Understory trees in airborne LiDAR Data –
Biased probing due to transmission losses and echo-triggering mechanisms

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Understory trees in multilayered stands are often ignored in forest inventories. Information about them would benefit silviculture, wood procurement, and biodiversity management. Cost-efficient inventory methods are needed and airborne LiDAR is a promising addition to fieldwork. The overstory, however, obstructs wall-to-wall sampling of the understory using LiDAR, because transmission losses affect echo-triggering probabilities and intensity (peak amplitude) observations.

We examined the potential of LiDAR in mapping of understory trees in pine (*Pinus sylvestris L.*) stands (62°N, 24°E), using careful experimentation. We formulated a conceptual model for the transmission losses and illustrated that loss normalization is highly ill-posed, especially for vegetation.

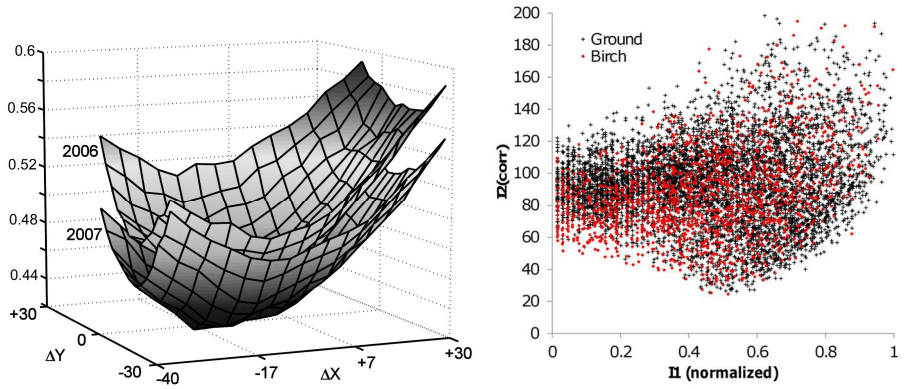
We could show that pulses are subject to power losses, up to 10−15%, even if an overstory echo is not triggered.

In LiDAR sensors, quantized intensity values start from binary zero, but actually should include an offset, the noise level. We estimated these empirically to enable the modeling of losses.

Constraining to low-loss pulses and ground data, we estimated parameters for compensation models that were based on the radar equation and employed the geometry of the pulse, as well as the overstory intensity observations as predictors. Intensity variation of second-return data was reduced, but in all, the intensity data were deemed of low value in species discrimination.

Our results highlight differences between sensors in near-ground echo-triggering and height data. Area-based LiDAR height metrics from the understory had reasonable correlation with the density and mean height of the understory trees, whereas assessment of tree species seemed out of reach even if the transmission losses were compensated for.

We conclude that canopy induced transmission losses are a general impediment for radiometric analysis of discrete-return or waveform LiDAR data. An inherent filtering skews the properties of the scatterers that produce subsequent echoes.



Removal of XY offsets in LiDAR data was based on using small understory trees as 3D signals. Trends remain in transmission-loss normalized second-return intensity data.