CGU HS Committee on River Ice Processes and the Environment
18th Workshop on the Hydraulics of Ice Covered Rivers
Quebec City, QC, Canada, August 18-20, 2015

Quantification of under ice cover roughness

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INTRODUCTION

Ice cover roughness is a key component of flow resistance for flow exposed to river ice. The roughness of under ice cover is difficult to determine directly because of its ephemeral nature as well as because of the difficulty to realise in situ measurement. Ice cover roughess is generally determined from velocity distribution analysis (White, 1999) or from manual (Crance and Frothingham, 2008) and visual (Demers et al., 2011) examination. As a result, very few studies have directly quantified the under ice cover roughness.

Rougness investigation is a common theme in gravel-bed river studies the terrestrial LiDAR for roughness quantification is well established (Heritage and Milan, 2009). Although LiDAR have been use to characterise the ice cover surface, it has not been used to quantify the under cover ice roughness. The aims of this study is to quantify the under ice cover rougness using a LiDAR and to examine the relationship between the flow structure and the roughness quantification.

METHODS

Ice blocks covering 2 m long by 1 m wide were cut into the ice cover of two river reaches in the Matane and Cap-Chat Rivers in March 2010. The ice blocks were flipped over to expose the underside. A terrestrial lidar (Leica ScanStation) was used to produce high density microtopographic clouds (1 000 000 points / m^2). The cloud was then filter to produce DEM at 2 mm resolution. DEM standard deviation and semi-variance analysis were used to quantify the ice cover roughness. River locations were selected to avoid frazil accumulation under the ice cover.

Prior to the ice block extraction, velocity measurements were obtained immediately downstream from the location of the block to produce velocity profiles. A sontek ADV was used to produce profiles having between 10 and 30 points depending on the flow depths.

Sampling rate and period were 25Hz and 1 min, respectively. Two hydraulic properties were extracted from the velocity profiles: the shear velocity under the ice and the depth at which the maximum velocity occurs. The shear velocity was computed from the velocity gradient near the ice cover.

RESULTS

Figure 1 shows the 2mm DEM for the 12 ice cover undersides. A visual appraisal allowed identifying four scales of roughness under the ice cover: smooth surfaces, individual cust, cusp surfaces and pseudo-dunes. Smooth surface encompasses mm scale microtopography. Cusps are cm scale microforms carved into the ice. They can be isolated into a smooth surface (P6) or they can cover the entire surface (P9). Pseudo-dunes are large scale microforms (dm) that have asymetric shape mimicking upside down dunes (P11). An under ice cover can present one or a combination of these rougnesses.

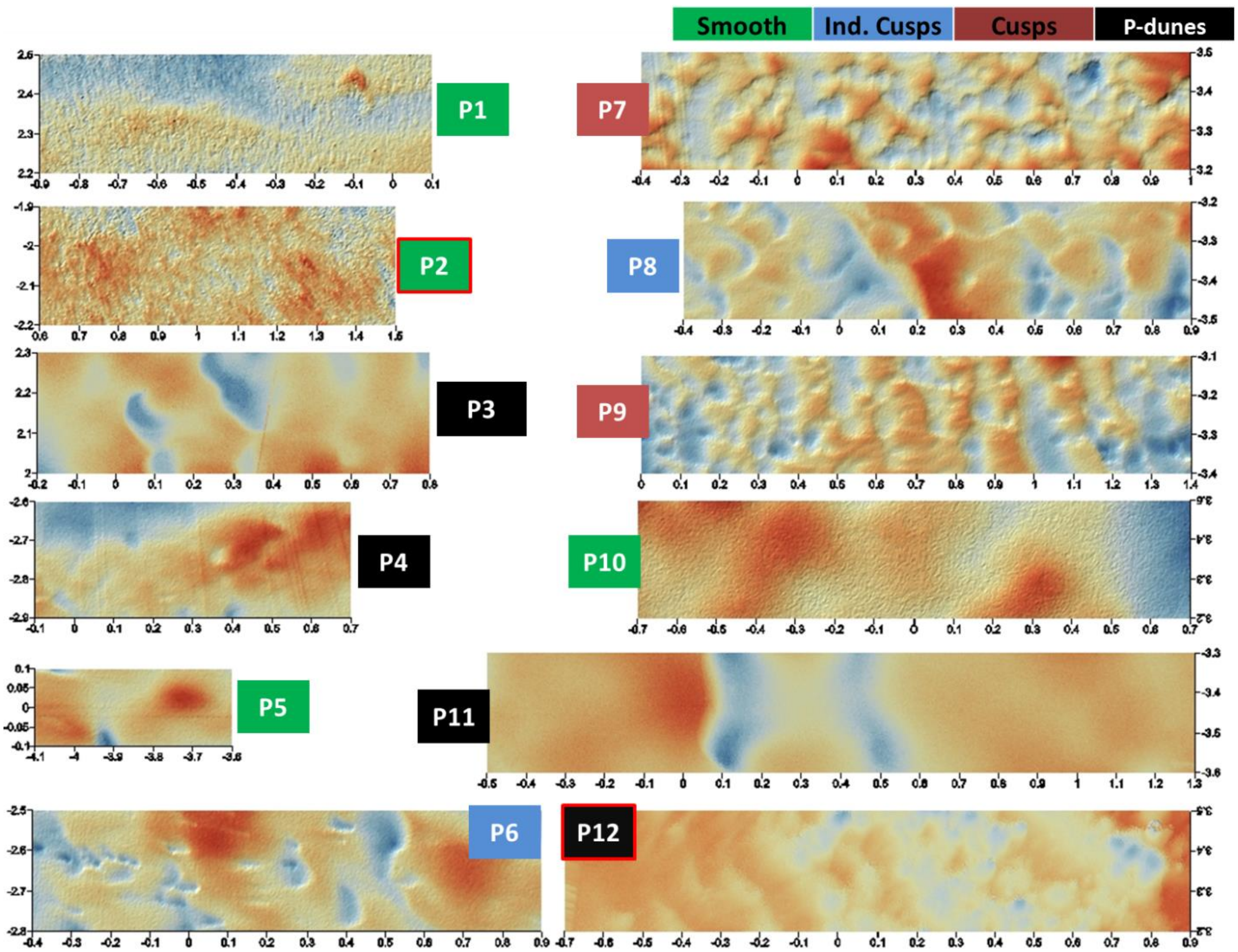

Figure 1. DEM from LiDAR scans on 12 under ice cover surfaces.

