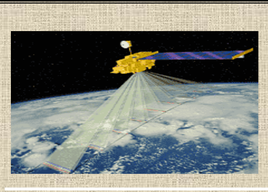

Forest Biomass from the NASA Multiangle Imaging Spectro-Radiometer

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Context: This research is aimed at mapping aboveground biomass (AGB, Mg ha^{-1}) in dense Oregon forests using data from the NASA Multiangle Imaging Spectro-Radiometer (MISR). Efforts to exploit geometric-optical (GO) model inversion to map cover, height, and aboveground standing biomass were found to be problematic in these high cover environments (Fig. 1), so a boosted regression tree (BRT) approach was explored as a means to leverage the information in MISR Li-Ross Bidirectional Reflectance Distribution Function (BRDF) model kernel weights and associated parameters.

MISR Data: MISR Level 1B2 Terrain radiance data from the Terra satellite overpass on 08/16/11 (Orbit 062028, Path 45, Blocks 55-56, centered on 44'32''N, 122'00'W) were converted to bidirectional reflectance factors (BRF) using MISR Toolkit routines and the MISR 1 km LAND product BRFs, and resampled onto a 250 m equal area grid. The data include nadir camera blue (B), green (G), and near-infrared (NIR) BRFs and red band BRFs in all nine MISR cameras. Surface BRF retrievals were initially missing in very dark, high forest cover areas, with the MISR aerosol product showing an aerosol optical depth upper bound of zero for all mixtures, i.e., the aerosol retrieval fails. To mitigate this, the LAND albedo threshold was reduced to zero and the topographic complexity threshold was disabled, extending coverage (Fig 5).

Figure 1. Dynamic nature of Oregon forests, from Google Earth imagery (a) 2001 (b) 2007 (c) 2011

BRDF and GO Model Inversions: Red band BRFs in all available cameras were used with AMBRALS to invert the RossThick-LiSparse-Reciprocal (RTLS-R) BRDF model to retrieve *iso(tropic)*, *vol(ume scattering)*, and *geo(metric scattering)* kernel weights, as well as model-fitting too mean square error (RMSE), weights of determination, white and black sky albedos, and BRDF-adjusted BRF at a solar zenith angle of 45 degrees (NBAR45). The red band BRFs were also used to invert a geometric-optical (GO) model using numerical minimization to retrieve estimates of fractional crown cover and mean canopy height.

Other Data: A 1-arcsecond (30 m) digital elevation model (DEM) from the National Elevation Dataset (NED) was used to calculate a topographic roughness map at 250 m in the following way: a 30 m slope map was calculated from the NED DEM; this was resampled to 50 m using bilinear interpolation; Focal Analysis with a 5x5 kernel and a St.Dev. function was used to produce roughness estimates that were subsequently degraded to obtain the 250 m roughness map (Grohmann et al. 2010). The National Biomass and Carbon Dataset (NBCD, Kellndorfer et al. 2013) was used to train the boosted regression tree model and in assessing the results of predictions. The 240 m Zone 6 data were resampled to the same 250 m Albers Conical Equal Area grid used for the MISR data.

Boosted Regression Tree Model: The MISR nadir B, G and NIR BRFs, BRDF model kernel weights, model-fitting error, albedos, NBAR45, and NBCD biomass data to train a Boosted Regression Tree (BRT) model. Boosted regression trees handle different types of predictor variables and accommodate missing data; these models have no need for prior data transformation or elimination of outliers, they can fit complex nonlinear relationships, and they automatically handle interaction effects between predictors (Elith et al. 2008). Training initially used two randomly-located sets of 1024 points each, removing data where BRDF model RMSE > 0.01. However, clear-cutting and regrowth are common, creating a problem when using the NBCD 2000 AGB data with 2011 MISR data (Fig. 1). *continued…*

