Temporal variability of discharge rating curve investigated using shallow-water acoustic tomography

Kiyosi KAWANISI (Hiroshima University) and Mohamad Basel AL SAWAF (Hiroshima University)

Introduction

Acquiring continuous streamflow estimates is paramount in hydrological studies, extreme event analyses, and water resources management. The streamflow is commonly estimated using stage-discharge relations because it hard to do direct continuous flow measurements for years. The relation is called rating curve (RC). It is believed that the RCs are liable to change depending on channel conditions such as cross-sectional shape, vegetation, and so on (Guerrero et al. 2012). However, a hydrological dataset sparse in time is insufficient to shed light on the temporal variability in the stage–discharge relation. **This study examines the temporal variability in RC from streamflow time series with uniquely high temporal density (every 10 minutes).** The streamflow time series are obtained using **a novel acoustic method: fluvial acoustic tomography (FAT)** developed by Hiroshima University. In this study, 16 hydrological events in a gravel-bed river for 2016-2018 were analyzed, and the variable rating curves were assessed.

Overview of the fluvial acoustic tomography (FAT) system

The shallow-water acoustic tomography technique has been under development for a number of years at Hiroshima University (Kawanisi et al. 2018; Kawanisi et al. 2012; Razaz et al. 2013). A new travel-time tomography technique/system makes it possible to accurately measure the sound arrival times in shallow waters. Although the range averaged velocity is measured using the “time-of-travel method” , FAT system can gauge the instantaneous section-average-velocity using multi-rays that cover the entire flow cross section unlike conventional acoustic velocity meters.

The received acoustic data at both riversides are transferred to the processing unit using the wireless LAN bridge. The GPS receivers provide two accurate timing signals. One timing pulse (1 Hz) is used to ensure that both systems run synchronously. Another signal of 10 MHz is used as the base clock of FAT system for high-precision transmitting and receiving signal processing.

Survay site

A 115-m wide straight reach of the Gono River, Miyoshi City, Japan was selected as the survey site (Figure 2). The details of the study area are shown in (Kawanisi et al. 2012). The riverbed was consist of gravel (d50=27mm). The bed slope around the observation site was approximately 0.11%, and the Manning roughness estimated from the stream velocity and the water surface slope was approximately 0.03. As shown in figure 2, a couple of transducers (T1 and T2) were diagonally installed in the straight reach.

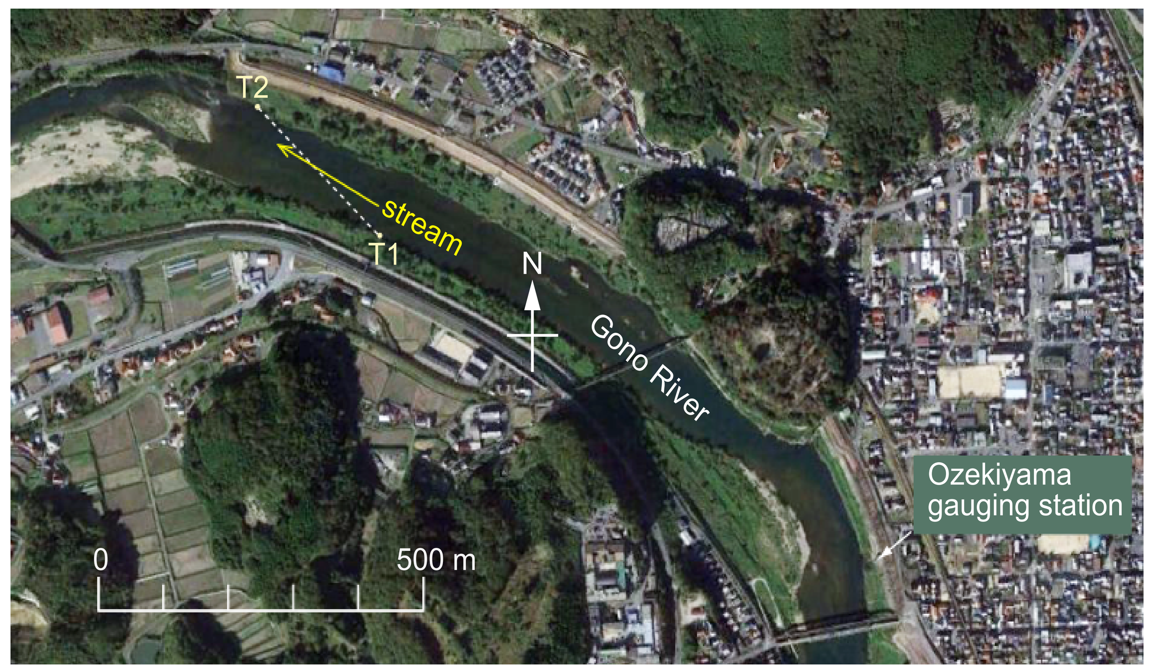

Figure 1. Study area: installation points of transducers (30 kHz) and location of Ozekiyama gauging station.

