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Characteristics of Preflood Season Flow Velocity in Southeastern Tibet, China

Pu, H. C.[1,2,3] Chen, B.[1,2,3*] Xiao, Y.[1,2,3] Liu, L.Y.[1,2,3] Shi, P.J.[1,2,3] Yan, P.[1,2,3] Zhang, G.M.[1,2,3] Liu, J.F.[1,2,3]

1. The State Key Laboratory of Earth Surface Processes and Resource Ecology, Beijing Normal University, Beijing 100875, China;
2. The Key Laboratory of Environmental Change and Natural Disaster, Beijing Normal University, Beijing 100875, China;
3. Faculty of Geographical Science, Beijing Normal University, Beijing 100875, China.

Abstract: The Tibetan Plateau is increasingly threatened by floods under climate change. The densely distributed rivers and relatively more developed socioeconomic conditions in southeastern Tibet make it necessary to survey flood characteristics across this region. Using a handheld radar current meter (RD-60) and outdoor rangefinders, a dataset of 141 samples from 85 rivers in southeastern Tibet was collected during a field survey from mid to late June 2021 (the preflood season). Based on this dataset, we investigated the relationship between stream flow velocity and Strahler stream order and the pattern of flow velocity from the river mouth to the channel head for the Sangqu, Lengqu and Puqu Rivers. The results showed that during the preflood season in southeastern Tibet, (1) the stream flow velocity is generally higher than that measured for nonmountainous rivers, (2) the average stream flow velocity increases exponentially with Strahler stream order, and (3) the flow velocity decreases from the mouth to the head of a stream, owing to the decrease in stream discharge toward the head. The dataset includes (1) flow velocity, river width, channel slope, Strahler order and floodplain width measured at 141 locations on 85 rivers in Southeast Tibet and (2) the distances of the sampling points measured from the river mouths for the Sangqu, Lengqu and Puqu Rivers. The dataset is archived in .shp and.xlsx data formats, consists of 8 data files and has a size of 159 KB (compressed into a single file of 37.3 KB).

Keywords: Tibetan Plateau; Stream flow velocity; Flood; Floodplain characteristics

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***Corresponding Author:** Chen, B., Faculty of Geographical Science, Beijing Normal University, bochen@bnu.edu.cn

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1 Introduction

The Qinghai-Tibet Plateau is the origin of many major rivers in Asia such as the Changjiang River, the Huanghe River, the Yaluzangbu River, the Ganges River and the Mekong River, and is crucial for the ecological security of Asia [1]. Southeast Tibet is demonstrably affected by the summer monsoon. Therefore, there are more extreme precipitation events [2], and the climate is warmer and wetter than that in the northwest [3]. The population and economy are more densely distributed in Southeast Tibet than in Northwest Tibet [4]. With the spatial configuration of terrain and climate, natural disasters occur frequently in the Qinghai–Tibet Plateau, particularly in Southeast Tibet. Floods often cause secondary disasters such as landslides and debris flows, which are highly destructive to the population, the economy, and transportation routes [5]. With the increasing trends of extreme precipitation under climate change [1, 6, 7] and socio-economic development, the risk of flood and flood-geological disaster cascades may increase in the Qinghai–Tibet Plateau [3]. The Qinghai– Tibet Plateau covers a vast area and has relatively sparse population, and there are relatively few hydrological data due to the sparse distribution of hydrological stations [8, 9]. Therefore, conducting field surveys of flood characteristics in the Qinghai–Tibet Plateau is of practical significance to facilitate risk prevention of floods and their disaster cascades in this region.

Table 1 Metadata of the Pre-flood Environment Field Survey dataset in Southeastern Tibet of China.

