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# Towards hydrological model calibration using river level measurements

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ABSTRACT

Due to the limited availability of discharge data in many catchments globally, it is important to develop a calibration method that does not rely solely on discharge data. Motivated by this limitation, two calibration approaches using water level data directly in hydrological calibrations are proposed in the study. The first is a Spearman Rank correlation (SRC) based scheme, which calibrates modelled streamflow against observed water level using Spearman Rank correlation. The second is an Inverse Rating Curve (IRC) function based scheme, which introduces three more parameters to simulate water level from an inverse rating curve. The new approaches are tested in 11 catchments in Australia and the resulting discharge predictions show good correlation with observations. However, the results present large biases between observations and estimated discharge data due to the inherent limitation of the approach: absence of information on the true discharge range in the calibration process. To mitigate the biases, the magnitude-sensitive SRC/IRC-based schemes that incorporate a small number of observations are developed in this study. The bias issue is then mitigated significantly, but the improvement is not consistent throughout the examined catchments. One of the most critical challenges of the bias correction is that the whole dynamic range of discharge is constrained by a few observed discharge data, but overall, the new calibration approaches using only water level data prove to be promising.


## 1. Introduction

Hydrological modelling provides an important means to predict streamflow as well as detailed understanding of water cycles and hydrological systems, thereby supporting studies of climate change, water resource management, land use and infrastructure design (Lørup et al., 1998; Vörösmarty et al., 2001). The modelling process requires calibration to optimize model performances (Gupta et al., 1998), for which observed stream discharge data are essential because streamflow discharge reflects the whole-of-catchment responses to meteorological forcing. However, discharge data are generally limited within a catchment, if not absent for many catchments, and insufficient gauging data can lead to significant uncertainties in estimated river discharge and hinder accurate hydrological prediction (Bjerklie et al., 2003; Smith et al., 1996). Globally, for many catchments, the correct and timely provision of discharge data is under pressure due to a decrease in the number of monitoring stations (Vörösmarty et al., 2001) or those with long-term records (Phillips and Melcher, 2006).

The availability of discharge data in many catchments is constrained by a number of factors. Firstly, the distance to remote catchment and sub-catchment outlets and the expense of instrumentation limits the number of gauged catchments.

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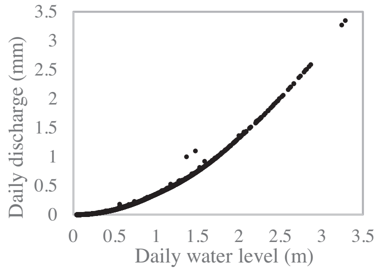


**Fig. 1.** Typical relationship between water level and discharge (catchment #6 from Table 1).

The inaccessibility of remote sites poses a significant obstacle for measuring discharge data in these areas (Getirana, 2010). Secondly, even where flow monitoring occurs, it can be difficult to estimate discharge. This is because what is measured in the gauging station continuously is water level, not discharge, thus the relationship between river levels and river discharge, namely the rating curve, is needed to convert water level data to discharge. The rating curve must be established with accurate information of river bathymetry and requires numerous measurements across the entire discharge range to define the relationship (Dottori et al., 2009). This is not a trivial task and requires substantial investment of people and equipment, in addition to the significant infrastructure costs of installing gauging stations. In addition, since many monitoring projects are undertaking by individual institutions, the spatial and temporal coverage and the availability of the data are limited by the scopes and privacies of the individual projects (Vörösmarty et al., 2001). Given that there are more locations measuring stream stage than discharge, it is imperative to develop methods that more effectively utilize stream stage data, where available, for hydrological modelling.

No, or limited discharge data for hydrological modelling, is one of the great practical challenges in hydrology. Methods for modelling of ungauged catchments typically make use of regionalization of information from gauged catchments (Wagener et al., 2004). For example, spatial gauging divergence, or regionalization, can be a useful method that provides an ungauged catchment with possibly suitable parameters by conducting the calibration in a hydrologically similar gauged catchment. Performance of this method, however, is highly dependent on the distance and hydrological similarity between the donor sites and objective ungauged catchments (De Vleeschouwer and Pauwels, 2013; McIntyre et al., 2005; Mohamoud, 2008; Montosi et al., 2012) and in practice it is very hard to find a sufficiently similar donor catchment.

The temporal gauging divergence approach is another acceptable calibration method for catchments that do not have continuously measured discharge data. The model parameters can be calibrated in the gauged period and applied in the ungauged period (De Vleeschouwer and Pauwels, 2013). In this method, only a small number of observed discharge data is required, which could help reduce the cost of monitoring significantly. For example, Seibert and Beven (2009) found that in a ten years' period, only 32 discharge observations could effectively constrain a model as long as these measurements contain sufficient information, both high and low flow, to represent the whole time scale of the catchment. However, using a particular period of observation to represent the entire record would likely bring some uncertainties. As the size of record is reduced, the results will be more sensitive to the choice of the measurement period (Seibert and Beven, 2009), so if the period is too short, or the data contains limited seasonal variation, it may not represent the whole characteristics of the catchment properly. Moreover, a catchment with large long-term flow variability would suffer difficulties in obtaining a representative observation data set (Seibert and Beven, 2009).

On the other hand, remotely sensed data can be an important source of information in ungauged areas. For example, stage data derived from satellite altimetry have been used in the establishment of rating curves in ungauged catchments (Bjerklie et al., 2005; Pan et al., 2016; Smith et al., 1996). This approach seems promising since satellite altimetry data are easy to access and cover large spatial areas (Medina et al., 2008). However, as the existing method still requires measurements of many variables (water surface width, surface velocity and channel slope), errors in any one measurement could affect its accuracy (Bjerklie et al., 2003; Bjerklie et al., 2005). Moreover, the sparse repeat cycle of the satellite data (e.g. 35-days repeat cycle for ENVISAT, 10-days repeat cycle for Jason-1 and -2) (Medina et al., 2008) hampers its ability to predict daily and weekly discharges; and this remotely sensed measurement is affected by topography, vegetation, ice and snow cover (Leon et al., 2006). Nevertheless, satellite altimeter data have been used as a source of stage data for estimating discharge used for monitoring and calibrating models (Smith et al., 1995, 1996).

A method that directly uses river stage data in the hydrological model calibration may reduce uncertainty introduced by the rating curve based discharge estimation and overall cost of the discharge observation. Such a method would also allow utilization of satellite altimetry based river stage data where discharge measurements are scarce or absent. Motivated by this potential, Jian et al. (2015) first introduced two calibration schemes to calibrate hydrological models at two catchments using only river stage data and assessed their reliability. Considering the monotonic trend between discharge and water level in most existing rating curves (Fig. 1), the information of discharge could be expressed and represented by the water level data via rank statistics or an inverse power function (described in Section 2.2.2).

In this work, we further test the proposed calibration schemes and apply it to a wider range of catchments (11 catchments) with variable hydrological and climatic characteristics around Australia. Their performance and limitations are distinguished