Using MISR to Map Woody Plant Canopy Crown Cover, Height, and Biomass

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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 reflectance factor shape). A sequence of crown cover and canopy height retrievals for 2000-2007 was also effected for desert grasslands in New Mexico in order to assess retrievals over this period.

Howland Forest & Maine

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 m, 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 areas 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. 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 Fig. 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 range: 10-30 m) but the MISR/SGM cover estimates (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.

Fig. 1: (a) LVIS H100 Canopy Heights (b) MISR/SGM Height (c) Aerial Orthophoto (d) MISR/SGM Crown Cover (e) MISR/SGM Height Estimates (f) MISR vs LVIS Hgt (rescaled)

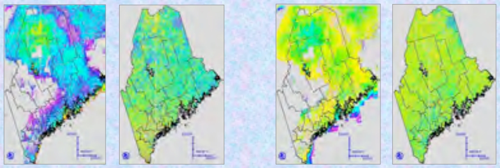


Figure 2 Canopy Height: (a) MISR/SGM (b) Forest Service Figure 2 Crown Cover: (c) MISR/SGM (d) FS % Stocking

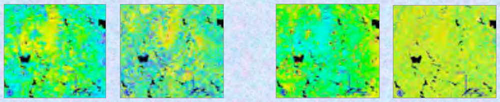


Figure 2 Detail (Height): (e) MISR/SGM (f) Forest Service Figure 2 Detail (Cover): (g) MISR/SGM (h) FS % Stocking

Arizona and New Mexico Forest: Comparison with Forest Inventory Analysis Survey Data

All relationships were positive but correlations between the MISR/SGM-estimated and FIA height, cover, and biomass values were low, with R^2 in the ranges 0.29–0.42, 0.23–0.57, and 0.43–0.55, respectively, amongst all the data sets. In general biomass was better estimated than canopy height or crown cover; and canopy height better than crown cover. MISR/SGM crown cover values diverged from the FIA value far more than canopy height for all data sets except the 2005 and 2001-2003 subsets. The best mean absolute error results were obtained for the "all data" set: 3.3 meters in height, 0.21 in fractional cover, and 10.81 tons acre^{-1} in biomass. Differences in means (MISR/SGM estimates minus FIA) were low: <=0.4 meters, <=0.2, and <=2.5 tons acre^{-1}. For the May-Sept 2002 set where both evergreen and deciduous species are in leaf, correlation coefficients were higher, with mean absolute errors of 4.0 m, 0.20, and 11.6 tons acre^{-1}, respectively. The disparity in scale is thought to be an important source of divergence between the MISR and FIA data sets; the extent of an FIA plot is small compared to the MISR ground-projected instantaneous field-of-view (GIFOV; Fig. 8). Moreover, tree measurements are made only at the four sub-plots and there is no indication of landscape spatial heterogeneity within plots.

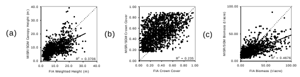


Figure 3. Filters: Month = All, Year = All; Plot Design = 1 (N = 1589)

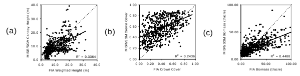


Figure 4. Filters: 4 < Month < 10, Year = All; Plot Design = 1 (N = 593)

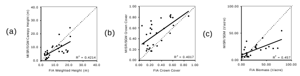


Figure 5. Filters: 4 < Month < 10, Year = 2002; Plot Design = 1 (N = 28)

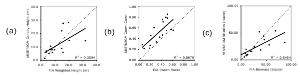


Figure 6. Filters: 4 < Month < 10, Year = 2005 (N = 17)

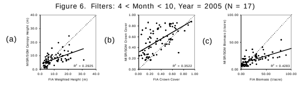


Figure 7. Filters: 4 < Month < 10, Year = 2001-2003 (N = 83)

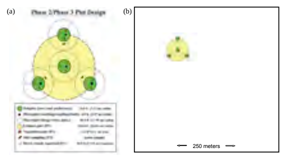


Figure 8. (a) FIA Plot Design (b) FIA plot in relation to a 250 m² raster cell. Note that the FIA plot might be located anywhere within the cell.

Arizona and New Mexico Forest

The southwestern forest maps (Fig. 9) 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 (Fig. 10). The height retrievals were consistent with data from the FS height map (Table 1, Fig. 11, bottom). 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 (Chopping *et al*. 2008a).

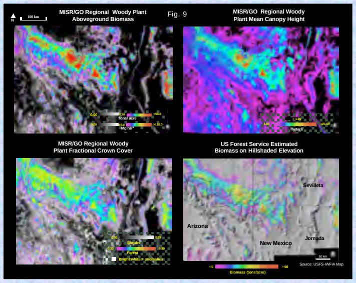


Fig. 10

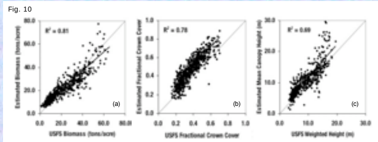
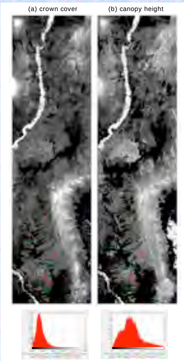