References

Guerrero et al., 2012, J Hydrol 446–447 doi:10.1016/j.jhydrol.2012.04.031
Kawanisi et al., 2018, J Hydrol Eng 23(2) doi:10.1061/(ASCE)HE.1943-5584.0001604
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Results

Figure 2(a) shows the time history of water level at the Ozekiyama gauging station from November 2015 to May 2018. The rating curves were established from streamflow time series with high temporal density using FAT system. The average of water level at both acoustic stations H_m were used as the water stage in rating curves. For falling limbs of 16 hydrological events, which are shown by the red marks in figure 2(a), the rating curves were analyzed. The stage–discharge and stage–water-slope relations did not show significant hysteresis loops at the survey site because of the steep bed slope. Figures 2(b) and (c) show temporal variations in the relative difference and correlation coefficient of between successive RCs, respectively. It is found that the rapid changes of the rating curve occurs owing to large flood events.

Figures 3(a) and (b) present the stage–discharge and stage–water-slope relations, respectively. The slope of water surface S_w is evaluated from the water levels at the both acoustic stations (T1, T2). The water slopes linearly increase with increasing stage by $H_m \approx 147$ masl (masl: m above mean sea level). The increases of S_w are insignificant while $H_m > \sim 147$ masl. Because the water slope is milder than the bed slope of 0.11%, the survey site is located in backwater; the backwater is caused by the downstream sand banks (Figure 1).

