.6	12.5	5.3	-3.4
	P(mm)	857.4	321.4	292.7	201.1	42.2
	R(mm)	160.9	35.6	78.6	38.5	8.1
LZ	T _{max} (°C)	15.0	15.1	21.4	15.7	7.9
(Lazi)	T _{min} (°C)	1.0	1.1	9.6	1.4	-8.3
	P(mm)	330.3	17.4	269.0	43.6	0.3
	R(mm)	17.6	1.7	9.2	4.8	1.9
NGS	T _{max} (°C)	16.5	16.4	23.2	17.1	9.4
(Nimu)	T _{min} (°C)	0.1	0.7	9.6	0.3	-10.1
	P(mm)	341.9	33.6	248.0	59.5	0.8
	R(mm)	61.4	3.5	35.3	17.8	4.8
YC	T _{max} (°C)	17.6	17.7	23.9	18.2	10.8
(Zedang)	T _{min} (°C)	3.1	3.1	11.3	3.6	-5.6
	P(mm)	380.1	49.8	260.5	67.7	2.2
	R(mm)	123.9	9.6	71.8	35.3	7.2
NX	T _{max} (°C)	17.0	17.2	22.6	17.6	10.6
(Linzhi)	T _{min} (°C)	4.7	4.6	12.1	5.2	-3.3
	P(mm)	688.6	153.5	365.1	162.5	7.5
	R(mm)	209.2	22.5	113.3	62.8	10.6
DX	T _{max} (°C)	16.8	16.1	23.4	17.4	10.2
(Bomi)	T _{min} (°C)	4.7	4.6	12.5	5.3	-3.4
	P(mm)	857.4	321.4	292.7	201.1	42.2
	R(mm)	444.6	76.2	220.7	123.2	24.4

Table S6. Values of glacier parameters under two different settings at each station. "Global" indicates uniform glacier parameter values across the entire basin, while "Local" signifies different glacier parameter values set at various stations.

Parameter Name	Global	Local				
	Optimized Value	Optimized Value				
		RKZ-LS-NGS-YC-NX	GZ	PL	LZ	DX
b _{gmlt6}	2.0	2.1	5.0	2.6	0.8	6.5
b _{gmlt12}	1.6	1.6	3.5	1.4	0.4	5.5
S _{gmlt6}	0.6	0.6	0.6	0.6	0.6	0.4
S _{gmlt12}	0.2	0.2	0.2	0.2	0.2	0.1
T _{gmlt}	0.8	0.8	0.8	0.5	0.5	0.2
β ₀	0.003	0.003	0.003	0.005	0.003	0.003

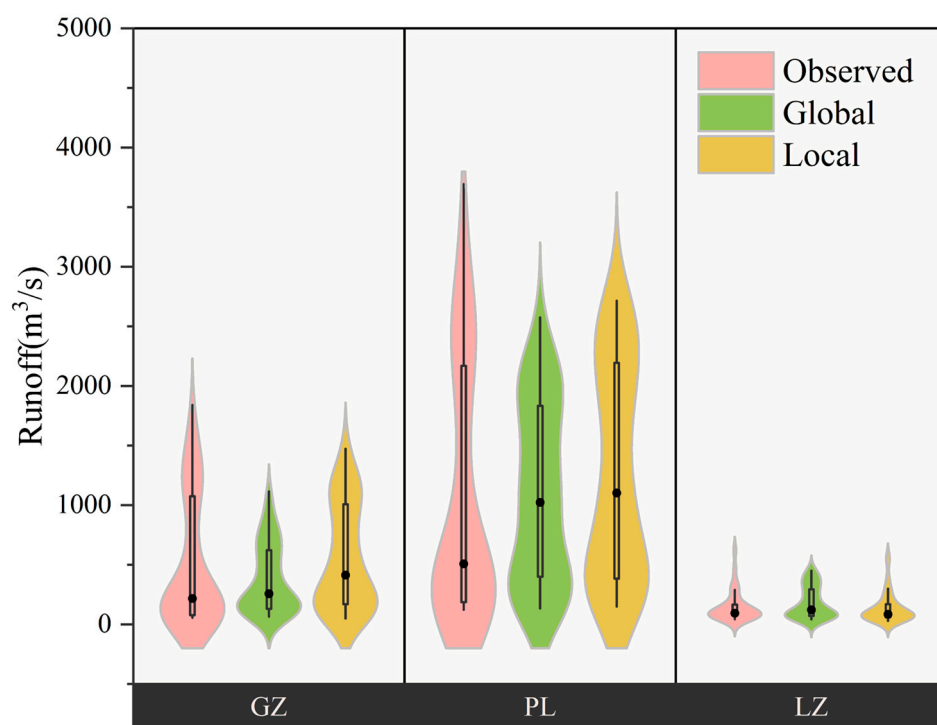


Figure S1. Violin plots of monthly average simulated and measured runoff at three stations (GZ, PL, LZ) under different glacier parameter settings. The red represents observed monthly average runoff; the green represents simulated results under global glacier parameterization; the yellow represents simulated results under local glacier parameterization.