Geophysical Research Abstracts
Vol. 21, EGU2019-10292, 2019
EGU General Assembly 2019

Stand scale reconstruction of architectural tree models from unmanned aerial vehicle laser scanning (ULS) data

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Forests are complex, multiscale systems, where processes on microscale (cell and organ level), single tree scale, stand scale, regional scale and global scale are interlinked and affecting each other. In order to understand these interrelationships, forest monitoring approaches require an adequate integration of all given scale levels. While traditional forest inventory approaches and laboratory techniques focus on point acquisitions on microscale, traditional airborne laser scanning (ALS), aerial imagery and satellite-borne remote sensing (optical and microwave) address the regional scale. This leaves a gap between tree and stand scale, where the arrangement of microscale elements such as leafs and branches could be interpreted with respect to the local stand structure. Addressing the stand scale can improve the understanding of regional structures. In order to close this gap, we suggest the automatic reconstruction of architectural tree models for forest stands, based on point clouds acquired by unmanned aerial vehicle laser scanning (ULS). Tree architecture should describe the detailed 3D organization of single tree objects (i.e. leafs, roots, branches), including position, orientation, dimension and shape, which can be reconstructed by novel computational algorithms and software. Adequate input data for such analysis can be provided by ULS point clouds, which are able to describe 3D tree architectures covering the area of whole forest stands. Processing these highly detailed input data sets with automated reconstruction algorithms allows the object based analysis of branches and leafs. For a mixed forest plot of 1 ha size we captured 13 scan strips with a RIEGL RiCOPTER equipped with a VUX-1LR lightweight laser scanner and an AP-20 (Applanix) inertial measurement unit, leading to a dense ULS point cloud (>10.000 pts/m2). After geo-referencing and strip-adjustment the point cloud was filtered into ground and non-ground points by a progressive densification of a triangulated irregular network. Using a Dijkstra region-growing, starting from the ground surface, single tree objects were segmented. For these single tree objects, models of the branching architecture and foliage structure were modelled. The processing resulted in a 3D stand model including 6466 objects (mostly young growth and shrubs), 1414 trees >10 m tree height, 312 trees >20 m tree height and 95 trees >30 m tree height. All objects are modelled as polygonal objects carrying information on wood volume and leaf count.