Mapping Forest Crown Cover, Height, and Biomass in the Southwestern US with MISR

Mark Chopping[1], Gretchen Moisen[2], Lihong Su[1], Andrea Laliberte[3], Albert Rango[3], and John V. Martonchik[4]

[1] Earth & Environmental Studies, Montclair State University, Montclair, NJ   [2] USDA, US Forest Service Rocky Mountain Research Station, Ogden, UT

[3] USDA, ARS Jornada Experimental Range, New Mexico State University, Las Cruces, NM   [4] NASA/JPL, Pasadena, CA

Introduction: Data from the Multiangle Imaging SpectroRadiometer (MISR) on the NASA Earth Observing System Terra satellite can be interpreted through a simple geometric-optical (GO) model (SGM) to retrieve estimates of crown cover, mean canopy height, and woody biomass. These are important parameters in western forests that are increasingly vulnerable to wildfire with earlier melting of the snow pack. **Method:** MISR Level 1B2 Terrain radiance data from overpasses in May and June 2002 over S.E. Arizona and S. New Mexico were atmospherically corrected using smoothed MISR aerosol optical depth data @558 nm and bidirectional reflectance factors (BRF) were mapped to a 250 m grid. 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 factors. Calibration of these relationships was effected using woody plant cover estimates obtained from Ikonos 1 m panchromatic imagery in the USDA, ARS Jornada Experimental Range. The SGM was adjusted against red MISR BRFs in 9 views using the Praxis algorithm to minimize the Root Mean Square Error (RMSE) between model and data, producing maps of crown cover, mean canopy height and woody biomass.
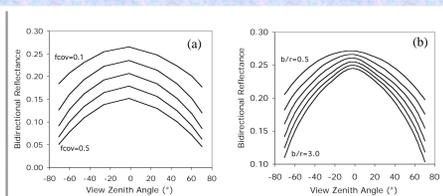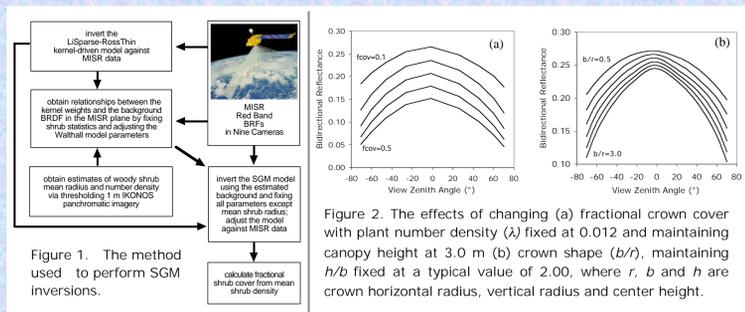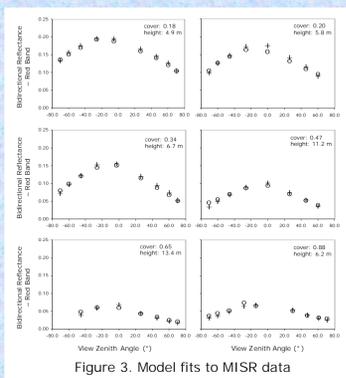
Figure 1. The method used to perform SGM inversions.

Figure 2. The effects of changing (a) fractional crown cover with plant number density (λ) fixed at 0.012 and maintaining canopy height at 3.0 m (b) crown shape (b/r), maintaining h/b fixed at a typical value of 2.00, where r, b and h are crown horizontal radius, vertical radius and center height.

