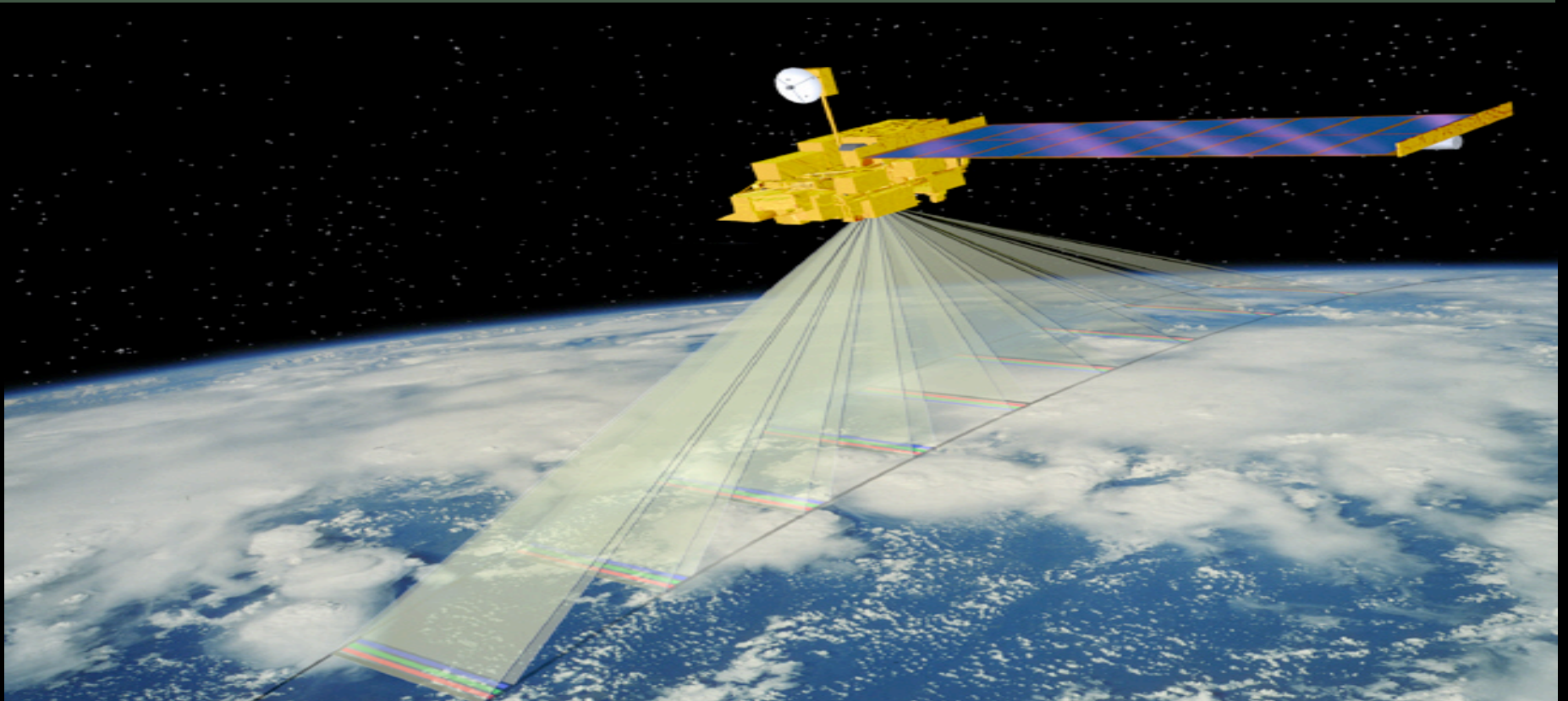


Mapping Forest Crown Cover, Canopy Height, and Biomass in the Southwestern US with MISR



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Large area mapping of southwestern forest crown cover, canopy height, and biomass using MISR: 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-RosThin 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.