Figure 2 shows the standard deviation (SD) of the DEM for the 12 ice cover undersides as well as a gravel-bed surface with a SD=12 mm for comparison. Semi-variance analysis was also performed and the semi-variance values at specific lag were strongly correlated with the SD values. The largest SD values are found for the pseudo-dunes and cusps surfaces roughness types.

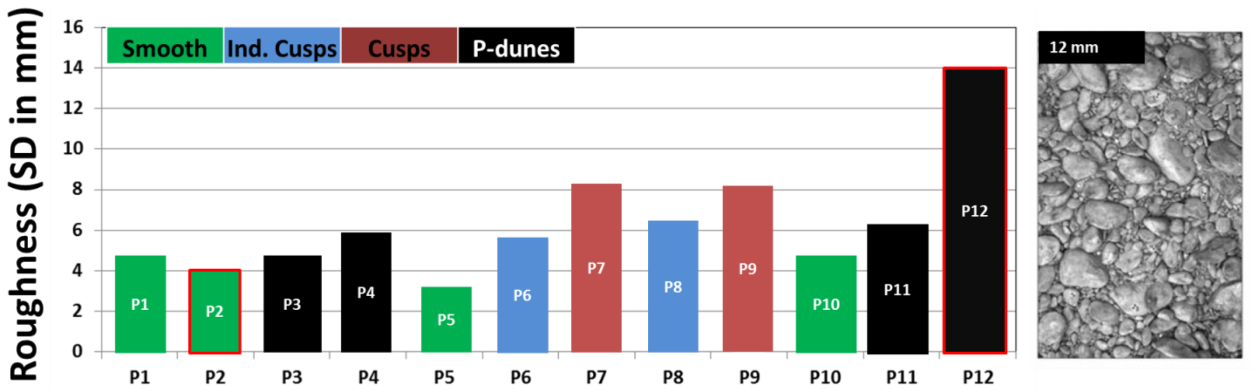

Figure 2. DEM standard deviation for the 12 under ice cover surfaces. For comparison, a gravel bed surface with a standard deviation of 12 is also shown.

Figure 3 shows the shear velocity near the ice cover and the depth at which the maximum velocity occurs against the roughness SD values for the 12 ice cover undersides. For the shear velocity, the relationship is weak at best since there is a wide range of shear velocity values for similar roughness values. For the depth at which the maximum velocity occurs within the profil, there is a weak tendency for the proportional depth to decrease as the roughness value increases. This would support the finding of Crance and Forningham (2008) that observed changing positions of maximum velocities within the height of effective flow for varying roughness.

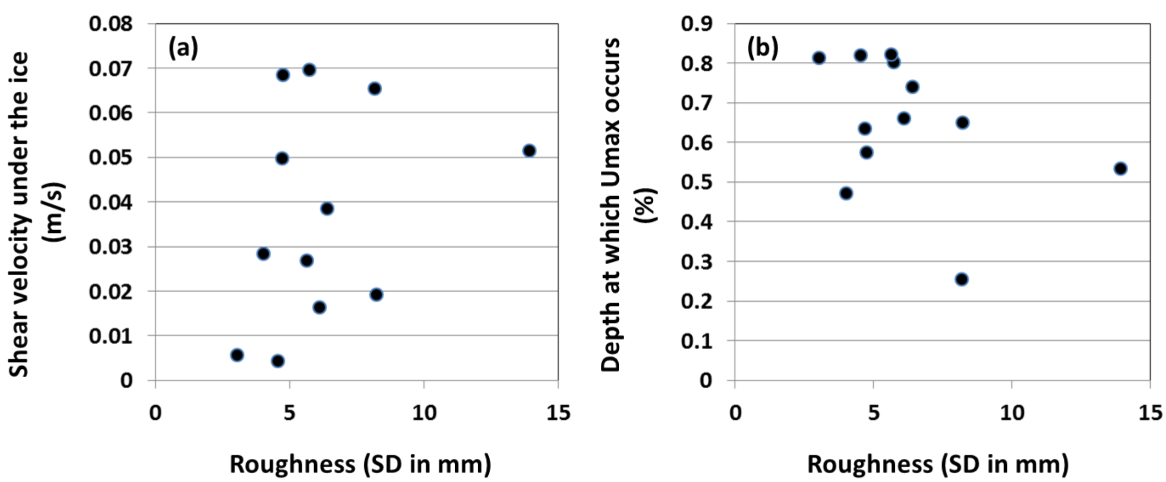

Figure 3. Relation between (a) the shear velocity and (b) the depth at which the maximum velocity occurs against the standard deviation of ice cover roughness.

CONCLUDING COMMENTS

Under ice cover roughness was quantified using LiDAR techniques. The method is disruptive because the ice cover has to be cut, but it proved to be effective in quantifying the complex microforms and microtopography of the under ice cover. To fully assess the relationship between under ice cover roughness and the flow structure, the quantification of roughness under larger blocks as well as of the river bed topography is needed.

Acknowledgments

NSERC and several field assistants.

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