Forest Cover and Height in Topographically Complex Landscapes from MISR
Assessed with High Quality Reference Data

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Introduction: Previous research has shown that inverting the simple geometric-optical model (SGM) with bidirectional reflectance factor (BRF) data from the NASA Multi-angle Imaging SpectroRadiometer (MISR) can provide spatially contiguous 250 m retrievals of forest canopy height and fractional crown cover, important primary forest parameters that are useful in estimating aboveground woody biomass and in other applications. However it remained unclear whether this approach could provide reliable estimates for topographically complex landscapes with marked relief, when the approach was applied over the entire southwestern US, anomalous results were sometimes obtained for such areas, with cover overestimated and height underestimated. These may be owing to model inadequacies, poor estimates of the soil-understory background bidirectional reflectance distribution function (BRDF), and/or problems with the inversion protocol. This study attempts to address these questions using high quality reference data sets for an extensive study area in the Sierra Nevada National Forest, an area of considerable topographic complexity. The study area is centered on the area surveyed by the NASA Laser Vegetation Imaging Sensor (LVIS, an advanced full waveform lidar), in September 2008 in the Sierra National Forest in southern California, USA. It encompasses an area of 65,625 ha (37° 10' 46" N, 119° 17' 40" W by 35° 31' 26" N, 118° 18' 21" W) with elevation ranging from -850 to 2,700 m (Figure 1).

Method: Tree number density (number per m²), mean crown radius (m), and fractional cover reference data were obtained via analysis of QuickBird 0.6 m spatial resolution panchromatic imagery using the Canopy Analysis with Panchromatic Imagery (CAPAPI) algorithm (Figures 2 and 3), while canopy height data were obtained from LVIS (Figure 4). The mean incidence angle of the LVIS data set was 2.8° with a standard deviation 1.4° - none of the data were acquired at an incidence angle greater than 10°. The LVIS RH50, RH75, and RH100 values within each mapped MISR 250 x 250 m cell were averaged (separately) to obtain canopy height reference data sets, thus these data are not original LVIS data but derived quantities. These canopy parameters were used together with an empirically-calibrated background BRDF to drive a modified version of the SGM to predict BRF for typical MISR viewing and illumination angles. The new model assigns signatures to shaded components and crowns rather than leaves, as in the original Li-Strahler model. The background model kernel weight regression coefficients were based on a set of highly contrasting surface types (Figures 5 – 7; Table 1). Fractional cover and mean canopy height maps were obtained through adjustment of the SGM against MISR 672 nm BRFs on a 250 m grid. The free model parameters were tree number density and mean crown radius; other parameters were fixed (crown reflectance = 0.03, shadow signature = 0.02, and crown aspect ratio = 4.0). Inversion results were evaluated with respect to the LVIS and CANAPI data (N = 1048).

Results: The model accurately reproduced patterns of MISR surface 672 nm band reflectance (mean Root Mean Square Error (RMSE) = 0.011, 0.004, and 0.022 for LVIS RH50, RH75, and RH100, respectively).

Results... mean R² = 0.82, N=1048), with little bias with cover (Figures 8 and 9). The ranges of the adjusted model parameters were very reasonable (Figure 10). Model adjustment against the MISR red band BRFs resulted in mean (standard deviation) model-fitting RMSE and coefficient of determination values of 0.009 (0.009) and 0.78 (0.199) respectively, with modes of 0.008 and 0.925 (Table 2). RMSE values for the MISR/GO cover and height retrievals with respect to the CANAPI and LVIS RH100 reference data were 0.03 and 6.65 m, respectively, with R² of 0.54 and 0.49, significant at the 99% level (Figure 11). The mapped inversion results and RMSE are quite reasonable (Figure 12).

Conclusions: The results show that GO model inversion for simultaneous retrieval of crown cover and mean canopy height can provide useful maps of canopy structural parameters even in areas of considerable topographic variation. Refinements to the model and its inversion protocol are required to improve the precision of retrievals. This study adds to the recent literature showing that it is possible to leverage multangle imagery for forest structure mapping, with the possibility of realizing important synergies with active instruments for forest mapping at regional scales.