Large area mapping of southwestern forest crown cover, canopy height, and biomass using MISR: Introduction

GO models predict BRF at specified illumination and viewing directions as a function of stand-scale canopy structure parameters of practical and ecological significance:

- mean crown shape (b/r)
- mean crown radius (r)
- plant number density (λ)
- mean canopy height (h)
- background brightness and anisotropy (functions of understory density and soil brightness)

$$R = G \cdot k_G + C \cdot k_C + T \cdot k_T + Z \cdot k_Z$$

G, C, T, Z can be assumed Lambertian or may have defined reflectance anisotropies

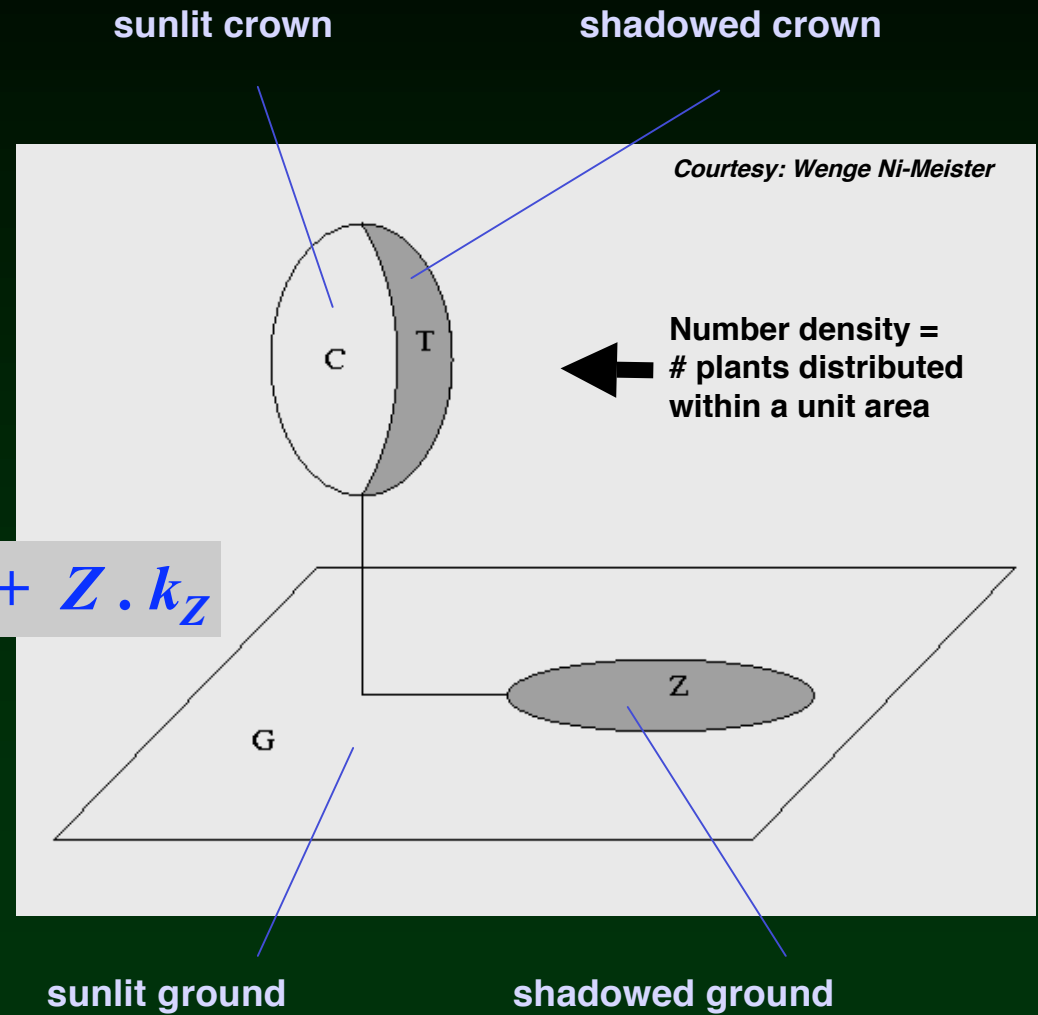


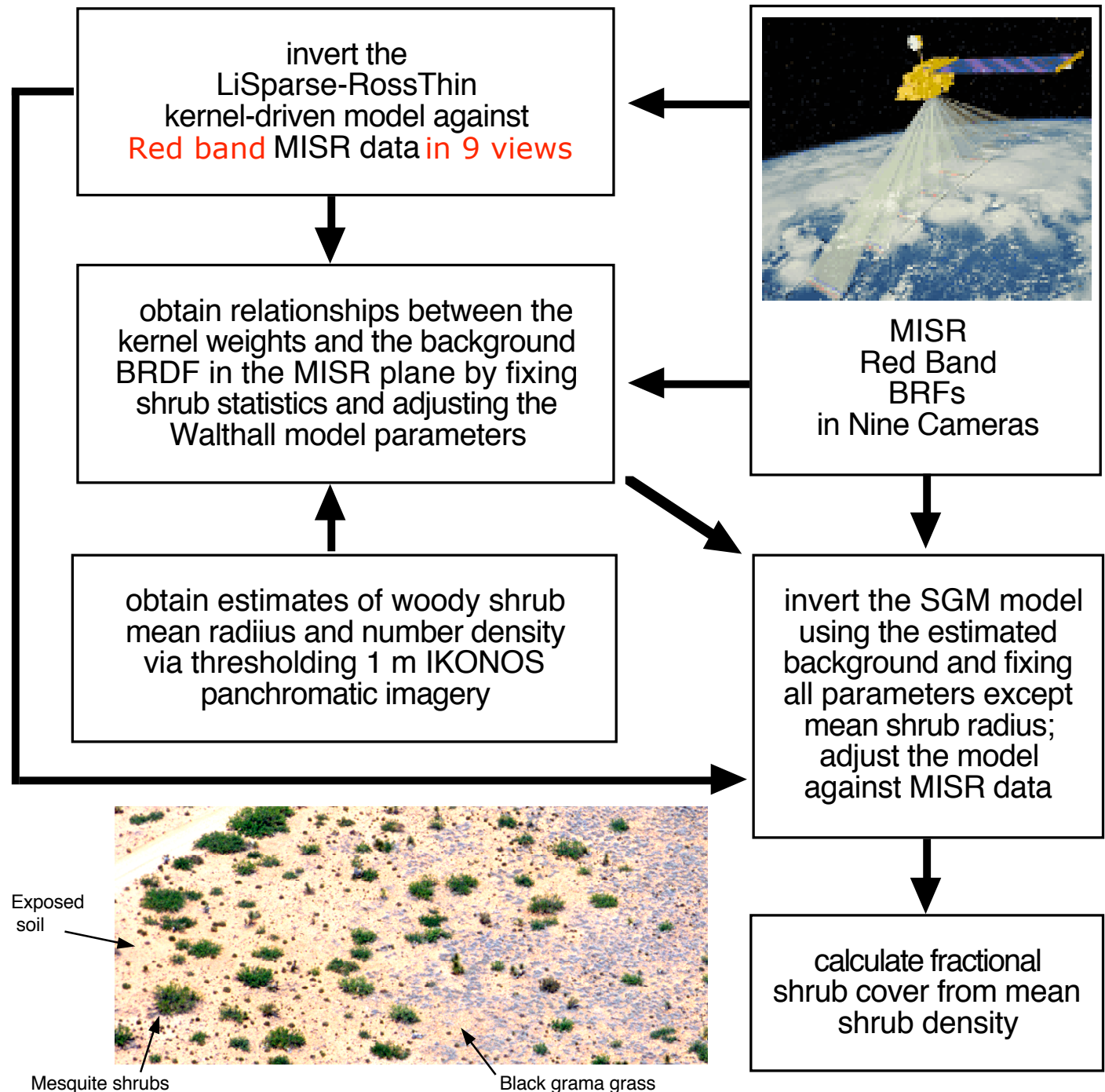
Figure 1. SGM example protocol for retrieval of shrub cover

The Walthall model (W) is used to represent the background and a Ross function allows for within-crown volume scattering; G is replaced with W and C with Ross, so that

$$R =$$

$$\cancel{G} W.k_G + \cancel{C} Ross.k_C$$

T and Z are considered black



Large area mapping of southwestern forest crown cover, canopy height, and biomass using MISR: Method

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

Adjustment of the Model for r and b/r with Praxis:

