Simulation Studies on Data Fusion Algorithms for Forest Structure from Lidar and SAR Data

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Spatial structure of vegetation including plant height, vertical and horizontal heterogeneities, and biomass are important factors that influence the exchanges of matter and energy between the landscape and atmosphere, and the biodiversity of ecosystems. The NASA's DESDynI mission will provide global systematic lidar point-sampling data and areal coverage of L-band InSAR data with polarimetric capabilities for 3-D structural studies of vegetation. The combined use of lidar's direct sampling measurements and radar's global areal mapping capabilities creates a real possibility and opportunity to map global ecosystem structures and functions that link to carbon dynamics. However, the relationship of the lidar point-sample data and corresponding areal InSAR data is yet to be established, much less the extrapolation of the relationship to location or area where only InSAR data are acquired. What is the proper lidar sampling design and how to expand the vegetation spatial structural parameters estimated at lidar footprints to areal coverage using InSAR data are major questions need to be resolved.

Lidar samples the vegetation material within a cylindrical volume passed by its beam, and radar records the backscattering from a volume of vegetation which is not coincides with that sensed by lidar (see Fig. 1). How these signatures related to each other and in what scale remain questions. Lidar waveform and radar backscatter models that take the same 3D structure of a forest stand as inputs were used to simulate data from various lidar/radar data acquisition modes to explore the possible parameters retrieval algorithms and uncertainties in the procedure. Lidar, radar and field data in test sites will be used to test and validate the algorithms and assess the accuracy derived from theoretical studies.

The methods for estimation of forest biomass from polarimetric and non-polarimetric radar measurements have been established, but mostly developed at flat areas. How to effectively and accurately estimate forest biomass in mountainous areas is rarely studied [1]. Various forest stand parameters have been used in previous studies, which include basal area, LAI, canopy or tree height in various definitions, crown depth, crown coverage, crown base height, above-ground biomass and timber volume. In addition to forest biomass, tree (canopy) height will be a parameter to be focused on in this study since it is directly related to forest age and biomass. We will define various "tree height" within a stand accordingly. As with other sensors, lidar doesn't measure biomass directly, even the canopy height defined by users. The lidar waveform signature from large footprint lidar, such as the airborne scanning lidar imager of canopies by echo recovery (SLICER) [2,3], and the Laser Vegetation Imaging Sensor (LVIS) [4-7], and spaceborne ICESat/GLAS [7-10], has been successfully used to estimate the tree height and biomass. Measurements derived from lidar waveform could be tree height profile, various tree height indices (e.g., Lidar Height, LHT, Height of Median Energy, HOME, HOME/LHT Ratio, and Ground Ratio, GRDRT), rising slope of waveform, and energy ratio of canopy to ground returns. Measurements from polarimetric radars can be backscatter from different scattering mechanisms [11,12], at different polarizations, and scattering phase information [13]. From InSAR data, the height of the scattering phase center can be derived [14,15], as well as the backscatter and coherence between image pairs (for repeat-pass InSAR data).

With the simulated lidar/radar signature database, we will test sensitivities of large footprint lidar and L-band polarimetric and InSAR to forest spatial structure and biophysical parameters in different scale and sampling rates, and identify the driving structural variables. There are two aspects in the sensitivity analysis, the sensitivity of lidar and radar measurements to the structure and parameters, and the commonality between lidar and radar responses to them. Using various statistical methods for multivariate analyses, we will identify the lidar/radar variables that are sensitive to forest parameters, and forest variables that drive modeled differences in lidar and radar signatures.

Then, we will assess the ecological and biophysical causes of the similarities and differences in the responses of lidar/radar to forest parameters. As one knows that the canopy volume sensed by lidar and radar in a 'geo-registered pixel' or location of a forest canopy is not exactly the same because of the looking geometry (near-nadir-looking lidar and side-looking radar). Also, lidar and radar sense different parts of the forest canopy (lidar to the green leaves and radar to the wet structures of a canopy). Because of the ecological and biophysical nature of the forest canopies, the amount and spatial position of various components of a forest canopy are closely correlated [16]. The lidar and radar responses to the same canopy should be correlated in some degrees. We will explore the correlation and its limitations using the simulated data sets, and identify relationships that should be globally robust given modest biophysical and/or ecological assumptions.

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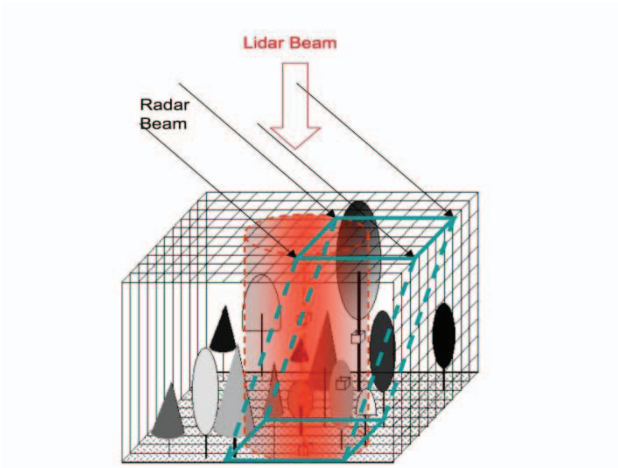

Fig. 1. Diagram of a lidar footprint and a radar resolution cell at the same scale (25m)