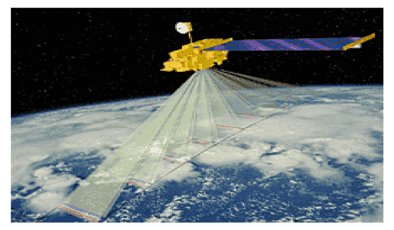

Mapping Aboveground Biomass in the Western US with the Multiangle Imaging Spectro-Radiometer

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Southwestern US: Bidirectional reflectance factor (BRF) data from the NASA Multiangle Imaging Spectro-Radiometer (MISR) were used to drive a boosted regression tree (BRT) model to estimate aboveground biomass (AGB) in the southwestern US for 2000 and 2009.

Predictors included May 15 - June 15 MISR nadir camera BRFs, MISR LiSparse-RossThin Non-Reciprocal bidirectional reflectance distribution function (BRDF) isotropic, volume scattering, and geometric scattering model kernel weights, RMSE and map coordinates, derived from MISR Level 1B2 Terrain radiance data. The National Biomass and Carbon Dataset (NBCD, Kellndorfer et al. 2013) was used to train the model. The NBCD data were resampled to the same 250 m Albers Conical Equal Area grid used for the MISR data. Calibration data consisted of training and validation data sets generated in two stages, including one set of 13,693 completely random points and a second set of 10,240 random points located in forest only. The combined set was filtered for cloud/cloud shadow/non-vegetated cases (LiSparse-RossThin model-fitting RMSE>0.01, NBCD AGB=0, and missing data) and divided randomly into training and validation data sets for model testing and (N= 2516 and 2459, respectively). The final model used a tree complexity of 10, a learning rate of 0.005, and 1200 trees. The model was tested using the validation data set yielding an R^2 of 0.73. BRT models were constructed using 4 combinations of predictors (Table 1).

The results were assessed against independent random samples, with N=1013 for all sites and 3390 for forest sites only. The results using all predictors showed the best agreement, with R^2 of RMSE of 0.76 and 18.0 Mg ha^{-1} (all sites) to 0.71 and 17.7 Mg ha^{-1} (forest). The model was then applied with 2009 MISR data. A mask was constructed to exclude invalid data (Figure 1). Since no appropriate independent validation data are available the results were assessed against the NBCD 2000 estimates, in the first instance for the locations of the combined training and validation data sets (N=4975) – showing very good agreement, with RMSE down to 31 Mg ha^{-1} (Table 1) – and for independent random points (Table 2).

TABLE 1. MISR/BRT ABOVEGROUND BIOMASS ESTIMATES W.R.T. NBCD 2000 (V2)

	R^2	RMSE	Predictor Variables
Bio7	0.73	35.2	An[1]: Blue, Green, Red, NIR LiSpRThin[2]: iso, geo, vol
Bio8	0.74	34.6	An[1]: Blue, Green, Red, NIR LiSpRThin[2]: iso, geo, vol, RMSE
Bio9	0.75	34.0	An[1]: Blue, Green, Red, NIR LiSpRThin[2]: iso, geo, vol, RMSE, Y
Bio10	0.80	30.6	An[1]: Blue, Green, Red, NIR LiSpRThin[2]: iso, geo, vol, RMSE, Y, X

Note: [1] MISR nadir-viewing camera [2] LiSparse-RossThin non-reciprocal model. N = 4975.