Fractional crown cover is from r with fixed λ (sensitive to brightness)

Canopy height is from b/r with fixed h/b (sensitive to BRF shape)

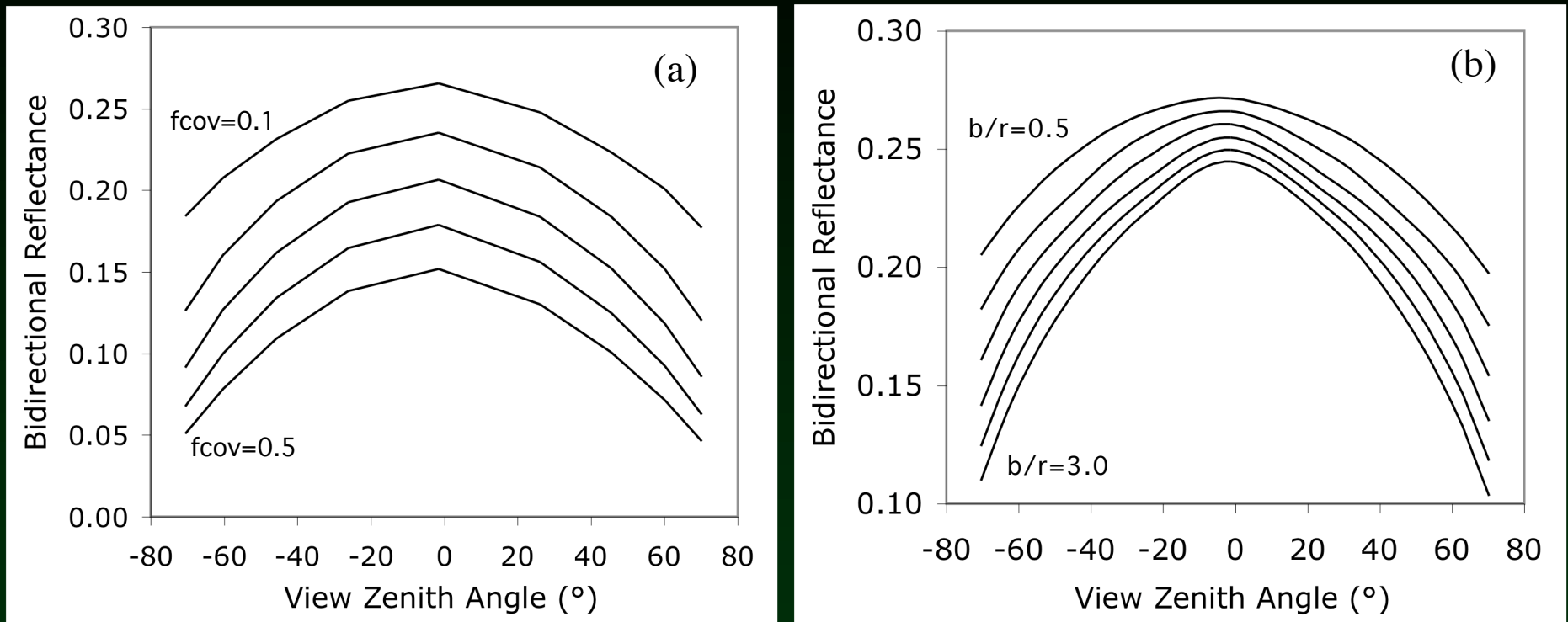


Figure 2. The effects of changing (a) fractional crown cover with plant number density (λ) fixed at 0.012 and maintaining canopy height at 3.0 m (b) crown shape (b/r), maintaining h/b fixed at a typical value of 2.00, where r , b and h are crown horizontal radius, vertical radius and center height. If we have r and b/r , and h/b is fixed, we can obtain h . We only have an estimate of r -- but this does not appear to be critical.

Model Fits to MISR Data

Model fits to MISR data were good with a RMSE mean (standard deviation) of 0.012 (0.025) and a mode of 0.004 for the composited maps.

Figure 3 shows typical fits to MISR data for a range of cover values.