Items	Description
Dataset full name	Preflood Environment Field Survey dataset in Southeastern Tibet of China (2021)
Dataset short name	Preflood _SETibet_2021
Authors	Pu, H. C., Faculty of Geographical Science, Beijing Normal University, 202121051170@mail.bnu.edu.cn Chen, B., AAA-2670-2022,Faculty of Geographical Science, Beijing Normal University, bochen@bnu.edu.cn Xiao, Y., Faculty of Geographical Science, Beijing Normal University, 202021051173@mail.bnu.edu.cn Liu, L.Y., Faculty of Geographical Science, Beijing Normal University, lyliu@bnu.edu.cn Shi, P.J., Faculty of Geographical Science, Beijing Normal University, spj@bnu.edu.cn Yan, P., Faculty of Geographical Science, Beijing Normal University, yping@bnu.edu.cn Zhang, G.M., Faculty of Geographical Science, Beijing Normal University, zgm@bnu.edu.cn Liu, J.F, Faculty of Geographical Science, Beijing Normal University, liujifu@bnu.edu.cn
Geographical region	Southeastern Qinghai-Tibet Plateau
Year	June 15 to June 26, 2021 Data format .xlsx, .shp
Data size	159 KB (before compression); 37.3 KB (after compression)
Data files	8 files (compressed into 1 file) (1).xlsx table file: Sheet 1 is the stream flow velocity, river width, channel slope, Strahler order and floodplain width at 141 measuring points in southeastern Tibet. Sheets 2, 3 and 4 are the distances from the measuring point of Puqu River, Sangqu River and Lengqu River to their river mouth, respectively. (2) Preflood _SETibet_2021 shp folder:.shp format file of the location of 141 measurement points in southeastern Tibet
Foundation(s)	Ministry of Science and Technology of P. R. China (2019QZKK0906，2016YFA0602404)
Data publisher	Global Change Research Data Publishing & Repository, http://www.geodoi.ac.cn
Address	No. 11A, Datun Road, Chaoyang District, Beijing 100101, China
Data sharing policy	***Data*** from the Global Change Research Data Publishing & Repository includes metadata, datasets (in the *Digital Journal of Global Change Data Repository*), and publications (in the *Journal of Global Change Data & Discovery*). ***Data*** sharing policy includes: (1) ***Data*** are openly available and can be free downloaded via the internet; (2) end users are encouraged to use ***Data*** subject to citation; (3) users, who are by definition also value-added service providers, are welcome to redistribute ***Data*** subject to written permission from the GcdataPR Editorial Office and the issuance of a ***Data*** redistribution license; and (4) if ***Data*** are used to compile new datasets, the 'ten percent principal' should be followed such that ***Data*** records utilized should not surpass 10% of the new dataset contents, and sources should be clearly noted in suitable places in the new dataset[11]
Communication and searchable system	DOI, DCI, CSCD, WDS/ISC, GEOSS, China GEOSS, Crossref

2 Metadata of the Dataset

The metadata of the pre-flood environment field survey dataset in Southeastern Tibet of China [10] is summarized in Table 1.

3 Data acquisition method

3.1 Acquisition time

The data were collected from June 15 to June 26, 2021, during the early stage of the flood season for the entire Qinghai–Tibet Plateau and its southeast. Figure 1 (a) displays the monthly distribution of long-term average precipitation (1961-2017) and flood disasters (1961-2010). Precipitation and flood disasters on the Qinghai-Tibet Plateau mainly occur during the period from June to August. The precipitation and flood disaster distribution from June to August accounts for 58% and 81% of the entire year, respectively. Compared with May, the proportion of precipitation and number of flood events in June increased by approximately 8% and 14%, respectively and were second only to levels in July and August. The precipitation in July accounts for the largest proportion of the annual total, about 20%, and the number of flood disasters accounts for approximately 34% of the total for the year.

In Southeast Tibet, in June, precipitation accounts for a large proportion of the entire year, and river runoff begins to rise, which is approximately 1-2 months prior to the time of monthly peak runoff. Using the hydrological and meteorological (Figure 1) data for Nuxia (the main channel of the middle reaches of the Yaluzangbu River, located in Pai Town, Milin County, Linzhi city), Lasa (Lasa River) and Changdu (the upper reaches of the Lancang River) as examples, the monthly runoff in June accounts for 10-13% of the total annual volume and ranks fourth for the year; monthly precipitation in June accounts for 17-20% of the annual total precipitation and ranks third for the year. In addition, the timing of peak runoff varies across regions. The monthly peak runoffs of the Nuxia and Lasa stations occur in July, whereas that of the Changdu station occurs in August. Conducting surveys at the beginning of the flood season can not only describe the hydrological characteristics of the flood to a certain extent, but help to safely record the hydrological characteristics of floods.

