Detection of rating shifts at hydrometric stations

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Aims

River discharge time series are usually established using "rating curves" (hereafter called RCs) that approximate the stage-discharge relation. These models are fitted using occasional stage-discharge measurements, also known as gaugings. However, two major problems affect the RC estimation: firstly, gaugings and RCs are both uncertain; secondly, the stage-discharge relation can be unstable and subjected to sudden or transient changes (also known as "rating shifts"). For the first problem many authors have proposed methods for the uncertainty quantification (Kiang et al. 2018). As regards the second issue transient changes require a dynamic approach while sudden changes require detecting the times of shift and estimating an RC for each stable period. We propose some tools for the detection of effective or potential sudden shift times in a retrospective analysis. To do this we use two main sources of information: the gaugings and the water level (or "stage") record.

Method

The proposed retrospective analysis of rating shifts is based on three principal steps:

1. Detection of some effective rating shifts using direct observations at the hydrometric station (e.g. segmentation of residuals between gaugings and a reference RC; segmentation of the recessions of the stage record).
2. Detection of all the potential (suspected) shifts using a proxy model (e.g. sediment transport model to detect morphogenic events; correlation with a reference discharge time series).
3. Elimination of the false detected shifts of step 2, if direct observations are available for the concerned period.

For the first step we propose two tools. The first tool is based on the segmentation of the time series of the residuals between gaugings and a time-invariant reference RC. The segmentation method accounts for uncertainty of both the gaugings and the RC. It is a multi change point detection method based on a Bayesian framework. The inferred parameters are the mean of each segment and the change point times that separate the segments. During the segmentation estimation the number of change points is fixed. Thus the procedure is iteratively performed for an increasing number of change points until the optimal segmentation is reached according to a criterion (e.g. BIC, Schwarz 1978). The detected shift times are then adjusted to real events causing the shifts (e.g. the peak of the floods). We then re-estimate the reference RC on each sub-period and re-segment the corresponding residuals in a "top-down" recursive way in order to reveal smaller changes. The second tool uses stage record. It estimates the riverbed morphological changes at hydrometric stations through the analysis of stage recessions. This method assumes that stage asymptotically tends to the river bed elevation as discharge tends to zero (Łapuszek & Lenar-Matyas 2015). After the identification of stage recessions, a Bayesian regression is performed to each recession using a two-exponential model and an asymptotic parameter. The time series of the asymptotic parameter is then segmented through the same method applied to the gaugings residuals. A change in the asymptotic parameter, strictly correlated to the riverbed elevation, may reveal a rating shift. This tool also provides important information about the magnitude of the shift. Finally, a verification of the consistence of the results from the two tools is performed.

While the first step searches for the "observed" shifts and would miss any shift not evidenced by gaugings or recessions, the second step searches for all potential shifts. To this aim we propose two tools. The first tool uses the stage record to perform a sediment transport analysis. In the absence of direct observations of sediment transport, the model is calibrated against the "observed" shifts of step 1. The analysis requires the knowledge of the temporal behavior of the

river bed elevation in order to compute the critical stage for sediment motion. To do that the results of step 1 are used to estimate the RC parameters (among which there is the river bed elevation) for each detected stable period (Mansanarez et al. 2019). A cumulative transport is then computed in order to detect all the other potential morphogenic events. The second tool is based on the correlation analysis between the discharge time series and the output of a simple hydrological rainfall-runoff model. This in an ongoing study and further investigation is needed. A "stable" neighboring station could also be considered in the correlation analysis.

Finally, a second set of potential and effective shifts times is available for the Step 3. An RC is estimated for each period of stability among the shift times. If there is no significant change of the RC parameters between two successive periods, the corresponding shift time is discarded.

Results

The proposed method for rating shifts detection has been applied to two case studies mainly affected by morphological changes: the Ardèche River at Meyras, France and the Wairau River at Barnett's Bank, New Zealand. We report in Figure 1 the results of the first case study only. The results are quite encouraging if compared to the official shift dates (black crosses). However some of the proposed tools are site-specific. Stations also affected by progressive phenomena such as hysteresis, backwater and aquatic vegetation growth may be more challenging. The generalization of the method requires further investigation.
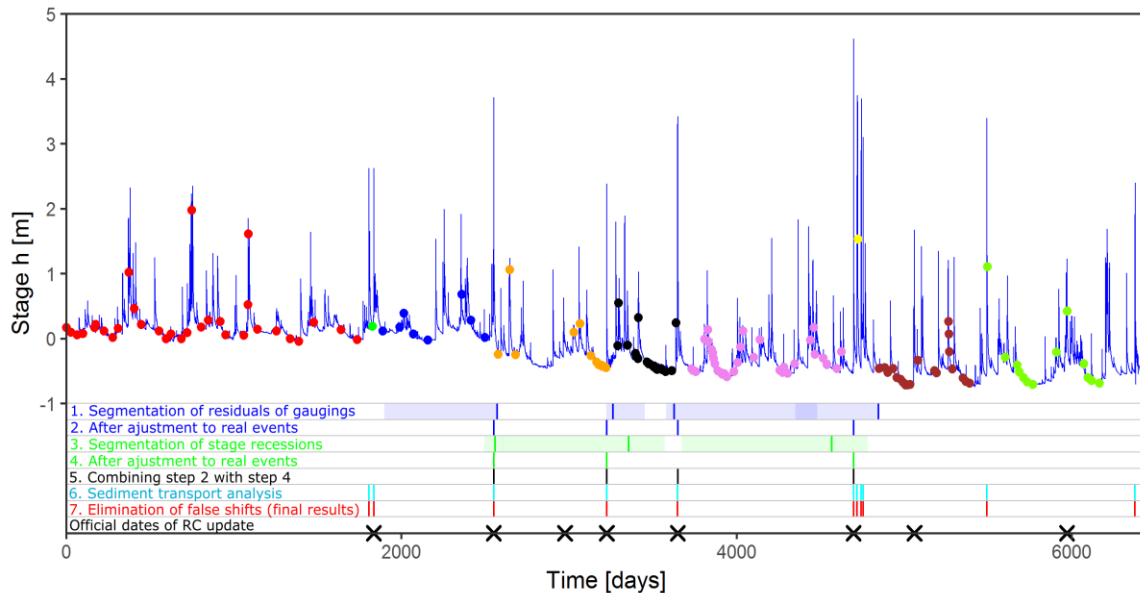

Figure 1 The set of rating shift times for each step of the proposed method plotted against the stage record for the Ardèche River at Meyras, France (period 11/2001-06/2019).

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