Forest Height, Cover, and Biomass Mapping using Passive Multiangle Data

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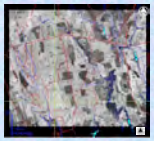
The Simple Geometric-optical Model (SGM) predicts top-of-canopy bidirectional reflectance as a function of viewing and illumination angles and important canopy parameters: plant number density, mean crown radius, mean crown aspect ratio, mean crown center height ratio, and background reflectance magnitude and anisotropy. The model was adjusted against red band data in nine views from the Multiangle Imaging SpectroRadiometer (MISR) on the NASA Earth Observing System Terra satellite to retrieve estimates of crown cover, mean canopy height, and woody biomass (via regression) on a 250 m grid for large parts of Arizona and New Mexico. A first test of the applicability of this method to northeastern forests was also examined at two scales: at Howland Forest and for a large part of the state of Maine (Terra orbit 013824). For the SW forests, the background angular response in the MISR viewing plane was estimated prior to model inversion using the isotropic, geometric, and volume scattering weights of a LiSparse-RossThin kernel-driven model, plus nadir camera blue, green and near-infrared reflectance, with calibration obtained using the SGM with plant mean radius and number density estimates obtained from Ikonos panchromatic imagery. For the NE forests, a fixed background bidirectional reflectance distribution function was used owing to lack of calibration data. In both cases, the mean crown center height ratio, crown foliage density, leaf reflectance, and tree number density were fixed at typical values and fractional crown cover and canopy height calculated by adjusting crown radius (exploiting sensitivity to brightness) and crown aspect ratio (exploiting sensitivity to BRF shape).

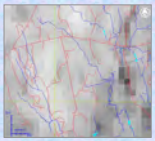
MISR/SGM canopy height and crown cover retrievals for Howland Forest show a spatial match with H100 heights from the Lidar Vegetation Imaging Sensor (LVIS) in the range 10.0 - 30.0, although there is a compression of the MISR height estimates to a range of 7 - 19 m (Fig. 1). The relationship is relatively weak (R^2=0.21) but positive. The cover estimates (range: 0.0 - 0.8) are more noisy than the height estimates. Height and cover estimates are lower for roads and area with few trees. In view of the lack of background calibration, the heterogeneity of the landscape, and the fixing of model parameters, these results are deemed promising.

Howland Forest, Maine

Figure 1: (a) Aerial Orthophoto

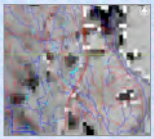


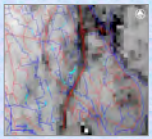
(b) LVIS H100 Canopy Heights

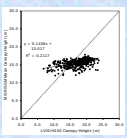


(c) MISR/SGM Canopy Heights for LVIS Coverage

Key: roads streams lakes







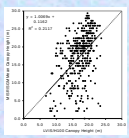
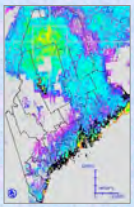


Figure 1: (d) Aerial Orthophoto (e) MISR/SGM Crown Cover (f) MISR/SGM Height Estimates (g) MISR vs LVIS Canopy Height (h) Heights: rescaled

Figure 2 (a) and (c) show MISR/SGM canopy height and crown cover retrievals for parts of Maine alongside Forest Service maps produced using a nearest-neighbor imputation method that exploits Forest Inventory Analysis (FIA) data Figure 2(b) and (d). Only one MISR orbit was used; data missing owing to surface or aerosol retrieval failures are shown in grey. There is a spatial correspondence between the height maps (MISR VIBGYOR range: 10 - 30 m) but the MISR/SGM cover estimates (VIBGYOR range: 0.3 - 0.6) show an anomalous distribution with respect to the Forest Service stocking % map, used here as a proxy for crown cover. These results are not unexpected in view of the lack of background calibration and the fixing of model parameters.

Maine



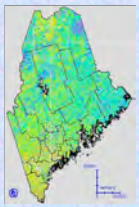
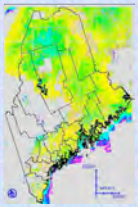


Figure 2 Canopy Height: (a) MISR/SGM (b) Forest Service



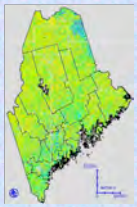
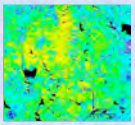


Figure 2 Crown Cover: (c) MISR/SGM (d) Forest Service



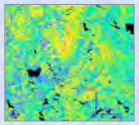
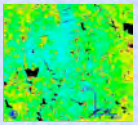


Figure 2 Detail (Height): (e) MISR/SGM (f) Forest Service



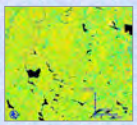


Figure 2 Detail (Cover): (g) MISR/SGM (h) Forest Service

Arizona and New Mexico

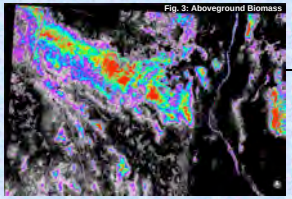
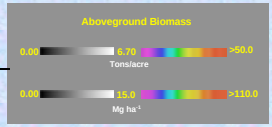