3.2 Acquisition method

Measurements were made for stream flow velocity, stream width, floodplain width and channel slope during the field survey. Flow velocity was measured using a RD-60 handheld radar flow meter (Figure 2 (a)). The instrument uses K-band radar to measure the flow velocity of rivers, sewage and oceans without contact. It has the advantages of compact size, a battery power supply, handheld operation and being simple to use. The instruments for measuring river width and floodplain width were two types of handheld outdoor rangefinders that use pulses to measure distance and can ensure accuracy under various lighting conditions. The measuring ranges were 1500 m (Figure 2 (b)) and 1000 m (Figure 2 (c)). River width refers to the maximum width of the water at the time of measurement, and floodplain width refers to the distance between the riverside vegetation zones on both banks. The channel slope at the measurement point is the ratio of the elevation difference at 200 m upstream and downstream of the measurement point to the flow length (400 m). Channel slope measurements were completed indoors using Google Earth.

Velocity was mainly measured from bridges for two reasons: first, a velocity measuring instrument is recommended for use on bridges; second, on the Qinghai-Tibet Plateau, bridges are ideal locations to approach water flow because it is convenient to select appropriate measurement points and control the measurement angle, which ensures the accessibility and accuracy of measurement [15] (Figure 3).

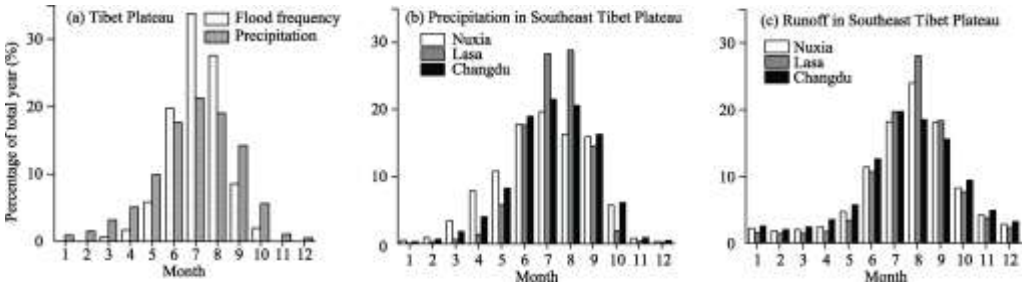

Figure 1 The precipitation and runoff characteristics of the Qinghai-Tibet Plateau and its southeastern region: (a) monthly precipitation and flood frequency on the Qinghai-Tibet Plateau (based on Ma, W.D., 2019 [12], modified), (b) percentage of precipitation relative to the annual total at three weather stations in southeastern Tibet (based on Ruan, B.Q., 2000 [13], modified)), and (c) percentage of runoff relative to the annual total at three hydrological stations in southeastern Tibet (based on Liu, G,W., 1992 [14] and Ruan, B.Q., 2000 [13], modified).

Figure 2 Data acquisition equipment: (a) the handheld radar current meter (RD-60) for measuring stream flow velocity, and two outdoor rangefinders, (b) and (c), used to measure river width and floodplain width.

Figure 3 Measuring flow velocity on rivers of various sizes

The bridges selected for the survey were located on rivers of different sizes such as the Tongmaiteda bridge (across the Yigongzangbu River, a tributary of the Plalongzangbu River, with a total length of 415.8 m), the medium-sized Padang bridge (across the Yaluzangbu River, with a total length of 225 m), and the small wooden and iron bridges (such as the QuXiao bridge and Labu bridge, both of which are 2-3 m long). In the process of data acquisition, the single-point method is used to measure the velocity near the channel thalweg. In general River velocity measurement, firstly, five or more measurement vertical lines from the river surface to the river bottom are set on the wetted cross section, and then the velocity is measured at different water depths by single- point, three-point or five-point vertical line method on each vertical line [16]. Because the Qinghai-Tibet Plateau has the characteristics of a deep river valley with rapid water and strong winds, the typical flow velocity measurement approach is dangerous and often not feasible. In addition, the flood survey covered a large area and had a tight schedule. Therefore, flow velocities were measured using the single point approach at river centerlines. The widths of the rivers and floodplains were generally measured at both ends of the bridge or at the nearest bank point. To reduce measurement error, three measurements of flow velocity, river width and floodplain width were made at each sampled location, and the average was taken as the final value.

