Mapping Canopy Structure in the Western United States using MISR and MODIS

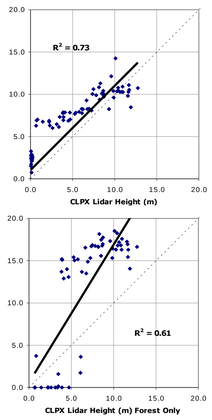
Mark Chopping[1], Crystal Schaaf[2], Feng Zhao[2], Zhuosen Wang[2], Anne W. Nolin[3], John V. Martonchik[4], Michael Bull[4]

[1] Earth & Environmental Studies, Montclair State University, Montclair, NJ [3] Center for Remote Sensing, Boston University, Boston, MA [3] Department of Geosciences, Oregon State University, Corvallis, OR [4] NASA/JPL, Pasadena, CA

The main science question addressed by the NASA Carbon Cycle and Ecosystems program is "***How are the Earth's carbon cycle and ecosystems changing and what are the consequences for the Earth's carbon budget, ecosystem sustainability, and biodiversity?".*** To address this we must know the distribution of aboveground woody carbon stocks and how much, where, and why these are changing in response to disturbance (fire, bark beetle, sudden oak death, pathogens, logging). Canopy fractional cover and height are important vegetation structural metrics that aid estimation of aboveground woody biomass and provide information on forest successional status: here we demonstrate mapping over large areas via interpretation of multiangle red band reflectance factors from MISR and MODIS using a simple geometric-optical model.

Below: Retrievals of canopy height from adjusting a simple geometric-optical (GO) model against **MISR red band reflectance data** (orbit 14073, 8/10/02), mapped to a 250 m grid (UTM zone 13N/WGS84). The area covered is about 211,490 km^2 with some missing data where MISR surface retrievals failed. The GO model predicts top-of-canopy bidirectional reflectance as a function of viewing and illumination angles, a set of canopy parameters, and background reflectance magnitude and anisotropy from the Walthall Bidirectional Reflectance Distribution Function (BRDF) model. A dynamic background was estimated prior to GO model adjustment using the red band kernel weights of a Li-Ross BRDF model. High resolution discrete return lidar data and orthophoto imagery from the Cold Lands Processes Field Experiment (CLPX) were used in background calibration and map assessment.

Overview MISR/GO Height Map



Canopy height comparisons for calibration sites (1-6: grassland, 7-14: forest). Top: MISR vs lidar. Bottom: MISR cover vs. airphoto and Forest Service estimates vs lidar (FS-IW maps include only forest).

Top: MISR/GO height retrievals (RSME=2.9 m) Bottom: FS Interior West 2005 map forest heights (RMSE=6.88 m) vs September lidar with all heights > 1 m

CLPX Sites on MISR/GO Height Map

Canopy height comparisons for all nine available CLPX sites (1-37: grassland, 38-107: forest). Top: MISR vs lidar. Bottom: Forest Service Interior West (IW) estimates vs. lidar, noting that the FS-IW maps include only forest. Note the MISR/GO anomaly for the Fraser Forest Fool Creek site (95-107) that is owing to clear-cutting in strips in the 1950s; however inversion failures are easily flagged.

MISR/GO canopy heights matched those from the high resolution lidar data and crown cover estimates were compatible with estimates from orthophotos and the USFS Interior West map (FS_IW), although the latter missed forest for some CLPX sites. Inversions were completed for 140 combinations of backgrounds (7, including two intentionally inaccurate backgrounds), crown radius (3.0-6.0 in increments of 1.0) and b/r (vertical/horizontal radii) ratio (0.5-2.5 in increments of 0.5). For all model inversion runs with reasonable backgrounds and initial b/r values < 2.0, root mean square error (RMSE) distributions were centered between 2.5 – 3.7 m while R^2 distributions were centered between 0.4 – 0.7. MISR/GO aboveground biomass estimates predicted via regression on fractional cover and mean canopy height for the CLPX sites showed good agreement with Forest Service Interior West map data (adjusted R^2 = 0.84).

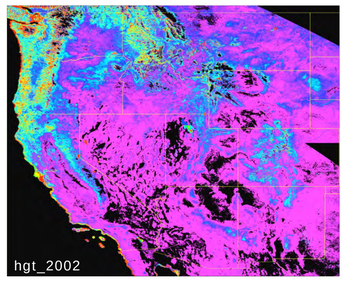
MISR/GO height retrieval root mean square error and correlation vs lidar-derived estimates.