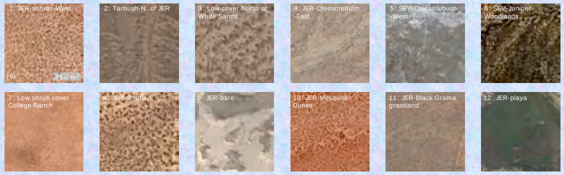
Table 1

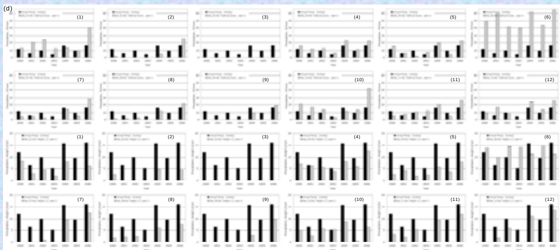
	Fractional crown cover (dimensionless)	Mean canopy height (meters)	Woody Biomass (tons acre^{-1})	(Mg ha^{-1})
Mean Relative Error (%)	30	28	28	-
Mean Absolute Error	0.10	2.2	4.5	10.1
Mean (MISR)	0.48	10.3	21.8	49.0
Mean (USFS)	0.38	8.7	21.8	0.0
Root Mean Square Error	0.12	3.3	6.2	14.0
R^2	0.78	0.69	0.81	-

New Mexico Desert Grassland

A sequence of SGM inversions using a dynamic background was performed using MISR scenes for May-June of 2000-2007 for the area in New Mexico bounding the USDA, ARS Jornada Experimental Range and the NWS Sevilleta National Wildlife Refuge. Woody plant mean radius and crown aspect ratio were adjustable, allowing mapped estimates of crown cover and canopy height to be obtained (Fig. 12 (a)-(b)). This approach was used to map forest with some success (Chopping *et al*. 2008a) but previous studies in grasslands had allowed only cover as the adjustable parameter (Chopping *et al*. 2008c, d). These preliminary results -- with no screening for the quality of the model fitting or cloud contamination -- are impacted by inter-annual variability in precipitation and the use of background coefficients from 2002. Since the modeling framework attempts to isolate the contribution from the soil-understory background prior to estimating the contribution from shrubs and trees, spikes in understory growth owing to precipitation result in changes to the structure and scattering properties of the background, even after senescence. Unusually large rainfall events prior to the 2005, 2006, and 2007 acquisitions are likely the reason for the anomalous retrievals for those years, and particularly 2005 and 2007 (Fig. 12 (d-9), (e)). Although it is clear from these results that measurement precision for shrubs is low when both cover and height are adjustable, the maps for all years show similar spatial structure. These results highlight the challenge of remotely measuring shrub cover and height under conditions in which the background is dynamic in both space and time.







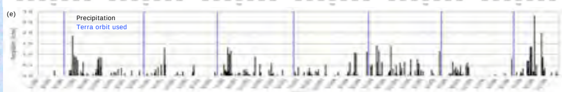


Fig 12. (above, right) MISR/SGM (a) crown cover and (b) height maps for 2002 (c) high resolution images, sites 1-12, (d) retrieved cover and height vs previous year's precipitation (e) daily precipitation. Fig. 13 (below) Mapped retrievals for playa (site 12) (a) crown cover (b) mean canopy height (c) high resolution image.

Multiangle reflectance factors from MISR were interpreted through an hybrid geometric-optical model. In an heterogeneous, managed boreal forest at Howland, Maine using a fixed background, the relationships with LVIS canopy height, roads, rivers, and clearcuts are obvious. Over a large part of Maine using the same fixed background matches with Forest Service maps were less consistent. However, using a dynamic background obtained *a priori* to map woody plant distributions (crown cover, mean canopy height, and aboveground woody biomass) for large parts of Arizona and New Mexico, good agreements with Forest Service maps and positive relationships with the FIA survey data were obtained. For desert grasslands in New Mexico, temporal stability in preliminary, unscreened retrievals over 2000-2007 was impacted by inter-annual variation in precipitation and the use of background coefficients obtained for a single year.

Chopping, M., Moisen, G. Su, L., Laliberte, A., Rango, A., Martonchik, J.V., and Peters, D.P.C. (2008a), Large area mapping of southwestern forest crown cover, canopy height, and biomass using MISR, *Remote Sens. Environ.*, 112: 2051-2063.
Chopping, M. (2008b), Terrestrial Applications of Multiangle Remote Sensing, in: Advances in Land Remote Sensing: System, Modeling, Inversion and Applications, S. Liang, ed., Springer- Verlag, 95-144.
Chopping, M., Su, L., Rango, A., Martonchik, J.V., Peters, D.P.C., and Laliberte, A. (2008c), Remote sensing of woody shrub cover in desert grasslands using MISR with a geometric-optical canopy reflectance model, *Remote Sens. Environ.* 112: 19-34
Chopping, M., Su, L., Laliberte, A., Rango, A., Peters, D.P.C., and Martonchik, J.V. (2006), Mapping woody plant cover in desert grasslands using canopy reflectance modeling and MISR data, *Geophsyical Research Letters* 33, L17402, doi:10.1029/2006GL027148.

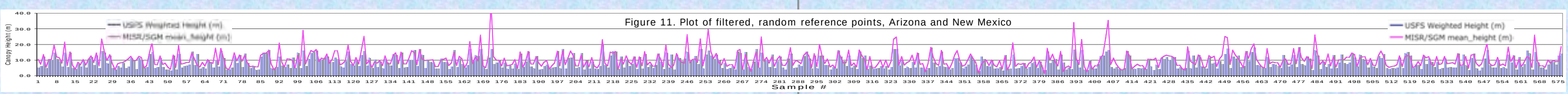


Figure 11. Plot of filtered, random reference points, Arizona and New Mexico

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WWW: http://csam.montclair.edu/~chopping/wood