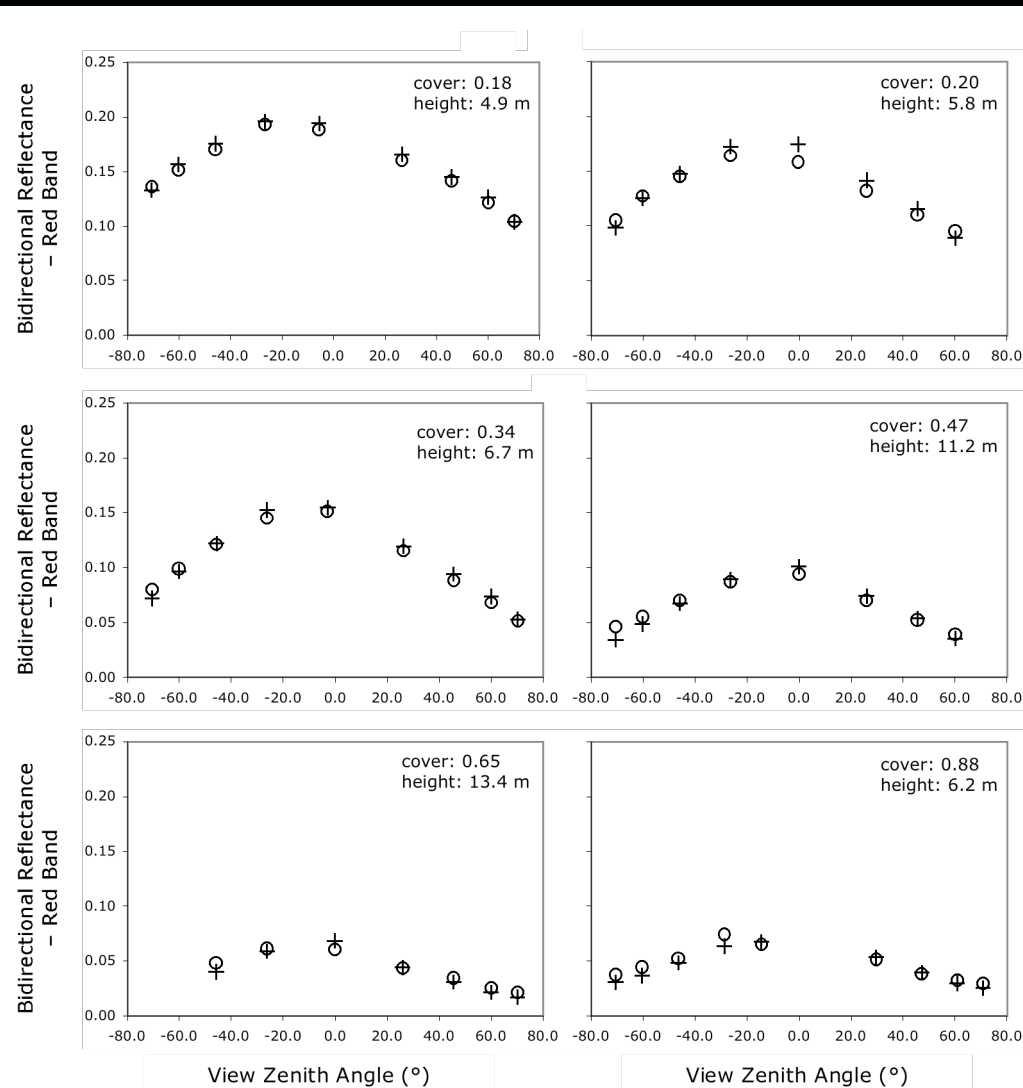


Figure 3. Model fits to MISR data

Large area mapping of southwestern forest crown cover, canopy height, and biomass using MISR: 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 (Figure 4). 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%).

