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Processing of Hyperspectral Aerial Images to Characterise the Bathymetry of Rivers

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A b s t r a c t

Fluvial remote sensing of river bathymetry is crucial for characterizing the topography of the riverbed and monitor changes in habitat at large scales. Hyperspectral data enables bathymetric retrieval through optical models. On the Ain River (France), multiple hyperspectral aerial campaigns with different sensors were conducted and processed to create bathymetric maps of the river for different flow conditions. In particular, a continuous bathymetric map was produced for a 20 km reach of the river with a median error of 20 cm for depths up to 2.5 m. Despite the uncertainties of the models tested, the result are more robust spatially and over a wider range of depth and flow conditions than optical models based on traditional colour imagery.

Keywords: bathymetry, hyperspectral, remote sensing.

1. INTRODUCTION

River bathymetry is important for mapping riverbed topography at the mesohabitat scale, and to monitor channel morphology changes after restoration actions. One promising tool for bathymetric remote-sensing in river environments is hyperspectral imaging which aims at establishing an empirical optical model based on the Beer-Lambert law by linking water depth with at-sensor radiance as measured through a high number of narrow spectral wavelengths. Compared to optical bathymetric models calibrated with more traditional colour or multispectral imagery, hyperspectral images have been shown to predict depths in deeper waters (up to 6 m), and are thought to allow for more robust depth detection (Legleiter and Fosness 2019). However, the ability of models to accurately predict bathymetry over long spatial extents (more than 10 km, and requiring several images) at different flow conditions and with different channel bottom substrates is poorly understood.

2. MATERIALS AND METHODS

Hyperspectral remote sensing data was acquired over the Ain River (France) during three campaigns that each used a different sensor, two in 2015 and one in 2021. One of those campaigns acquired information for a reach of 20 km while the other two focused on smaller reaches of the river (100–300 m). This data was coupled with a 2D bathymetric model built at the scale of the studied reach in order to adjust for differing discharge conditions between campaigns (low flow conditions at 27 m^3/s and mean flow conditions at 127 m^3/s), and to provide spatially-continuous calibration and validation data for the full extent of the imaged reaches.

The dimensionality of the hyperspectral data was increased by calculating band rations and the ln() transform of spectral bands and their ratios. By iterating through every such wavelength combination, the strength of the linear relationship between depth and reflectance was assessed for the full spectral resolution of each sensor – discharge combination. Bathymetric maps were then produced and compared to each other and to the validation dataset in order to investigate the spatial distribution of errors along the reach.

In the case of the data available for the 20 km reach, the model was built by focusing on smaller river reaches to be able to assess the portability of site-based models to long river corridors.

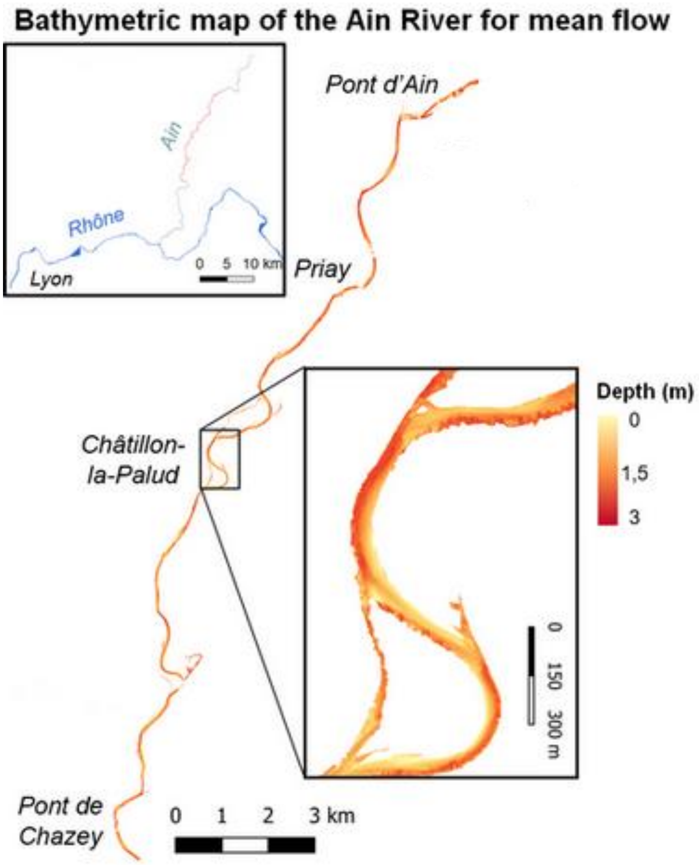

Fig. 1. Bathymetric map of the Ain River for mean annual flow conditions (127 m^3/s).

3. RESULTS

Multiple bathymetric maps were able to be built at the site-level with a high vertical accuracy (~15 cm). In addition, the campaign acquired under mean flow conditions (127 m^3/s) in 2015 was also able to predict low flow bathymetry (27 m^3/s) with a similar accuracy to the low flow campaign from 2015 (27 m^3/s).

When expanding the bathymetric models from the shorter reach to the full extent of the 20 km campaign (Fig. 1), accuracy was reduced (~20 cm). This reduction in accuracy is related to: (i) the presence of pool areas (5% of the study reach, depths > 2.5 m at mean flow) for which quality calibration – validation information was not available, (ii) the presence of glint and turbulence on the water surface, and (iii) vegetation shadows. In addition, (iv) changes in the water column and the riverbed properties led to errors for some wavelengths combinations, but not others. Therefore, the best bathymetric model for a given reach may not always be the one with the strongest correlation to the calibration data because the range of good bathymetric models may be narrower in practice.

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