TABLE 2. SUMMARY OF MISR/BRT & GO MODEL BIOMASS PREDICTIONS VS NBCD 2000

	R^2	RMSE	Predictor Variables
All-Bio7	0.69	36.7	An[1]: Blue, Green, Red, NIR LiSpRThin[2]: iso, geo, vol
All-Bio8	0.69	20.5	An[1]: Blue, Green, Red, NIR LiSpRThin[2]: iso, geo, vol, RMSE
All-Bio9	0.69	19.0	An[1]: Blue, Green, Red, NIR LiSpRThin[2]: iso, geo, vol, RMSE, Y
All-Bio10	0.76	18.0	An[1]: Blue, Green, Red, NIR LiSpRThin[2]: iso, geo, vol, RMSE, Y, X
For-Bio7	0.63	38.7	An[1]: Blue, Green, Red, NIR LiSpRThin[2]: iso, geo, vol
For-Bio8	0.64	21.1	An[1]: Blue, Green, Red, NIR LiSpRThin[2]: iso, geo, vol, RMSE
For-Bio9	0.64	19.2	An[1]: Blue, Green, Red, NIR LiSpRThin[2]: iso, geo, vol, RMSE, Y
For-Bio10	0.71	17.7	An[1]: Blue, Green, Red, NIR LiSpRThin[2]: iso, geo, vol, RMSE, Y, X

Note: [1] MISR nadir-viewing camera [2] LiSparse-RossThin NR model. N = 1013 for all sites (All-) and 3390 for forest sites only (For-), after filtering for missing data and poorly-constrained BRDF model inversions.

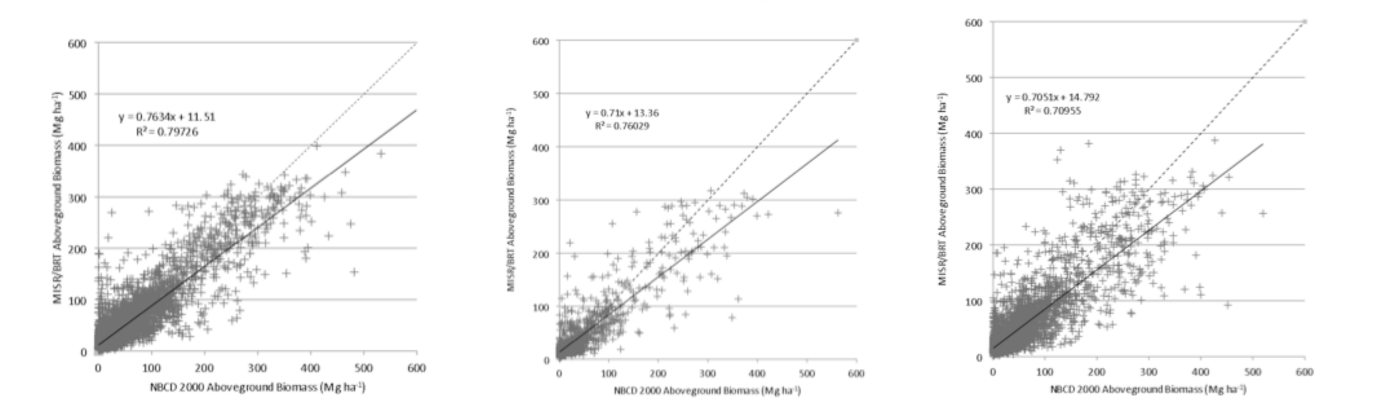
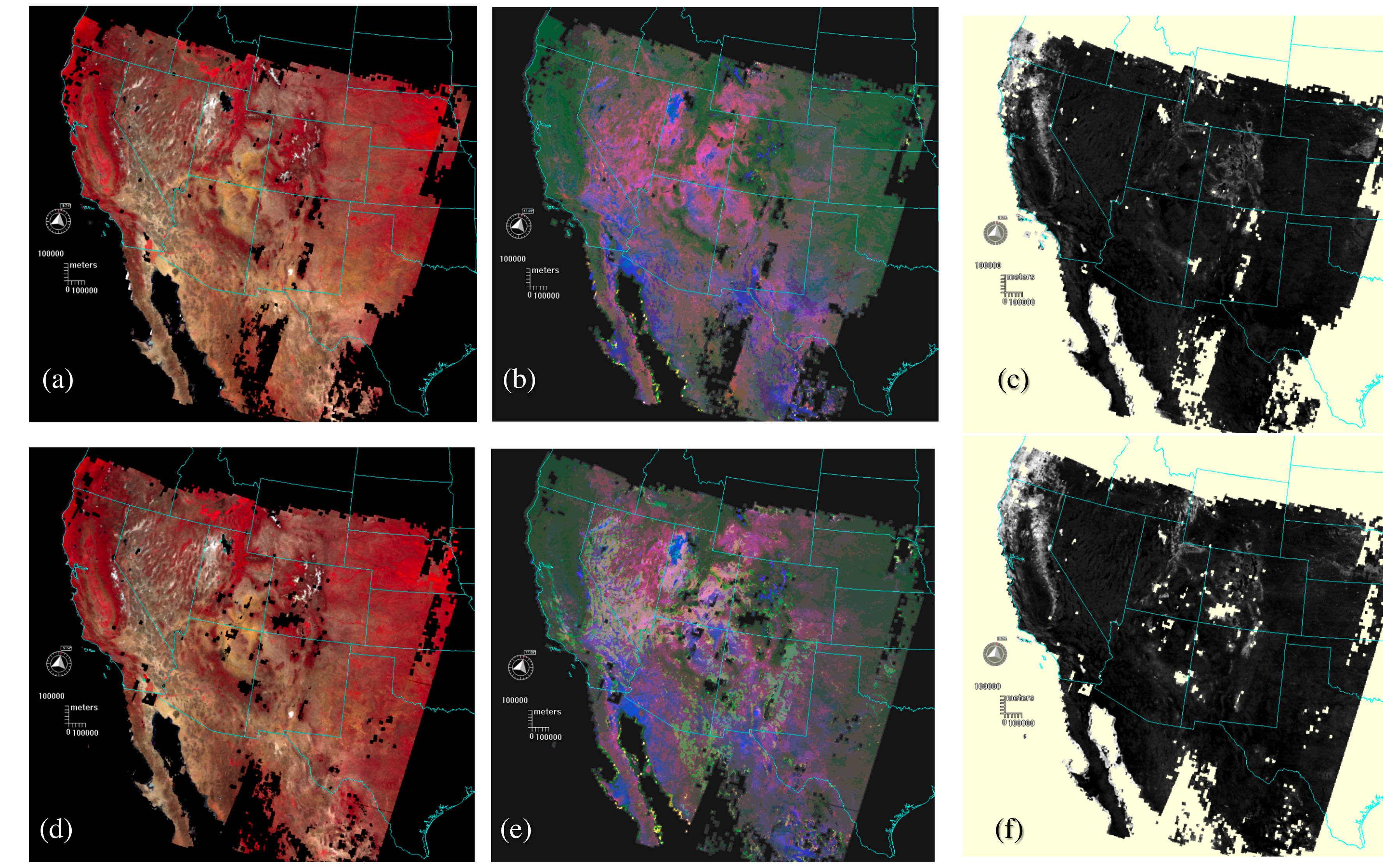


