Development of a Digital Water Surface Model and in situ bathymetric correction of multi-spectral LiDAR; a case-study at the Bow and Elbow rivers

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ABSTRACT

Airborne LiDAR has established itself during the past two decades as a unique high-resolution remote sensing technology due to its 3D sampling of land cover and terrain, and its ability to penetrate into vegetation structure from treetop to ground. At the same time, airborne LiDAR bathymetry has been rapidly evolving in the context of capturing shallow water bodies, utilizing either a green laser due to its better penetration through water body or a combination of green and near infrared laser beams for better water surface detection. Cutting-edge LiDAR technology produces active multi-spectral (MS) 3D imagery, which allows multipurpose spectral sampling of land cover combined with moderate bathymetric capabilities for shallow coastal and river waters. Recent floods in Canada have increased the interest in improved flood modeling based on riverbed geomorphology data which may be collected by such multi-spectral LiDAR systems. However, bathymetric correction should be applied to raw data based on proximity to the overlying water surface. Current algorithms within off-the-shelf (OTS) software were developed for coastal waters and lakes, and therefore have difficulties with rivers possessing high stream gradients. The objective of this paper is to present (i) a new methodology of rough bathymetric correction, (ii) methods of deriving digital water surface model, (iii) preliminary analysis of system depth performance from the case study, and (iv) to assess water surface elevation uniformity within stream cross sections. LiDAR data were collected over two areas of interest (AOI) inside the Calgary City limits, featuring Bow River as the first AOI and Elbow River as the second, with a multi-spectral Teledyne Optech Titan system. The LiDAR system collected data at three wavelengths: 1550 nm, 1064 nm, and 532 nm. Planned survey parameters were 200 kHz per channel with 36 degrees of field of view. Flight lines were planned with 50% overlap at an altitude 500 m above ground and provided double coverage for all overlapping lines with a planned pulse density of 18 points per square meter per channel or 56 points per square meter overall. A proposed simplified correction algorithm is based on a shift (scaling with $k = 0.765$) in Z-values of riverbed returns, normalized toward the overlying water surface, and disregards dependence from a laser beam angle of incidence for each point. For this purpose, two types of digital water surface models have been developed: the first based on LiDAR intensity and the second based on virtual transects derived from LiDAR points within a priori defined water boundaries. The resulting correction proved superior to that of the OTS software. In addition, water surface variations of up to 80 cm were observed across two channels of the river around a small island, illustrating that assuming flat water surfaces is not a viable approach for bathymetric correction in dynamic river environments.