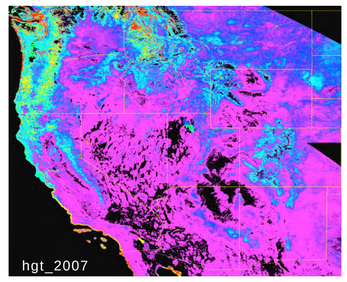
	RMSE (m)			R^2		
	Mean	Min	Max	Mean	Min	Max
April	2.6	1.4	5.5	0.38	0.10	0.48
April (abs[i])	2.0	1.4	3.8	0.44	0.22	0.52
September	3.8	2.8	5.6	0.59	0.24	0.73
September (abs[i])	3.6	2.8	5.6	0.66	0.38	0.73

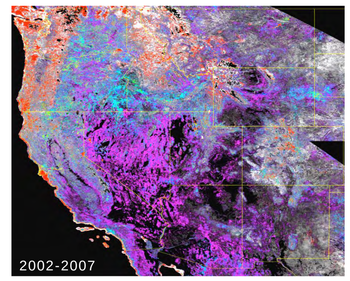
MISR and initial MODIS (2002) GO-derived cover, height, and aboveground standing woody biomass maps for large parts of Arizona and New Mexico were assessed against FS_IW map data. Both MODIS and MISR fractional cover and mean canopy height retrievals show strong linear relationships with the USFS map data for random sites, with some unexplained scatter and bias in the MODIS height retrievals, likely owing to inadequate prediction of the background contribution.

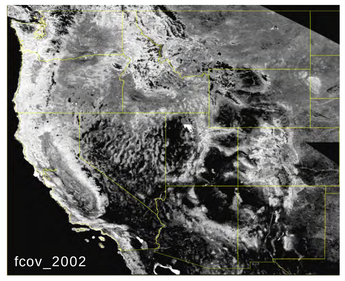
MODIS (N= 895) and MISR (N= 576) Error Statistics vs Forest Service Interior West Map Data.

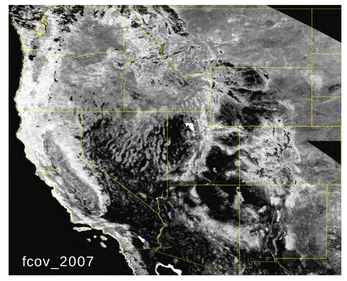
	Fractional cover (dimensionless)		Mean height (meters)		Aboveground Woody Biomass tons/acre		Mg ha^{-1}	
	MODIS	MISR	MODIS	MISR	MODIS	MISR	MODIS	MISR
Mean relative error (%)	26	30	20	28	25	28	n/a	n/a
Mean absolute error	0.09	0.10	8.4	2.2	4.5	4.5	10.1	10.1
2 Standard Deviations	0.19	0.30	5.4	10.1	20.8	26.0	46.6	58.2
Means	0.44	0.48	7.8	10.3	20.5	21.8	46.0	49.0
R^2	0.55	0.78	0.50	0.70	0.75	0.81	n/a	n/a
RMSE	0.10	0.12	2.6	3.3	6.0	6.2	13.4	14.0

