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Analysis of full-waveform LiDAR pulse properties for vegetation discrimination and characterisation

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Accurate information about vegetation/forest structure, health and growth is needed in many fields of forest management, environmental planning, resource management, fire risk assessment and soil moisture retrievals. Airborne laser scanning has proven over the last nearly two decades to be an invaluable tool in describing vegetation and providing 3D information about its structure. In particular, the new generation full-waveform laser scanners offer an excellent source of not only accurate XYZ information, but also allow the extraction of additional parameters in the process of light curve analysis and interpretation.

This analysis was carried out on full-waveform airborne LiDAR data that was collected with a Riegl LMS-Q560 instrument in the Yanco area (NSW) in Australia. The initial analysis was performed on the data acquired in 2006 during the National Airborne Field Experiment. The way the waveform data was extracted made it impossible for the targets included in the footprint to be geo-coded accurately. Nevertheless it was still possible to analyse the waveforms' shapes. For the purpose of this experiment two test sites were chosen – one very small site covering only a single Eucalyptus tree, and the second over an orange orchard (218m by 110m). Analysis included peaks detection, pulse width calculation and waveforms classification according to the number of peaks present within them. Subsequently, an amplitude-width analysis was carried out, including two-tailed t-tests, histograms and scatter plots. Based on the assumption that the first and middle returns were from vegetation (due to specifics of the sites), it was concluded from the analysis that vegetation returns are wide and weak (wider than emitted pulse). The scatter plots of amplitude versus width according to the pulse type played a crucial role in the analysis - they clearly indicated different 'fingerprints' of vegetation and last return (assumed to be a mixture of vegetation and ground returns) distributions. By overlaying vegetation (first and middle) returns over last return scatter plots it was possible to separate ground echoes from vegetation echoes in last return data. Consequently, it was found that ground returns have narrow widths and high amplitudes. After ground pulses were separated using simple empirical thresholds on width and amplitude, the t-test between width and amplitude mean confirmed that vegetation and ground returns are significantly different from each other.

Following the initial experiment, further analysis was carried out on data captured in September 2011 during the Soil Moisture Active Passive Experiment 3, also in the Yanco area in Australia. This waveform data was geo-coded more accurately, allowing elevation-based validation of the amplitude-width analysis against ground truth.

The strong influence of vegetation properties on the structure of return pulses indicates great potential for improved measurement of vegetation characteristics such as foliage distribution using airborne laser altimetry.