Fig. 3: Aboveground Biomass



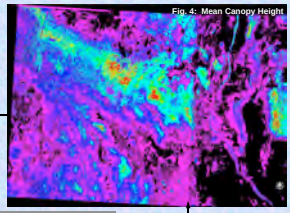
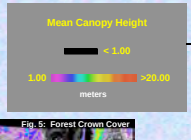


Fig. 4: Mean Canopy Height



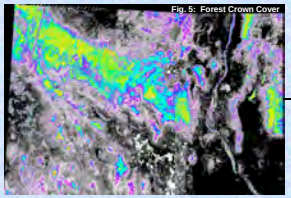
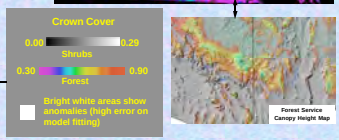


Fig. 5: Forest Crown Cover



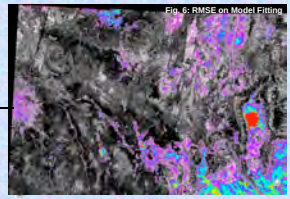
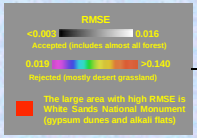


Fig. 6: RMSE on Model Fitting



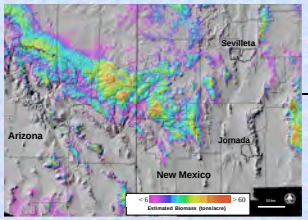
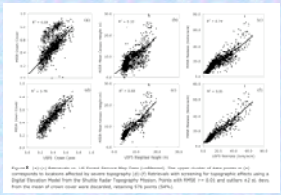


Fig 7: Reference: USDA Forest Service map showing estimated forest biomass for the Interior West on a hill-shaded background; the Arizona / New Mexico border; and the locations of the Jornada Experimental Range and the Sevilleta National Wildlife refuge (NM).

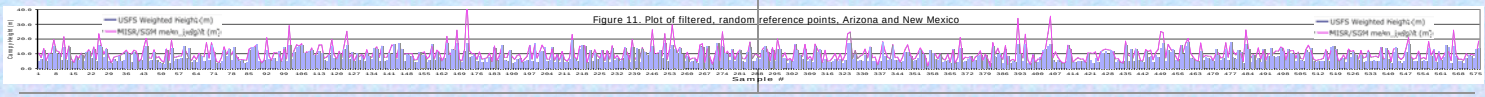
	Fractional crown cover (dimensionless)	Mean canopy height (meters)	Woody Biomass (tons acre^{-1})	(Mg ha^{-1})
Mean Relative Error (%)	30	28	28	-
Mean Absolute Error	0.10	2.2	6.5	10.1
Mean (MISR)	0.48	10.3	21.8	49.0
Mean (USFS)	0.38	8.7	21.8	0.0
Root Mean Square Error	0.12	3.3	6.2	14.0
R^2	0.78	0.69	0.81	-



The southwestern maps (Figures 3-5) were produced by merging data from nine Terra overpasses using model fitting error as the compositing criterion, removing clouds. 1063 random forest locations were used to extract MISR/SGM retrievals and the corresponding data from Forest Service maps for the Interior West, based on FIA and other data. Filtering on high model fitting RMSE, a few outliers, and screening for topographic shading reduced N to 576 (54%). These results show that MISR data can be interpreted through a simple GO model to provide maps of canopy crown cover, canopy height, and biomass over large areas of the southwestern US that are highly compatible with US Forest Service data. They also demonstrate a strong potential for application in temperate and boreal forest, although retrievals are more difficult in these environments as contrast between the canopy and the background is much lower. The use of lidar canopy height estimates in constraining model inversions with multiangle data is a promising approach that is being explored together with other multi-sensor strategies.

Chopping, M., Moisen, G. Su, L., Laliberte, A., Rango, A., Martonchik, J.V., and Peters, D.P.C. (2008), Large area mapping of southwestern forest crown cover, canopy height, and biomass using MISR, *Remote Sens. Environ.*, in press.
Chopping, M. (2008), Terrestrial Applications of Multiangle Remote Sensing, in: Advances in Land Remote Sensing: System, Modeling, Inversion and Applications, S. Liang, ed., Springer- Verlag, in press.
Chopping, M., Su, L., Rango, A., Martonchik, J.V., Peters, D.P.C., and Laliberte, A. (2008), Remote sensing of woody shrub cover in desert grasslands using MISR with a geometric-optical canopy reflectance model, *Remote Sens. Environ.* 112: 19-34

Figure 11. Plot of filtered, random reference points, Arizona and New Mexico



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