Distribution of Reference Data Points

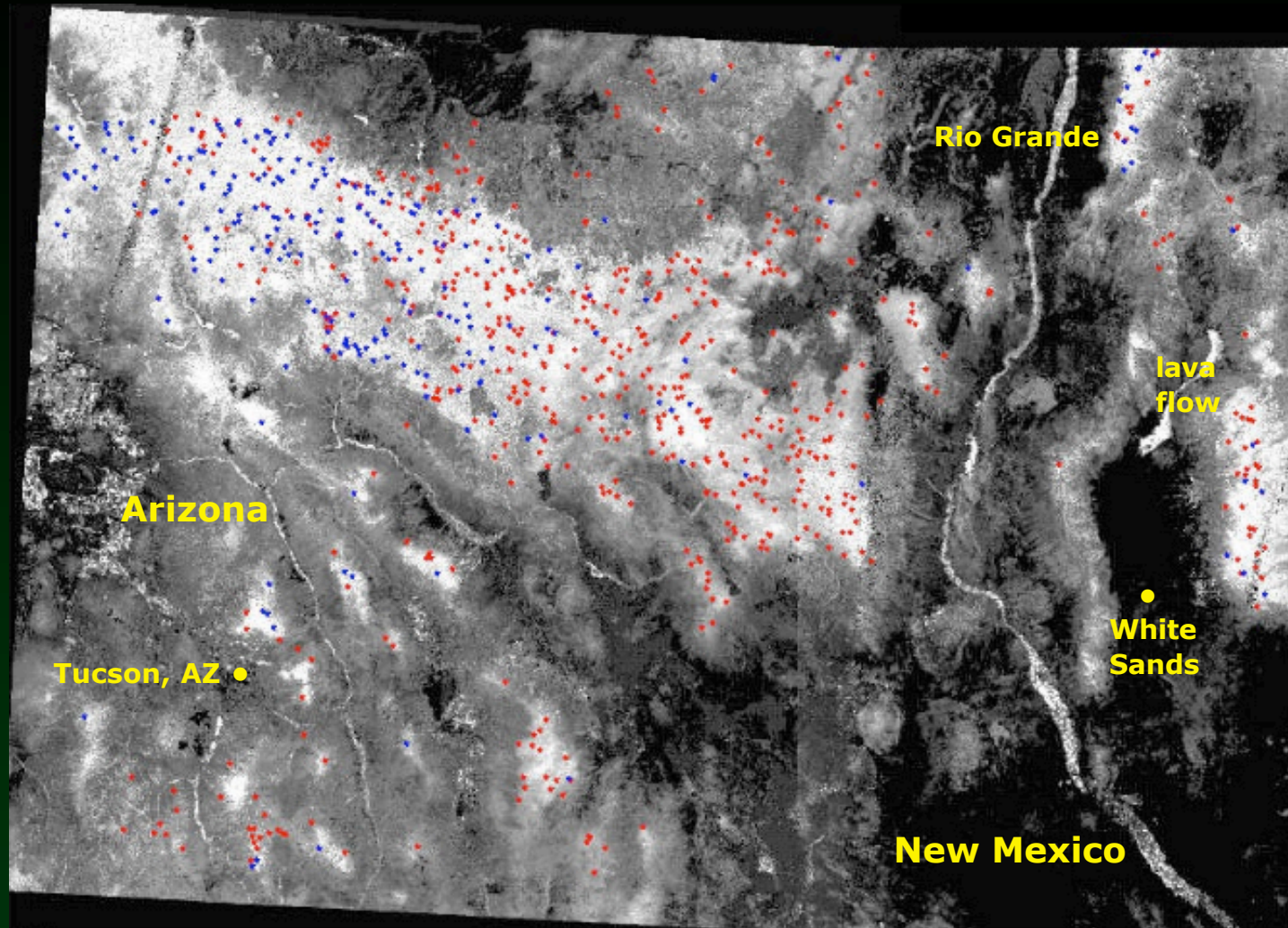


Figure 4. MISR/GO crown cover map in grayscale showing illuminated reference locations (red points) and those impacted by topography (blue points).