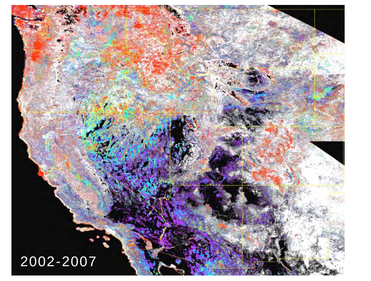


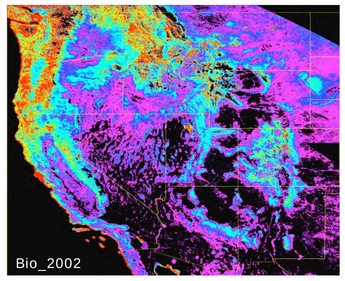


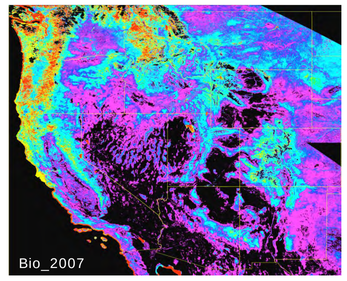


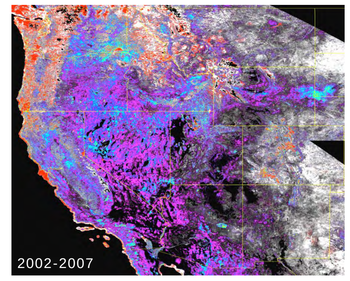


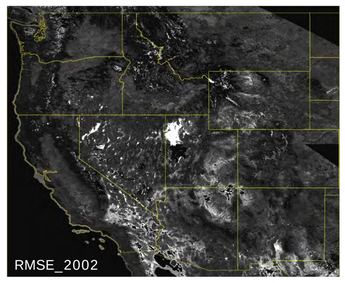


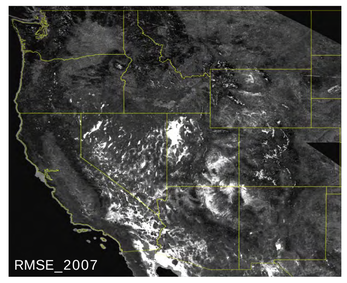


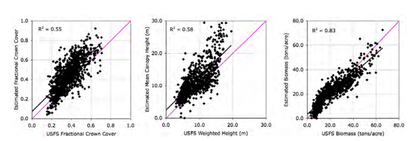










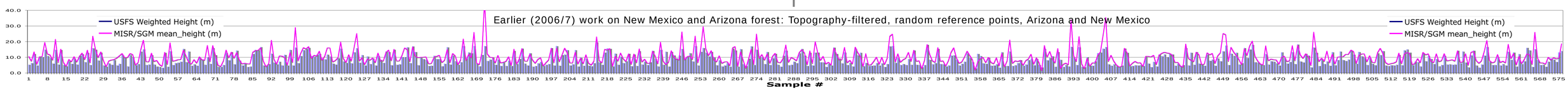


Error Table	frac. cov	mean_hgt	AG Biomass	
	dim.less	meters	tons/acre	Mg ha^{-1}
MRE (%)	27.88	41.52	26.35	26.35
MAE	0.10	3.18	4.12	9.23
2 ST.DEV.	0.31	6.65	23.19	51.99
MEANS	0.45	7.33	3.46	7.75
R^2	0.55	0.59	0.83	0.83
RMSE	0.13	4.16	5.28	11.84

MODIS cover, height, and aboveground standing woody biomass map assessment vs reference data from the 2005 Forest Service Interior West map series (random samples, N=1058).

Above: Maps of crown center height (m), fractional crown cover and aboveground standing woody biomass (Mg ha^{-1}, regressed on cover and height using USFS data) for the western United States were obtained by inverting the GO model against **MODIS red band reflectance factors** for DOY 153-168 for 2002 and 2007. These results are not validated but the 2002 maps show reasonably good agreement with the FS_IW maps. Difference maps for the five-year period show losses from large fires (Rodeo-Chediski in Arizona, Biscuit in Oregon, and Hayman in Colorado) as well as some large changes in forest in Idaho, manifestation of pine beetle damage in Colorado, and logging in the Pacific Northwest (reductions in cover that are not reflected in MODIS fire maps for 2002-2007). Note that 1. the 2002 and 2007 GO inversions used the same static background BRDF derived from means of forest and desert grassland BRDFs, 2. the same regression coefficients based on the 2002 retrievals were used to estimate biomass, and 3. no masking was performed to screen out non-vegetated features (gypsum, salt flats, lava flows, cities, lakes, etc.), or atmospheric anomalies (two long aircraft contrails are visible in the 2007 RMSE image). Mapping canopy height, crown cover and biomass by exploiting the angular information in MISR and MODIS data will enable assessment of trajectories in aboveground carbon stocks in western forests and desert grasslands over the entire NASA Earth Observing System era (2000-).

Chopping, M., Nolin, A.W, Moisen, G.G., Martonchik, J.V., and Bull, M. (2009), Forest canopy height from the Multiangle Imaging Spectro-Radiometer (MISR) assessed with high resolution discrete return lidar, *Remote Sensing of Environment*, in press.
Chopping, M., Schaaf, C.B., Zhao, F., Wang, Z., Nolin, A.W., Moisen, G.G., Martonchik, J.V., and Bull, M. (2009), Forest structure and aboveground biomass in the southwestern United States from NASA moderate resolution remote sensing, in review.
Imhoff, M., L. R. Wolfe, D. J. Diner, M. Chopping, R. Kahn, V. Salomonson, J. Gille, J. Drummond, D. Edwards, N. Loeb, B. Wielicki, M. Abrams, B. Eng, K. J. Ranson, and S.-C. Tsay (2009), A brief overview of Terra mission results and the carbon cycle, *Geography Compass* 1749-8198, Blackwell, DOI: 10.1111/j.1749-8198.2008.00183.x.
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., Su, L., Rango, A., Martonchik, J.V., Peters, D.P.C., and Laliberte, A. (2008b), Remote sensing of woody shrub cover in desert grasslands using MISR with a geometric-optical canopy reflectance model, *Remote Sens. Environ.* 112: 19-34



Global Vegetation Workshop 2009, June 16-19,Missoula, Montana USA. This work was supported by NASA grant NNG04GK91G to MC. Thanks: David Diner, J. Bryan Blair, Gretchen Moisen, NASA Vegetation Structure Working Group. Data credits: NASA/JPL; LARC/ASDC; National Snow and Ice Data Center/CLPX (Miller, S.L. 2003. *CLPX-Airborne: Infrared Orthophotography and LIDAR Topographic Mapping)* Boulder, CO; US Forest Service, Ogden, UT.

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