Figure 3. MISR/BRT vs NBCD 2000 aboveground biomass estimates (a) 4975 points used in training and validation (50/50 random split) (b) 1013 points filtered from 10,000 random points (c) 3390 filtered from 10,000 random points in forest only. Filtering was for missing data, model-fitting RMSE > 0.01 (cloud/shadow/non-vegetated) and NBCD 2000 values of zero.



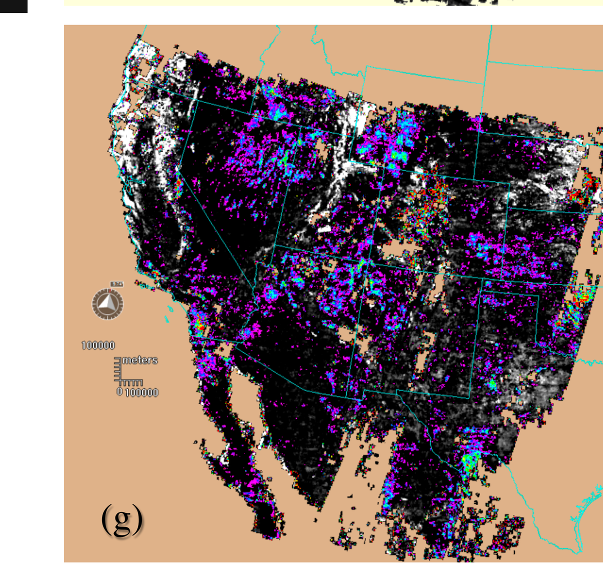


Figure 1. (a) 2000 NIR-Red_Green False Color Composite (FCC) (b) 2000 geometric-volumetric-isotropic BRDF model kernel weight FCC (c) 2000 AGB from MISR/BRT (d) 2009 NRG FCC (b) 2009 geo-vol-iso kernel weight FCC (c) 2009 AGB from MISR/BRT (g) 2009 AGB minus 2000 AGB. ROYGBIV color scale indicates biomass loss from 30 to 5 Mg ha^{-1} with loss > 30 Mg ha^{-1} in red; gray scale indicates biomass gain from 5 to 30 Mg ha^{-1} with gain> 30 Mg ha^{-1} in white.

Oregon Forest: In dense forests, geometric-optical (GO) model inversion is problematic, so empirical methods such as BRT models must be employed to interpret multiangle metrics. In this study, MISR Level 1B2 Terrain radiance data from the Terra satellite overpass on 08/16/11 (Orbit 062028, Path 45, Blocks 55-56) were converted to BRF using MISR Toolkit routines and the MISR 1 km LAND product BRFs (nadir camera blue, green, and NIR BRFs and red band BRFs in all nine MISR cameras). The LAND product albedo threshold was reduced to zero and the topographic complexity threshold disabled in order to increase coverage.

Fig 2. Dynamic nature of Oregon forests from high resolution imagery 2001-2011

The RossThick-LiSparse-Reciprocal (RTLS-R) BRDF model was inverted to retrieve the kernel weights, model-fitting root mean square error (RMSE), white and black sky albedos, and weights of determination. A 1-arcsecond (30 m) digital elevation model (DEM) from the National Elevation Dataset was used to calculate a topographic roughness map at 250 m following Grohmann et al. (2010). NBCD data were used to train the BRT model and to assess the results. The 240 m Zone 6 NBCD AGB data were resampled to the 250 m MISR grid as before. 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*. The filtering yielding N = 756 and 789 for corrected training and validation sets, respectively, reduced from 991 and 1007 for the uncorrected sets, respectively.