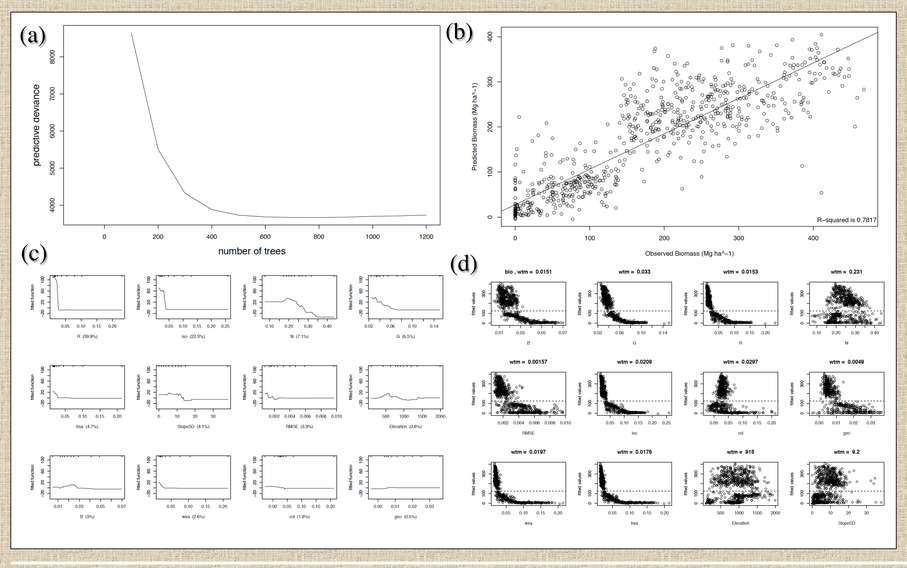

Figure 2. Boosted Regression Tree training and validation (a) Predicted deviance vs number of trees (b) Observed vs predicted biomass, validation data set only, N=991 (c) Fitted functions showing contributions of predictor variables (d) Fitted values vs predictors.

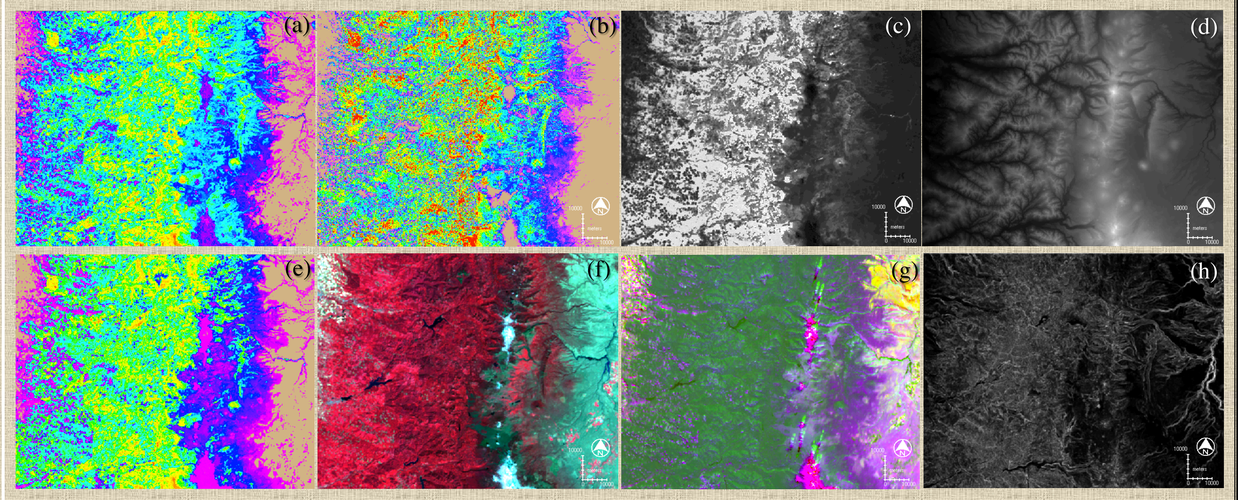

Figure 3. (a) AGB from MISR/BRT, filtering training data only on Li-Ross RMSE < 0.01 (b) NBCD AGB map for 2000 (c) MISR/GO model number density, 0–2300 trees (d) Roughness (slope st.dev.) from NED DEM, 0–50 (e) AGB from MISR/BRT, filtering training data on temporal coherence as well as Li-Ross RMSE < 0.01 (f) Standard NRG false color composite (g) MISR LRST-R *iso*, *vol*, *geo* FCC (h) NED DEM 100-3000 m. AGB map scale for (a)(b)(e): 0-10 11 Mg ha^{-1} 400

Filtering out points that had likely changed in 2011 over 2000 improved the model importantly. This was achieved by testing whether the NBCD AGB value was less than the median AGB, while the GO model #density was greater than the median #density and *vice versa*. In the first case this means it is likely that the trees in that MISR cell regrew over the 2000-2011 period, while in the second it is likely that trees existing in the MISR cell in 2000 were clear-cut by 2011. If either test failed, or RMSE < 0.01 then the data point was removed, yielding N = 756 and 789 for corrected training and validation sets, respectively, reduced from 991 and 1007 for the uncorrected sets, respectively.

