Optimizing vegetated coastal environment observations with terrestrial remote sensing

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Highlights: Fine-scale, simultaneously acquired classification from terrestrial lidar and imagery may characterize the tidal and phenological components of LandSat 7 and 8 imagery. Terrestrial lidar provides a way to quantify geomorphological changes in saltmarshes in response to nitrogen fertilization. Adaptation of forest analysis techniques allows biomass models of saltmarshes and mangroves.

Key Words: *Lidar, coastal, mangroves, saltmarshes, LandSat*

Introduction

Coastal environments play substantial roles in geochemical cycles, and are essential for carbon sequestration, coastal armoring, and storm energy mitigation. They serve as the front line of global climate change, subject to and sensitive to potential changes in freshwater, oceanic and atmospheric chemical conditions as well changes in the frequency and intensity of storms. Therefore it is extremely important to determine, monitor and eventually model conditions and function in coastal environments globally. Remote sensing has provided the ability to observe general ecosystem conditions and change at meaningful spatial and temporal resolutions for large spatial extents. However, coastal ecosystems present considerable challenges in the use of remote sensing resources due to the high temporal dynamism resulting from the strong, regular influence of tides and vegetation phenology. This dynamism can be exacerbated by influences such inundation by extremely strong, episodic flooding or storm surge, and snow cover at some latitudes. Characterizing these sources of variation and quantifying their effect on remote sensing observations clarifies the investigation of underlying, long-term ecological changes.

Content

Through a synthesis of terrestrial and airborne remote sensing resources, validated with traditional field methods, we have developed classification, reconstruction and quantification methods for vegetated coastal ecosystems. In saltmarshes, we are establishing fine-scale classification techniques by combining terrestrial lidar observations with RGB imagery. A highly-portable, rapid-scanning, highly-resilient terrestrial lidar, the 905nm, 4mrad resolution, 40m range Compact Biomass Lidar (CBL), built around a SICK LMS151 lidar unit, was developed by the University of Massachusetts Boston in collaboration with Rochester Institute of Technology to meet the challenges of deploying terrestrial lidar in coastal environments. The CBL scans from a tripod in mangrove environments, or a mobile tram system to maximize overhead views of saltmarsh vegetation and creeks while minimizing disturbance. While mangrove classification follows traditional forestry methods, saltmarsh classification techniques utilize observable structure, reflective properties and imagery to separate water, soil and vegetation species.

Throughout the 2015 growing season, fine-scale classifications are being acquired for seven adjacent areas co-located with LandSat 7 and 8 pixels, by scanning with terrestrial lidar at a unique-coverage sampling distance of 5m within each pixel, and combining with overhead optical imagery captured from a portable rig suspending a GoPro Hero3+ camera at a height of 2.5m. The acquisition times for these data corresponds to the times of the satellite overpasses at the Plum Island Long Term Ecological Research site in Massachusetts, USA. Relating the biological and structural components of the pixels to the intensities of the various LandSat spectral bands allows characterization of the various components of the signal, especially the relative contribution of water, vegetation, and exposed soil, depending on the tidal state. We will present validation by manual classification and sensitivity studies in terms of frame-shift of the pixels and component level identification, as well as preliminary comparisons to LandSat data in terms of relating prominent ecosystem components such as water and exposed soil to LandSat per-channel reflectance values.

These classification techniques are also being transferred to NASA Goddard's Lidar, Hyperspectral and Thermal (G-LiHT) airborne instrument package, which acquired data over Plum Island LTER during 2014. The potential to augment the lidar structural classification of water, soil and vegetation species with the hyperspectral and thermal instruments is under investigation. Future saltmarsh overpasses by G-LiHT will be accompanied by simultaneous terrestrial data acquisition, facilitating validation.

In conjunction with the ongoing TIDE (Trophic Interactions in Detrital Ecosystems) project to study the effects of nitrogen fertilization on saltmarsh ecology we employ the CBL to examine creek geomorphology. Nitrogen fertilization has been associated with loss of conserved creek bank structural form, via changes in the root morphology of creek bank vegetation [1]. Preliminary studies in 2014 suggested that analyzing lateral sections of creek banks extracted from lidar scans can provide a quantification of structure loss. Throughout 2015 we are acquiring a temporal series of scans of the complete experimental and control creeks, and investigating geomorphological differences with a spatial function-fitting method. Scans are acquired with a purpose-built tram system allowing the lidar to be deployed above the center of each creek. Scans are then co-located by manual alignment and segmented perpendicular to the predominant creek direction. Segments from each slice of the control creeks are fitted to quadratic functions and the fit of experimental creek segments to these functions is tested to describe geomorphological differences.

