A periodic approach to river geometry and its implication for At-Many-stations Hydraulic Geometry

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ABSTRACT

The geometry of river cross-sections is known to vary at the scale of a hydrographic network, with a strong dependence on drainage area, but also at much shorter scales within a reach (e.g. pool-riffle sequences). We propose a simplified, periodic approach to this high-frequency variability.

1 INTRODUCTION

The high frequency variability of river geometry is not easily taken into account in hydraulic models at the scale of a large hydrographic network, in many cases we have to make a crude assumptions such as geometrical parameters correlated with large scale descriptors (e.g. upstream drainage area) as in DHG (downstream hydraulic geometry, see e.g. [1]). However, a higher frequency variability is superimposed on these trends, with facies or alternating morphological units: shallow portions with fast flow velocity (e.g. riffles, or crossings between two meanders) alternate with deep portions, with low flow velocity (pools, e.g. the outside of the meander curves). Such sequences occur at intervals of 5 to 10 times the bank-full width. In addition, the irregularity of the stream geometry for a given flow rate (Considered constant at the reach scale) generates a variability of the hydraulic variables (width, depth, hydraulic radius, velocities, the energy slope, etc.). Therefore, any geometric variability "smoothed out" by a uniform approach will come back in the form of a bias in effective friction parameters, thus reducing the robustness of the model.

1.1 *Periodic approach*

This variability represented in the rating curves at the scale of some morphological sequences, coined "At-Many-stations Hydraulic Geometry" (AMHG), is a new research topic (see for example [2]). However, very few approaches based on the simple 1-D steady-state flow equation (backwater curve) have attempted to explain the emergence of AMHG and the longitudinal variability of rating curves at the reach scale. Nonetheless, it is likely that the AMHG is the result of a coevolution of geometrical bed parameters [3], and of an emerging covariance structure between these parameters at the reach scale. We can take advantage of this covariance structure to reduce the dimensionality of the bathymetric model, without smoothing out the high frequency variability as in the uniform approach. At the end, it can be represented by strictly periodic functions, which allows at the same time a quasi-analytical resolution of the backwater curve equation (Fourier transform, the resolution in the frequency domain, and inverse transform), sending upstream and downstream boundary conditions at $\pm\infty$.

1.2 *Resolution's method*

For this, we established our approach on the Shallow Water Equations (SWE) that requires data such as along-stream channel and floodplain bathymetry, friction parameters, and reach boundary conditions (typically, upstream infow hydrograph and downstream rating curve). Generally, these data are difficult to recover at sufficient spatial resolution, but the use of the periodic resolution will decrease the system's degrees of freedom (elimination of boundary conditions).

In our case, we worked on a dataset of 17 reaches of small French rivers extensively studied in [4]. In our approach, a reach is modeled as a succession of pools and riffles in a trapezoidal cross-sections, with periodic series for the talweg depth anomaly, the bankfull width and the bankfull depth, the banks slope and floodplain lateral slope. Furthermore, we put in the interactions between the bank and floodplain using the "Debord" formulation [5]. The mean spatial period of the sequences is obtained using wavelet analysis. The spectral treatment of AMHG on this dataset allowed us to reproduce a 1-D model of variability in rating curves at successive cross-sections by solving the SWE, with a periodic parameters describing the along-stream covariance structure of the main cross-sectional parameters. This parsimonious model could be well-suited for inverse problems in which the in flow discharge has to be estimated using the sole measurement of water level, without a knowledge of low-flow bathymetry and friction parameters (e.g. in remotely-sensed discharge estimation).

We propose perspectives to extend the results obtained in 1-D in the case of a 2-D steady-state flow, using a conformal mapping of a periodic half-floodplain into a rectangular, computational domain where a spectral solution is to be calculated.

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