Results: Using the improved training data set ("set 1") to fit a BRT model with a learning rate of 0.005, a tree complexity of 10, and 1200 trees, the optimum number of trees was ~600 yielding a prediction R^2 of 0.78 for the validation data set ("set 2"; Fig. 2). The two BRT models were used to predict AGB for a 1,251,600 ha region (Fig. 3 (a) and (e)) and the corresponding NBCD and MISR/BRT AGB values were extracted for the (random) set 1 and 2 locations. These show very good results compared with predictions via regression based on Simple GO Model (SGM) forest cover and height retrievals (Table 1, Fig. 4).

TABLE 1. SUMMARY OF MISR/BRT AND GO MODEL BIOMASS PREDICTIONS VS NBCD 2000 (MGHA^{-1})

	RMSE	R^2
MISR/BRT Set 1, UNCORRECTED	57	0.80
MISR/SGM Set 1 UNCORRECTED	100	0.36
MISR/BRT Set 2, UNCORRECTED	80	0.58
MISR/SGM Set 2 UNCORRECTED	98	0.39

	RMSE	R^2
MISR/BRT Set 1, CORRECTED	42	0.90
MISR/SGM Set 1, CORRECTED	69	0.72
MISR/BRT Set 2, CORRECTED	62	0.78
MISR/SGM Set 2, CORRECTED	68	0.73

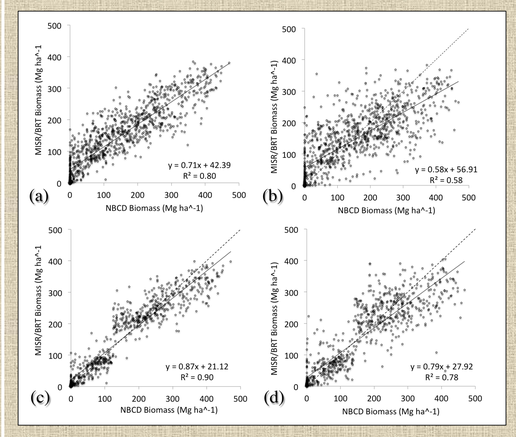

Figure 4. NBCD vs predicted AGB (a) set 1, uncorrected (b) set 2, uncorrected (c) set 1, corrected (d) set 2 , corrected.

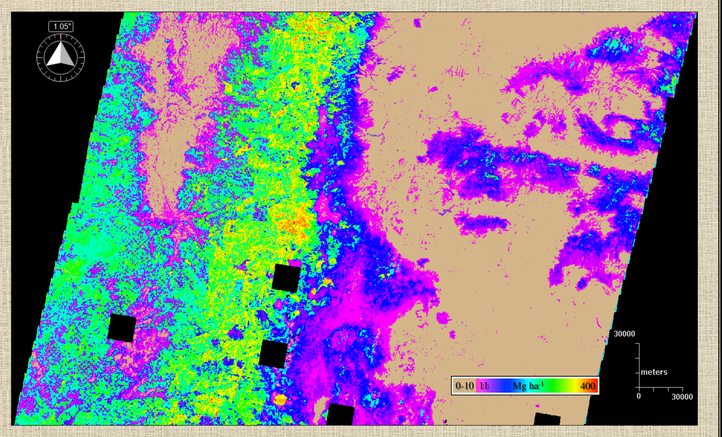

Figure 5. MISR/BRT predicted aboveground biomass map for MISR blocks 55-56 (123700 km^2), August 16, 2011, using only B, G, R, N nadir BRFs, RMSE, and Li-Ross kernel weights as predictors.

Conclusions: The BRT approach provides a means of mapping AGB using MISR BRFs and derived BRDF model kernel weights with reasonable accuracy and better than that obtainable using a GO model in dense forests. The results presented here are based almost entirely on the NBCD 2000 data set with 2011 MISR data, so further work is required using temporally consistent data; and to validate results with independent data.

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References:

Elith, J., Leathwick, J.R., and Hastie, T. (2008). A working guide to boosted regression trees, *Journal of Animal Ecology* 77:802–813. doi: 10.1111/j. 1365-2656.2008.01390.x

Grohmann, C.H.; Smith, M.J.; Riccomini, C. (2010). Multiscale Analysis of Topographic Surface Roughness in the Midland Valley, Scotland, *IEEE Transactions on Geoscience and Remote Sensing*, vol.PP, no.99, pp.1-14.

Kellndorfer, J., W. Walker, K. Kirsch, G. Fiske, J. Bishop, L. LaPoint, M. Hoppus, and J. Westfall. 2013. NACP Aboveground Biomass and Carbon Baseline Data, V. 2 (NBCD 2000), U.S.A., 2000. Data set. Available on-line: **http://daac.ornl.gov** from ORNL DAAC, Oak Ridge, Tennessee, U.S.A.

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