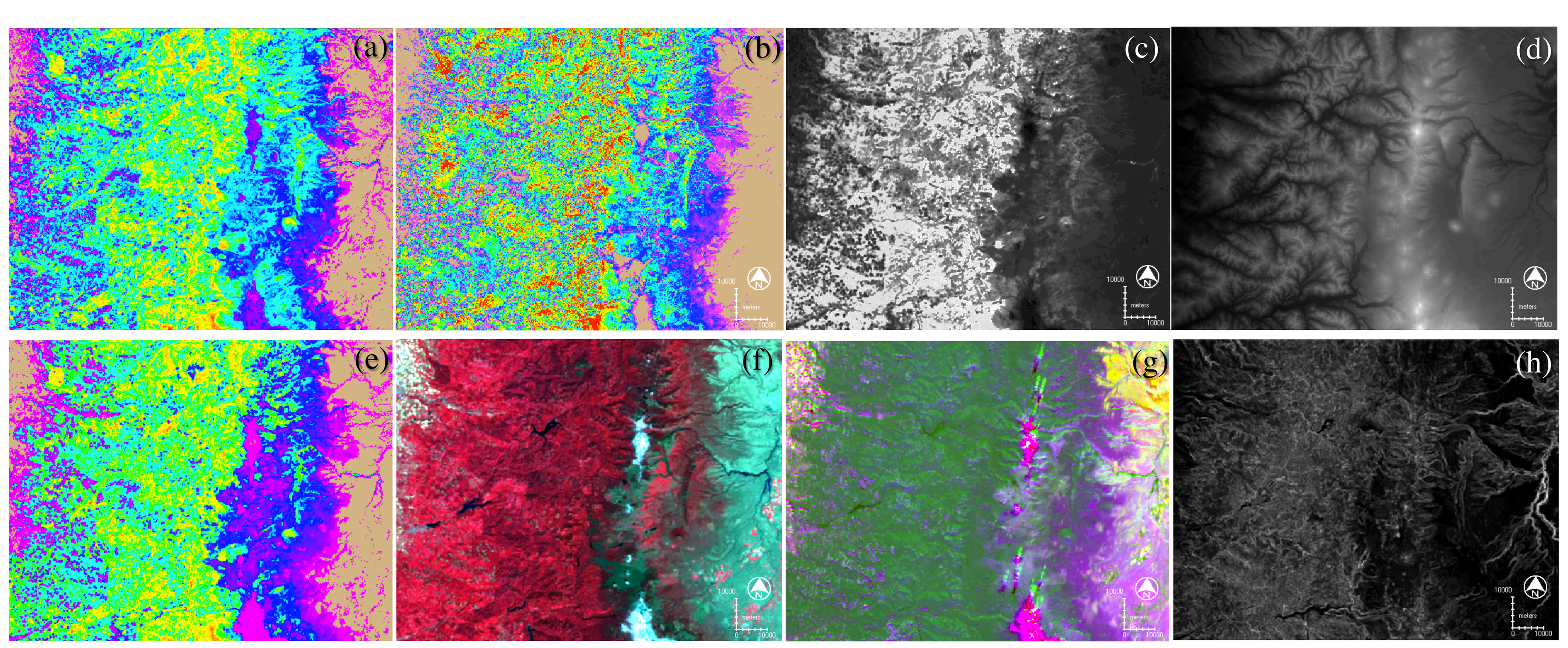


Figure 3. (a) AGB from MISR/BRT, filtering training data only on Li-Ross RMSE < 0.01 (b) NBCD AGB map for 2000 (c) MISR/GO model number density, 0–2300 trees (d) Roughness (slope st.dev.) from NED DEM, 0–50 (e) AGB from MISR/BRT, filtering training data on temporal coherence as well as Li-Ross RMSE < 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

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"). 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 3, Fig. 4). 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 geometric-optical model inversion in dense forests. cont…

These show very good results compared with predictions via regression based on Simple GO Model (SGM) forest cover and height retrievals (Table 3, Fig. 4). The BRT approach provides a means of mapping AGB using MISR BRFs, derived BRDF model kernel weights and limited ancillary data with good accuracy and better than that obtainable using geometric-optical model inversion in dense forests.

TABLE 3. SUMMARY OF MISR/BRT AND GO MODEL BIOMASS PREDICTIONS VS NBCD 2000 (MGHA^{-1})

	RMSE	R^2		RMSE	R^2
MISR/BRT Set 1, UNCORRECTED	57	0.80	MISR/BRT Set 1, CORRECTED	42	0.90
MISR/SGM Set 1 UNCORRECTED	100	0.36	MISR/SGM Set 1, CORRECTED	69	0.72
MISR/BRT Set 2, UNCORRECTED	80	0.58	MISR/BRT Set 2, CORRECTED	62	0.78
MISR/SGM Set 2 UNCORRECTED	98	0.39	MISR/SGM Set 2, CORRECTED	68	0.73