3.3 Data coverage

The data were collected at 141 locations on 85 rivers in 23 counties over more than 2000 kilometers of river (Figure 4). Among the rivers surveyed there were: (1) 41 survey locations for large rivers (Strahler order [17] greater than 5), including 19 major rivers in Tibet such as the Yaluzangbujiang River, Nujiang River, Lancangjiang River, and Niyanghe River; (2) 80 survey locations for medium rivers (Strahler order 3-5), including 45 rivers such as the Gengzhangqu River, Miduiqu River, Puqu River and Lengqu River; and (3) 20 survey locations for small rivers (Strahler order 1-2), including approximately 10 rivers such as the Bindaqu River and Daqu River. In addition to flow velocity measurements, we also conducted a detailed survey for a few watersheds of various sizes, including the Puqu River (Figure 4(a)), Lengqu River (Figure 4(b)), Sangqu River (Figure 4(c)), Zhaqu River, Langxuejiegou River, and Miduiqu River. As shown in Figure 4, high flow velocities tended to cluster southeast of the surveyed area, and flow velocity appears to increase gradually downstream from the mountainous area.

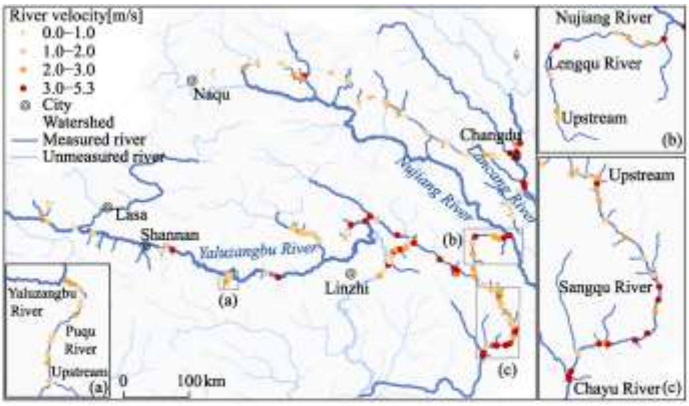

Figure 4 Distribution of survey locations.

4 Results and Validation

Based on the data collected by the survey, flow velocity characteristics in the southeastern Qinghai-Tibet Plateau are analyzed, including the relationship between velocity and Strahler order and the pattern of velocity from the river mouth to its headwater.

4.1 Statistical summary of flow velocities

The flow velocity and channel slope are relatively large in Southeast Tibet, which is a region with high discharge [18]. Figure 5 shows the statistical distribution of stream flow velocity and slope in Southeast Tibet from June 15 to June 26, 2021. As shown in Figure 5a, among the 141 measuring points, 70 measuring points have velocities above 2 m/s, accounting for approximately 50% of points; 15 measuring points (10.6%) fall within the velocity range of (1.25, 1.5]. There are 11 measuring points with velocities above 4 m/s, mainly located in the southeast of the surveyed region (Figure 4). Included in these measurements are velocities from the Sangqu River(3 measurements), the Miduiqu River in Midui glacier (2 measurements) and the Bomi County section of the Egongzangbu River (2 measurements). The maximum velocity of survey (5.32 m/s) was measured at the Daxing middle bridge over the Egongzangbu River in Daxing village of Bomi County. As shown in Figure 5b, the channel slopes of river in Southeast Tibet are generally large and distributed exponentially. The channel slope of the measuring points for approximately 80% is greater than 10% and for more than 50% of the measured points is greater than 2%. There are 3 measurement points where the channel slope is greater than 30% (48%, 35% and 32%). The largest two channel slopes are located on the Ganongqu tributary at the Zhamo Highway and at the Yanatongqu near Guoluo Village, Basu County, Changdu. The point where the channel slope is 32% is located at Renatongqu river near Guoluo Village, Basu County, Changdu. These three measuring points belong to rivers that flow into the valley from steep hillsides at an angle close to the vertical valley. In southeastern Tibet, rivers flow fast, and the slopes are steep. After heavy rainfall, the confluence time of floods is short, so flash floods with short occurrence times and high intensities often form, resulting in large economic losses and casualties of human and livestock [19].