Figure 3. Model fits to MISR data

Fractional crown cover was calculated by adjusting crown radius (r) with fixed tree number density (λ), exploiting sensitivity to *brightness*. Canopy height was calculated by adjusting b/r with fixed h/b, where b is vertical crown radius and h is crown center height above the reference plane, exploiting sensitivity to BRF *shape* (Figure 2). The starting point for the inversions was $r = 0.25$, $b/r = 0.2$, with fixed parameters set to 0.012 (λ), 2.0 (h/b), 0.09 (leaf reflectance) and 2.08 (crown foliage density). Model fits were good (Figure 3), with a RMSE mean (standard deviation) of 0.012 (0.025) and a mode of 0.004.
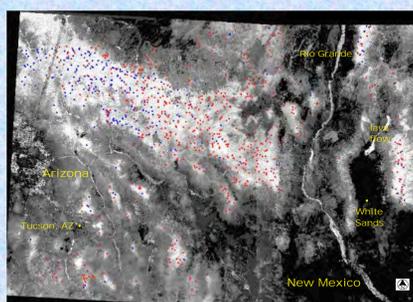
Figure 4. MISR/GO crown cover map in grayscale showing illuminated reference locations (red points) and those impacted by topography (blue points).
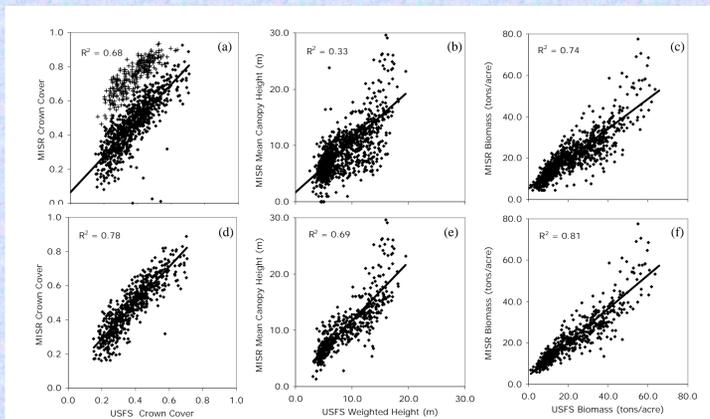
Figure 5. (a)-(c) Retrievals vs. US Forest Service Map Data (unfiltered). The upper cluster of data points in (a) corresponds to locations affected by severe topography (d)-(f) Retrievals with screening for topographic effects using a Digital Elevation Model from the Shuttle Radar Topography Mission. Points with RMSE >= 0.01 and outliers ± 2 st. devs. from the mean of crown cover were discarded, retaining 576 points (54%).

Results: The results from nine Terra overpasses were merged using model fitting error as the compositing criterion, producing almost cloud- and cloud shadow-free maps. 1063 random locations in forest were used to extract MISR/SGM and corresponding reference data from US Forest Service maps for the Interior West, based on Forest Inventory Analysis (FIA) survey data, elevation, slope, aspect, soils, existing eco-region and land cover maps, MODIS data, and climate variables. Topographic effects were visible in the extracted cover data as an isolated cluster (Figure 5 (a)). Filtering on high RMSE, outliers, and screening for topographic shading reduced N to 576 (54%).
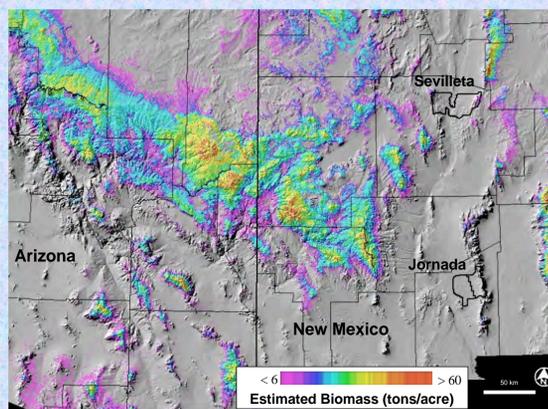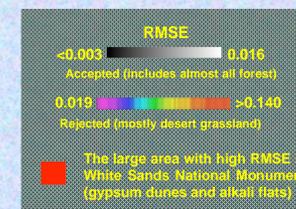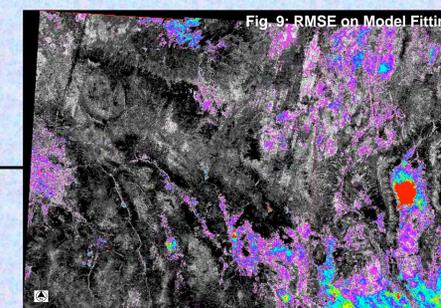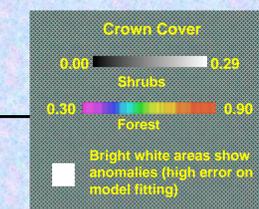
Fig. 6: Regional Aboveground Biomass

