# Determining Vegetation Metrics Using a Temporal Waveform-Resolving Lidar at Assateague Island National Seashore

Amar Nayegandhi[1] and John Brock[2]

[1] ETI Professionals, Inc., Contracted with U.S. Geological Survey, Florida Integrated Science Center, Center for Coastal and Watershed Studies, St. Petersburg, Florida

[2] U.S. Geological Survey, Florida Integrated Science Center, Center for Coastal and Watershed Studies, St. Petersburg, Florida

The NASA Experimental Advanced Airborne Research Lidar (EAARL) acquired airborne lidar data for beach and vegetated communities at Assateague Island, Maryland, in September 2002 and August 2004. The EAARL system is a raster-scanning, temporal-waveform-resolving, green-wavelength lidar designed to map nearshore bathymetry, topography, and vegetative structure simultaneously. The NASA EAARL sensor records the time history of the return waveform for each laser pulse, enabling characterization of canopy structure and "bare earth" under a variety of vegetation types. Each lidar waveform describes the time-resolved amplitude of a reflected laser pulse as a function of the laser pulse time of flight at 1-nanosecond duration. The EAARL system also includes a 3-band color-infrared (CIR) multispectral camera that is tightly coupled with lidar acquisition. Information from EAARL overflights and accompanying ground-based field measurements is used to evaluate the capability of lidar data to determine the vertical distribution of canopy and sub-canopy across a diverse set of vegetation classes.

The EAARL small-footprint waveform represents the amount of energy returned to the sensor as a function of a series of equally spaced time intervals. At the nominal flying altitude of 300 m, a single EAARL laser pulse illuminates a small horizontal sampling area (20-cm-diameter footprint). As a result, in a forest environment, the information content of the returned laser signal includes a small portion of the canopy, which may describe the vertical distribution starting from the side of a tree crown *versus* the top or peak of the crown. This principle is in contrast to large-footprint lidars, where the returned waveform contains information on forest canopy and multiple forest elements rather than individual trees. To describe the vertical structure of a vegetated canopy, several individual small-footprint laser pulses are combined to make a composite "large-footprint" waveform that defines a larger horizontal area. The size of this composite footprint is a variable and can be determined in post-flight processing software, unlike the large-footprint lidar systems, where footprint size is determined by optical laser-beam-divergence hardware prior to data acquisition. The reflected amplitude backscatter within each vertical bin (also defined in post-processing software) for all the individual waveforms comprising the composite waveform are averaged, and the resulting composite waveform is normalized for the number of individual waveforms.

Composite waveforms (5-m or 10-m diameter) describing a significant horizontal area, were determined from the EAARL small-footprint waveforms for the September 2002 EAARL survey at Assateague Island National Seashore. The 5-m composite footprint waveforms were used to derive three metrics: ground elevation, canopy height, and canopy reflection ratio (or canopy closure). Ground elevation is the elevation of the peak or mode of the last return in the waveform that is inferred to be from the ground. Canopy height is the distance from the first return to the ground. Canopy reflection ratio is the sum of the portion of the waveform return reflected off the canopy divided by the sum of the portion of the waveform return reflected off the canopy and the ground. The canopy reflection ratio is a relative measure of canopy closure. Independent knowledge of the average reflectance of the canopy and ground surfaces within the footprint is necessary to convert the canopy reflection ratio to an absolute measure of canopy closure.

The lidar-derived metrics of canopy height and canopy reflection ratio were used to classify vegetated regions with significant vertical information on the island. Results show that the vegetation metrics derived from a waveform-resolving lidar system can reliably differentiate among forests, woodlands, and shrublands, which are difficult to discern from digital camera imagery, thereby improving the capability to classify vegetation on this barrier island.