Species-level classification of saltmarsh vegetation also facilitates biomass estimation through a combination of individual unit reconstruction to estimate density, and volumetric analysis of polygons formed by fitting facetized meshes to lidar data. Preliminary studies at Thompson Island, Nantucket Island, Plum Island and Waquoit Bay (Massachusetts, USA) throughout 2013 and 2014 suggest these techniques are particularly effective in saltmarshes where the influence of salinity gradients results in highly conserved areas of vegetation species. Validation at a fine scale will be facilitated by traditional field measurements of vegetation at Plum Island during 2015. We present the biomass estimation methods, as well as extrapolative modeling techniques under development.

In addition to the saltmarsh deployments, the CBL was deployed alongside the collection of traditional field measurements as part of a validation campaign for NASA's EcoSAR (Synthetic Aperture Radar) instrument in mangroves in Drake's Bay, Costa Rica in 2014. This also served as an initial study of the capabilities of terrestrial lidar to provide reconstructions of mangrove vegetation for quantified analysis. Stems, branches and leaves were captured effectively by high-density scanning schemes, and reconstructed for biomass quantification utilizing an adaption of the Quantitative Structure Modeling (QSM) [2] which is typically used for terrestrial forests. We are investigating two alternative approaches for quantification of the biomass of the morphologically distinct exposed root structures of the mangrove species. We show initial results from both structural inversion, which allows the utilization of QSM to model the roots of each tree, and a volumetric voxelization analysis applied only to the root layer.

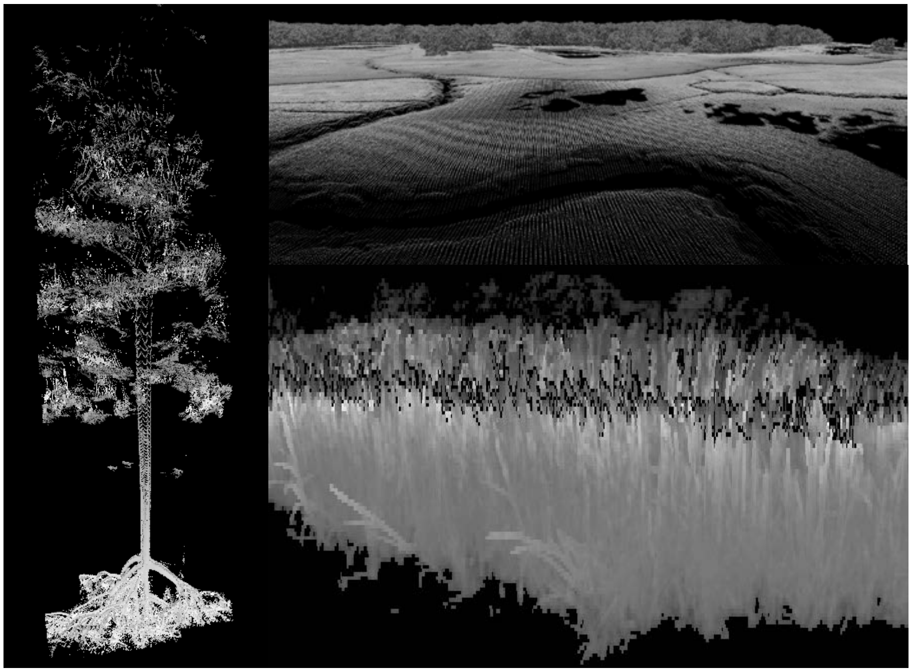

Figure 1: (Clockwise from top-left) Point cloud extracted from multiple CBL scans for a mangrove tree in Drake's Bay, Costa Rica; from G-LiHT lidar instrument for Plum Island saltmarsh, MA, USA; and reprojected from CBL scan for Thompson Island saltmarsh, MA, USA.

References

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