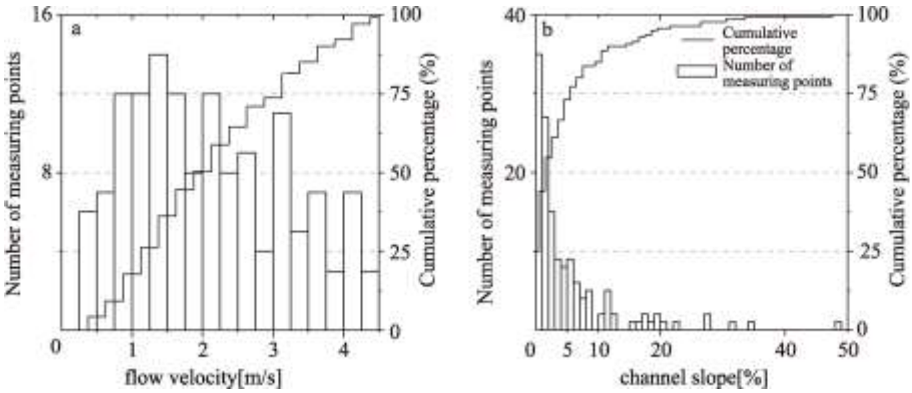

Figure 5 Statistical distribution of measured flow velocity (a) and channel slope (b).

4.2 The relationship between stream flow velocity and Strahler order

Based on the collected data, the velocity of rivers in the southeastern Qinghai–Tibet Plateau is exponentially related to the Strahler order (Figure 6). Using the traditional Strahler river characteristic analysis method [20], the flow velocity and characteristic values were classified according to the Strahler order. Although the velocity of the same order river varies greatly, in general, the average velocity (v) of the river increases exponentially with the increase in Strahler order (ω). The fitted exponential function is:

$$v = 1.116e^{0.158(\omega-1)} \tag{1}$$

At a significance level of $p < 0.001$, the Strahler order of the river explained 91% of the variance in the average river velocity (R^2 = 0.911). The average velocity of the first order rivers measured in the southeastern Qinghai–Tibet Plateau is 1.10 m/s, and the fitted value based on Formula (1) is 1.12 m/s. Although there is some fitting error in the velocity-Strahler order relationship of the river, the relationship can be used for the simple calculation of velocity in areas with scarce data in the southeastern Qinghai–Tibet Plateau.

4.3 Pattern of flow velocity from the river mouth to its source

Taking the Sangqu, Lengqu and Puqu Rivers as examples, Figure 7 shows the changes in the stream flow velocity, river width and slope of the three rivers (Sangqu, Lengqu and Puqu Rivers) from the river mouth to the source of the river. From the simple linear fit between flow velocity and the distance from the river mouth to the source, the slopes of all fitted lines are negative (–0.009, –0.017 and –0.044, respectively, excluding singular values). The significance levels of the fit relationship were < 0.01, < 0.01 and < 0.1 (excluding singular values). The flow velocity of the three rivers gradually decreases from the river mouth to the source. This result is inconsistent with the general impression that rivers in mountainous areas have relatively steep slopes, and so the flow velocity is greater than that of rivers in relatively flat areas downstream.

According to the Manning equation, the channel slope and hydraulic radius (when the river width is much greater than the water depth, the hydraulic radius is approximately equal to the water depth) are the main factors influencing stream flow velocity [21]. Generally, the slope upstream is greater, but the runoff (or water depth) downstream increases with the increase in catchment area or the number of confluence tributaries. Therefore, the change in velocity from the source area to the river mouth along the same river is the combined effect of slope and flow.