Aboveground Biomass
0.00   6.70   >50.0   Tons/acre
0.00   15.0   >110.0   Mg ha⁻¹

Fig. 7: Regional Mean Canopy Height

Mean Canopy Height
< 1.00
1.00   >20.00   meters

Fig. 8: Regional Forest Crown Cover

Crown Cover
0.00   0.29   Shrubs
0.30   0.90   Forest
Bright white areas show anomalies (high error on model fitting)

Fig. 9: RMSE on Model Fitting

RMSE
<0.003   0.016   Accepted (includes almost all forest)
0.019   >0.140   Rejected (mostly desert grassland)
The large area with high RMSE is White Sands National Monument (gypsum dunes and alkali flats)
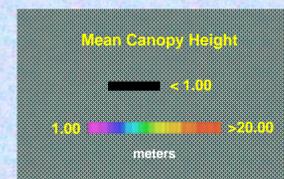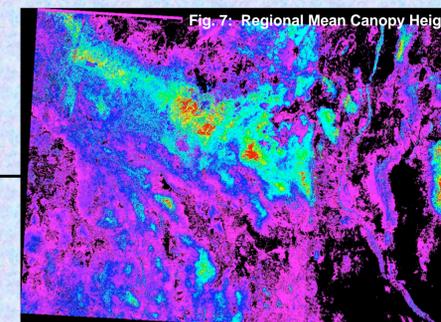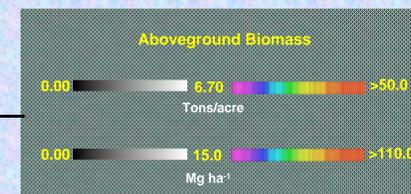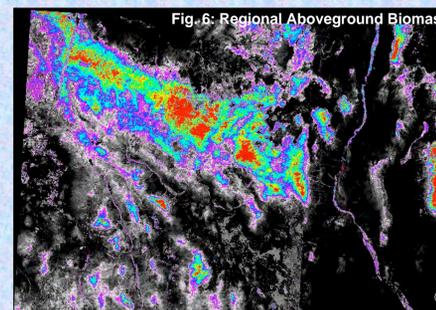
Fig 10: Reference: USDA Forest Service map showing estimated forest biomass for the Intermountain West on a hill-shaded background; the Arizona / New Mexico border; and the locations of the Jornada Experimental Range and the Sevilleta National Wildlife refuge (NM).

Estimated Biomass (tons/acre)   < 6   > 60

TABLE 1: Error Analysis

	Fractional crown cover (dimensionless)	Mean canopy height (meters)	Woody Biomass (tons acre⁻¹)	Woody Biomass (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
R²	0.78	0.69	0.81	–

The mean absolute error in estimates of fractional crown cover, mean canopy height, and woody biomass were 0.10, 2.2 m, and 4.5 tons acre⁻¹ (10.1 Mg ha⁻¹), with RMSE errors of 0.12, 3.3 and 6.2 (14.0), respectively (Table 1). The maps also include woody shrubs in desert grasslands as the approach relies mainly on surface physical characteristics (Figures 6-8). 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 that are highly compatible with US Forest Service data. A more robust validation is being pursued using FIA field survey data. To our knowledge, these results demonstrate the first use of passive moderate resolution EOS data to map forest, cover, canopy height, and woody biomass over large areas.

Figure 11. Plot of the filtered, random reference points showing MISR/SGM retrievals of mean canopy height versus USFS weighted forest height.

— USFS Weighted Height (m)   — MISR/SGM mean_height (m)

Montclair State University