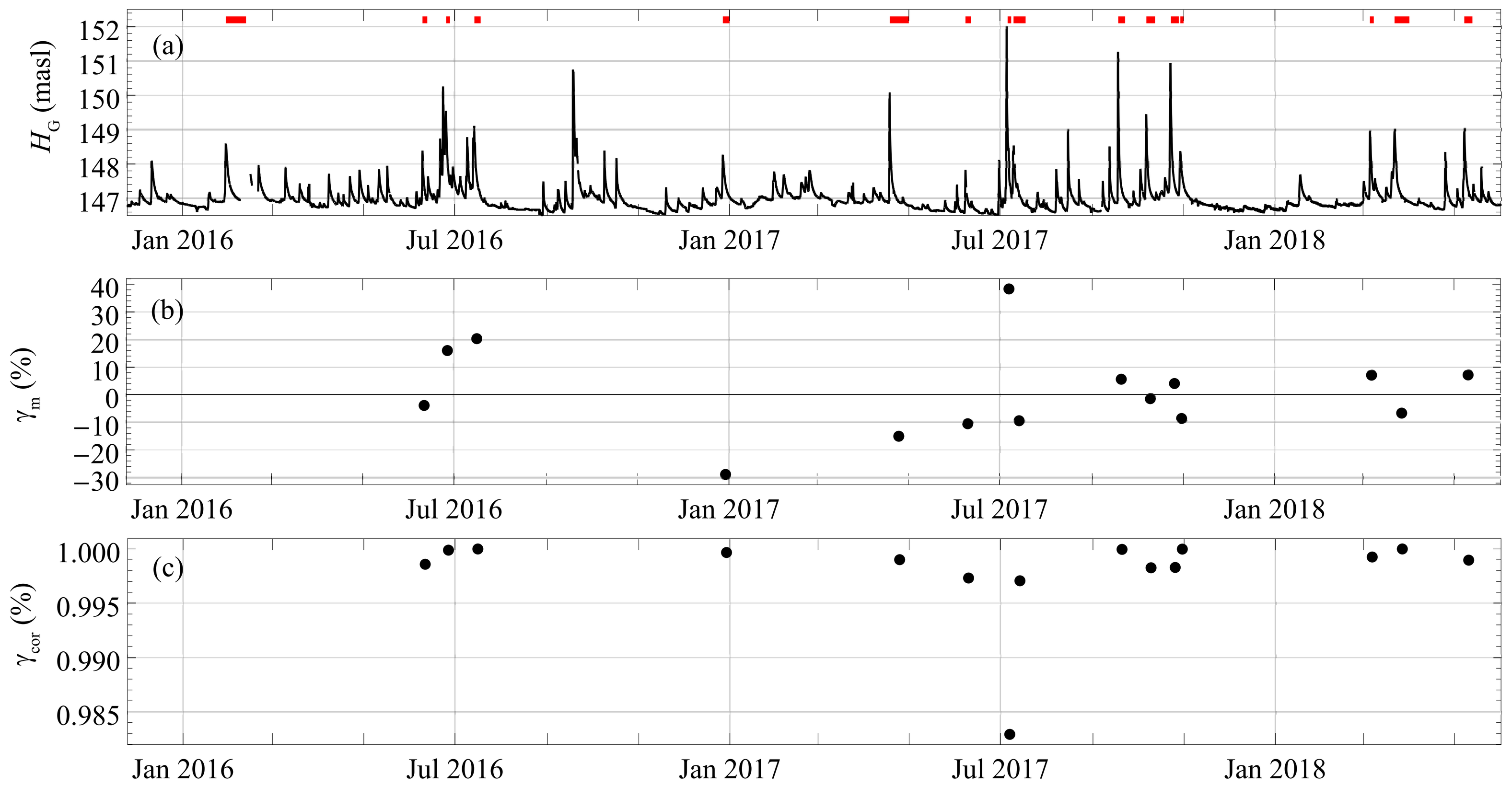

Figure 2. (a) Time series of the water level at the Ozekiyama gauging station (masl: m above mean sea level). Red marks denotes the analyzed periods. (b) Temporal variation in the relative difference of between successive RCs. (c) Temporal variation in correlation coefficient between successive RCs.

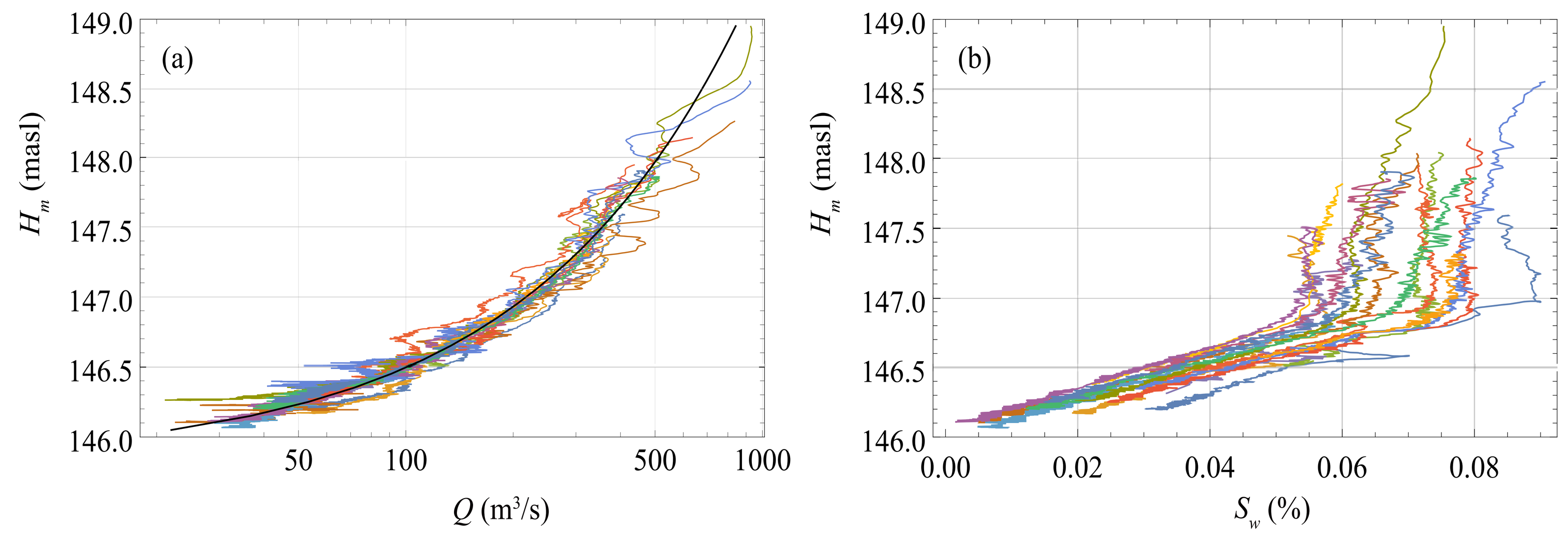

Figure 3. (a) Stage–discharge relations; black line denotes fitting curve; (b) Stage–water-slope relations.

Conclusions

- A RC established from the sparse gauging in a hydrological year can result in large errors in the streamflow estimation.
- The novel FAT system allowed the unique high-frequency (every 10 minutes) streamflow gauging.
- The uncertainty of RC reached around ±40% in the mountainous river. The streamflow records with uniquely high temporal density shed light on the irregularity in stage–discharge relations. It shows that the power function is too simple as a real rating curve.