The above data and analysis show that for the Sangqu, Lengqu and Puqu Rivers, the closer the distance to the river mouth, the larger the catchment area and/or the greater the number of tributaries. Although the stream flow velocity decreases from the river mouth to the source, the overall trend may show small fluctuations due to local river slope and river width changes. For example, the Puqu River shows the stream flow velocity that differs from the overall trend at the maximum value of river width and the maximum value of channel slope (Figure 7). When these two singular points are included, the slope of the general curve fitting equation is –0.004, and the statistical test is not significant. When they are not included, the downward trend of the velocity tracing becomes 0.044 m/s per kilometer and passes the statistical significance test at the level of p = 0.1. It shows that there are fewer tributaries on both sides of the Puqu River, and the increase in river water volume is not as great as that in the Sangqu River and Lengqu River.

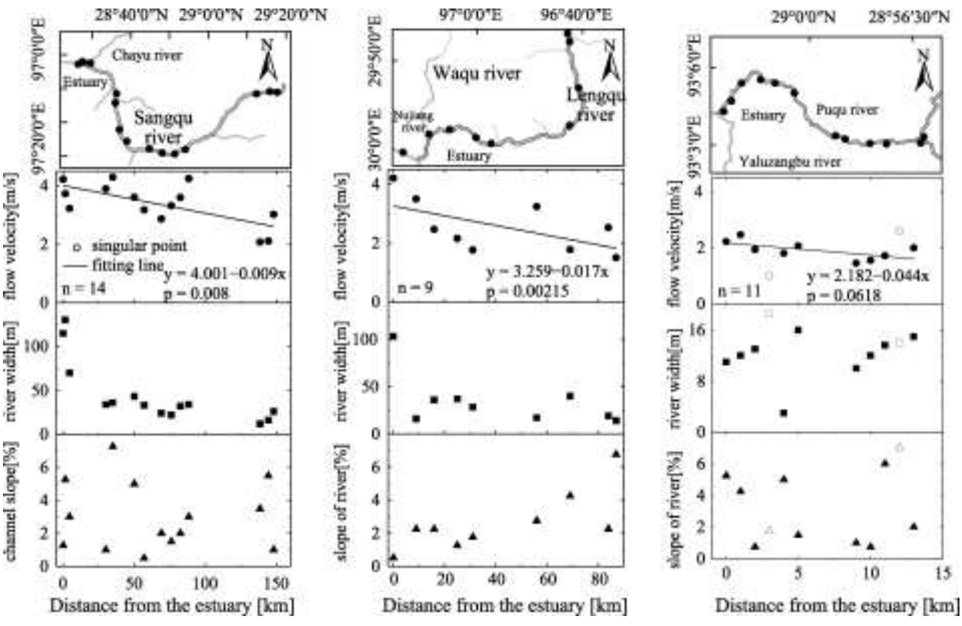

Figure 7 Changes in velocity, width and slope of the Sangqu River, Lengqu River and Puqu River from the river mouths to their sources.

5 Discussion and Conclusions

The dataset was developed through field measurements based on a handheld radar current meter (RD-60) and outdoor rangefinders. By analyzing the statistical distribution characteristics of the data, the relationship between the velocity and the Strahler order of river, and the pattern of flow velocity from the river mouth to the channel head, the following conclusions are drawn: compared with plain areas, the flow velocity of the Qinghai–Tibet Plateau is generally higher; as a whole, the higher the Strahler order, the faster the river flows; in some rivers on the Qinghai–Tibet Plateau, the closer the distance to the river mouth, the higher the stream flow velocity, and the increase of stream flow velocity mainly comes from the increase in runoff.

Author Contributions

Chen, B., Pu, H.C. and Xiao, Y. designed the survey and compiled the dataset. Xiao, Y., Pu, H.C., and Chen, B. contributed to the data collection, processing and analysis. Pu, H.C. and Chen, B. wrote the paper. Liu, L.Y., Shi, P.J., Yan, P., Zhang, G.M., and Liu, J.F. discussed the data collection plan and revised the manuscript. We thank Professor Yang, W.T. for helpful discussion and Ouzhu, P.J. and others for their patient and kind help with data collection.

Conflicts of Interest

The authors declare no conflicts of interest.

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