Small footprint, full waveform LiDAR modelling of canopy 3d structure in complex, semi-natural woodland communities

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Abstract

The last decade has seen the rapid emergence of LiDAR technology as a tool for terrain and vegetation analysis. Large footprint LiDAR systems developed by NASA have been used to examine the three dimensional structure of forest stands with a view to measurement of key forest parameters including biomass, LAI, above ground carbon content and carbon flux. They have also provided a basis for satellite deployment of LiDAR technology (e.g. ICESAT) which will enable global monitoring of these variables. In parallel, there has been a dramatic growth in small footprint, discrete return systems that have found extensive application in terrain modelling, measurement of tree heights and statistical estimation of other key forest variables.

To date, it is undoubtedly the case that small footprint systems have been limited to measurement of discrete returns – first, last and sometimes one or two intermediate pulses – by data volume and bandwidth issues which have prevented the capture and storage of small footprint, full waveform returns. A consequence of this is that their potential for measuring the full vertical structure of forest canopies has been restricted.

This paper will describe the design, construction and implementation of a small footprint, full waveform LiDAR tailored for forestry applications. The system measures and records the full waveform return for sub-meter footprints at a frequency of up to 70 Khz. It has a vertical height resolution of 15cm over a maximum height range of approximately 65 m. The system is a fully integrated extension to an Optech ALTM 3033 device with Applanix GPS and IMU positioning.

The performance of the system will be evaluated by presenting results from full waveform LiDAR surveys of Woodwalton Fen Site SSSI in Eastern England and the Alice Holt research forest in Hampshire. Waveform properties for both deciduous and coniferous forest types will be described and their potential for measuring canopy height, openness, density, vertical structure and gaps will be evaluated. A methodology for assessing the accuracy of the results will be presented based on gap fraction analysis from hemispherical photography and ground-based laser scanning techniques.

The results will highlight biases which occur when discrete return observations are used to model 3d structure. They will also demonstrate that such bias can be overcome with full waveform data and effective calibration/integration and modelling techniques. The results carry important implications for measurement of above ground biomass, carbon content and LAI.