Developing a Detailed Reach-Scale Digital Elevation Model of the Congo River's Main Stem Bathymetry

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Abstract

A reach-scale high resolution digital elevation model (DEM) of the Congo's main stem bathymetry is presented. The Bathymetry DEM covers a multichannel reach of the main stem situated in the Cuvette Centrale, and is developed from a series of in-situ measurements of bathymetry, water surface elevation and discharge that were obtained during a CRuHM fieldtrip in summer 2017. The main stem's complex network of channel threads requires a bathymetry modelling methodology that is capable of intelligently interpolating the raw bathymetry measurements. The methodology must also estimate a significant portion of the bathymetry, since it is not feasible to measure the entire extent of the massive and complex channel network that this study reach is comprised of. This methodology is also presented. Remote sensing from satellites is increasingly being used to resolve the scarcity of contemporary hydrological and hydrographic measurements in the Congo Basin. However, river channel bathymetry information cannot yet be reliably obtained from remote sensing methods. This is problematic since river channel representation has been shown to be an essential input into a hydraulic model. Analyses of satellite observations suggest that, relative to other global rivers, in-channel flows on the Congo's main stem represent a relatively large proportion of total flows through the river-floodplain system. This implies the Congo's in-channel bathymetry may play a relatively large role in controlling Congo main stem hydrodynamics. When used in a hydraulic model, the bathymetry DEM presented here will provide new information on Congo in-channel hydraulics and the extent to which bathymetry controls the Congo's middle reach hydrodynamics. It will help better quantify the capacity of the Congo main stem channels through the Cuvette Centrale, and thus provide further insights into the extent to which the main stem channel floods in this region. It is also intended to be used for testing simplified methods of Congo bathymetry representation that are necessary for larger scale hydraulic models.

Modelling the Bathymetry and Hydraulics of the Congo's Main Stem Through the Cuvette Centrale

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1. Introduction

A scarcity of river bathymetry data along the middle reach of the Congo presents a major challenge for river hydraulic research and in particular numerical hydraulic modelling. In this study we conducted a hydraulic survey of a 70km study reach (shown in Figure 1 & Figure 2) in order to investigate the middle reach bathymetry and its influence on hydraulics.

Figure 1: Hydraulic Survey of Study Reach on CRuHM Fieldtrip

Obtaining full bathymetry of the Congo's massive multichannel main stem is not feasible, even on a discrete study reach. We have therefore developed a bespoke bathymetry modelling methodology suitable for sparse sonar data on a multichannel river. The results of the bathymetry model (BM) are presented in the form of a bathymetric Digital Elevation Model (DEM).

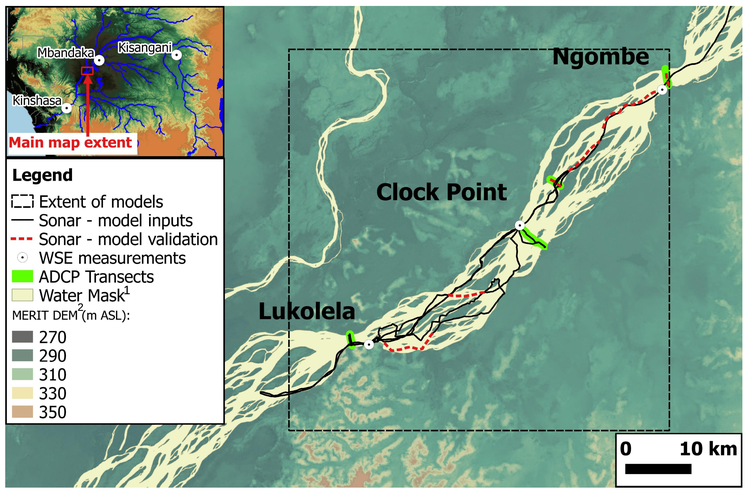


Figure 2: Map of CRuHM fieldtrip hydraulic survey with annotations

2. Methods

- The bathymetry modelling process is described in Figure 3. All calculations are performed in the QGIS open source software.
- Geometric validation of the completed Bathymetric DEM (Section 3) was carried out by comparing it against a validation dataset comprising five sections of sonar data.
- The bathymetric DEM was then fed into a hydraulic model using LISFLOOD-FP[3] (Section 4). Steady state simulations were run using the discharge collected during the field trip, and modelled velocities were validated against ADCP measurements.