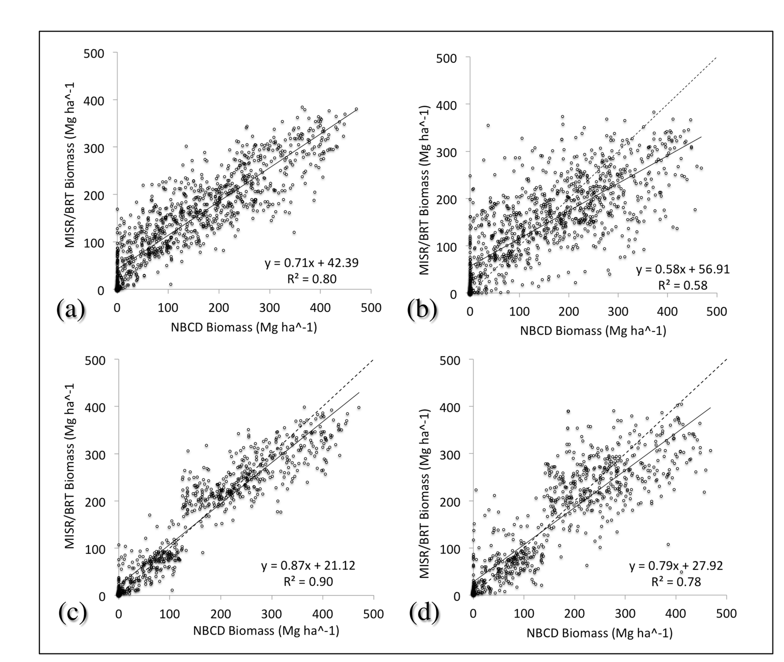


Figure 4. NBCD vs predicted AGB (a) set 1, uncorrected (b) set 2, uncorrected (c) set 1, corrected (d) set 2 , corrected.

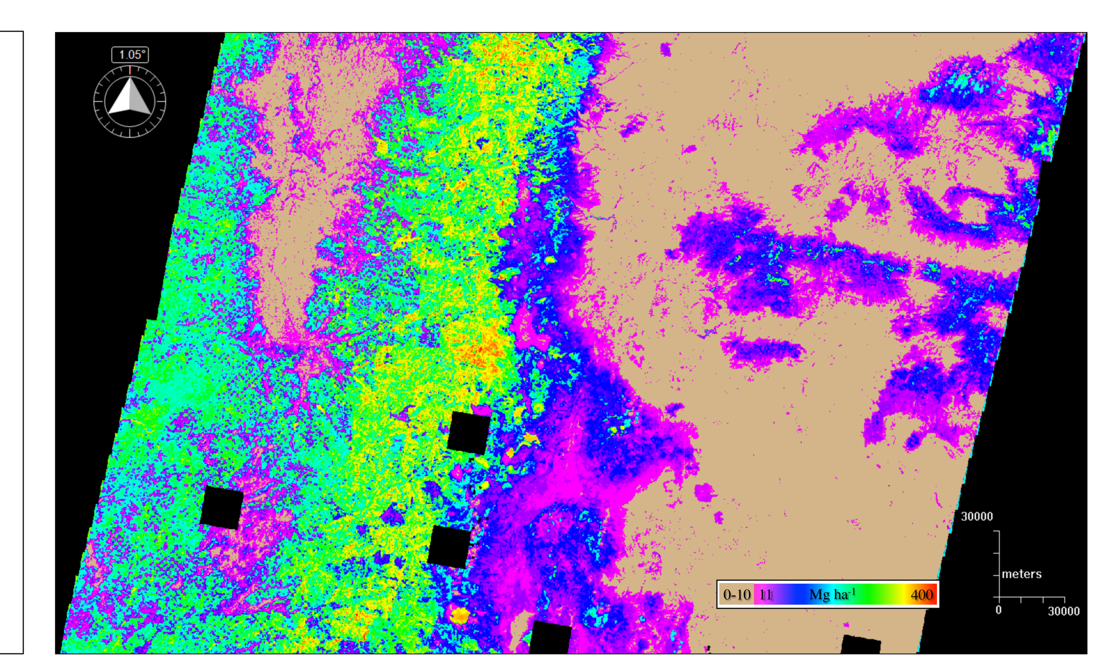


Figure 5. MISR/BRT predicted aboveground biomass map for MISR blocks 55-56 (123700 km²), August 16, 2011, using only B, G, R, N nadir BRFs, RMSE, and Li-Ross kernel weights as predictors.

Acknowledgments: This work was supported by NASA Science of Terra and Aqua Award NNX11AF90G and NASA/JPL subcontract #1365499. Data credits: NASA LARC/ASDC, Digital Globe, Inc., plus those referenced below. More information, maps & code: http://csam.montclair.edu/~chopping/wood

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