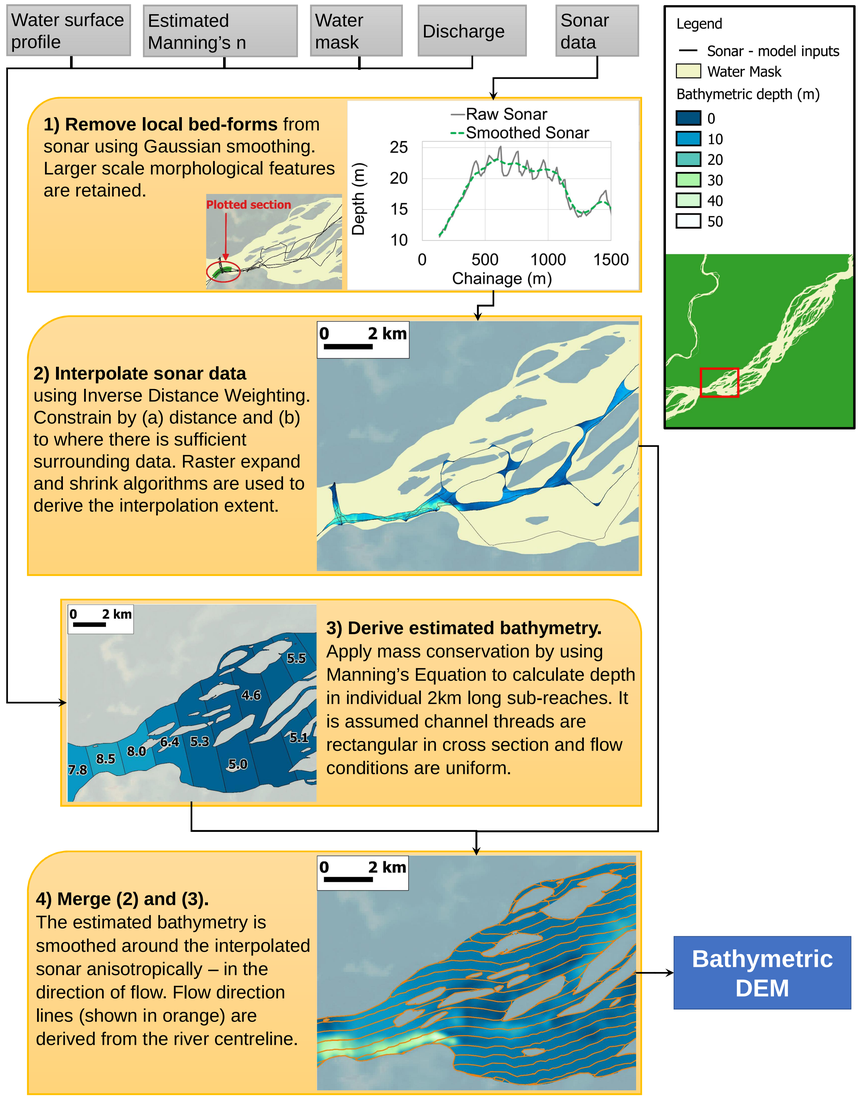
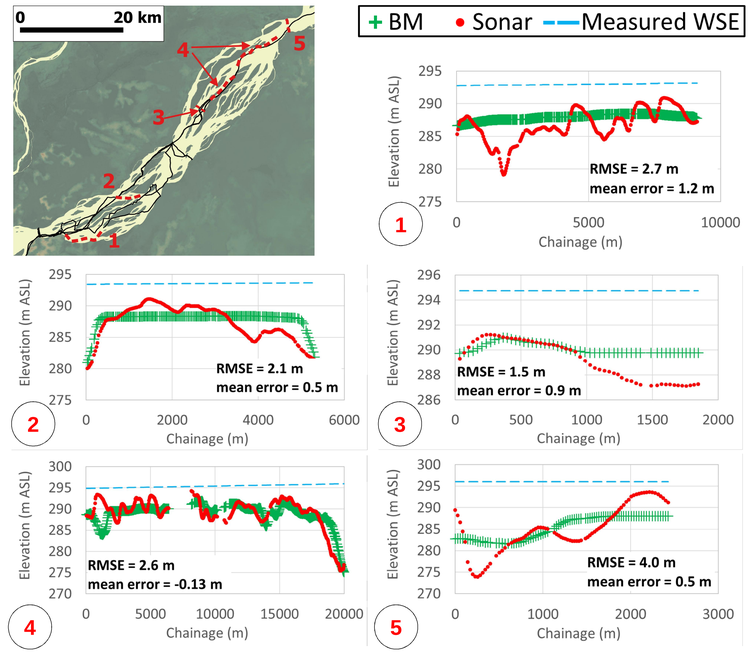


Figure 3: Flow Diagram Showing the Bathymetry Model (BM) Process

3. Results – Geometric Validation



4. Results – Hydraulic Validation

Using the LISFLOOD-FP 2D Inertial Formulation, a spatially uniform Manning's n value of 0.028 was assigned following adjustment to match the modelled water surface profile to the observed. A 25m cell size was used. The resulting cross sectional average velocities were compared against the ADCP measurements, the results are summarized below.

Location	Velocity (m/s)		% error
	Hydraulic Model	ADCP Measurement	
Ngombe	0.84	0.77	9
Clockpoint	0.69	0.82	-16
singlethread section	1.05	0.86	22

5. Conclusions and Future Work

- The Bathymetry model (BM) presented derives a physically realistic bathymetric DEM of a large and complex multichannel river. The BM requires sparse observations of river depth only. Other required inputs can be obtained from publically available satellite data.
- Geometric validation detected a tendency for the BM to under predict depth. Adjustment of the Manning's n input into the BM could reduce this under prediction. Hydraulic validation showed velocities predicted by the BM to be both above and below observed values.
- Future work includes applying the BM to a larger part of the Congo's middle reach, and automation of the BM to enable rapid adjustment of BM parameters such as Manning's n, and smoothing parameters.

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