MISR/GO Forest Structure Mapping: First-order Validation

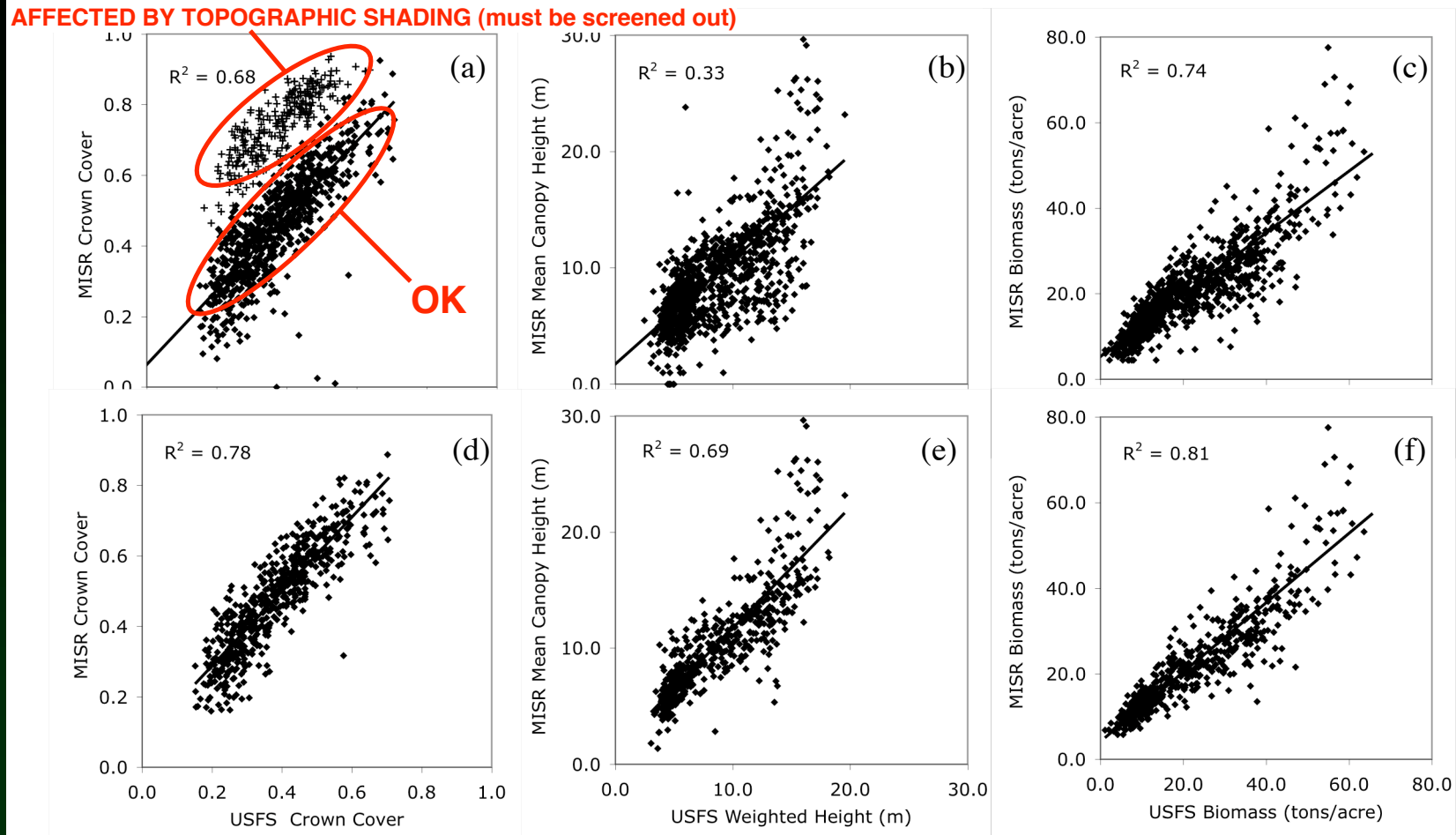


Figure 5. (a)-(c) Retrievals vs. US Forest Service Map Data. The upper cluster of data points in (a) corresponds to locations affected by severe topography (d)-(f) Retrievals with screening for topographic effects using a Digital Elevation Model from the Shuttle Radar Topography Mission. Points with RMSE ≥ 0.01 and outliers ± 2 st. devs. from the mean of crown cover were discarded, retaining 576 points (54%).

Large area mapping of southwestern forest crown cover, canopy height, and biomass using MISR: Results

The maps also include woody shrubs in desert grasslands as the approach relies mainly on surface physical characteristics (Figures 6-8).

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).

Fig. 6: Regional Aboveground Biomass

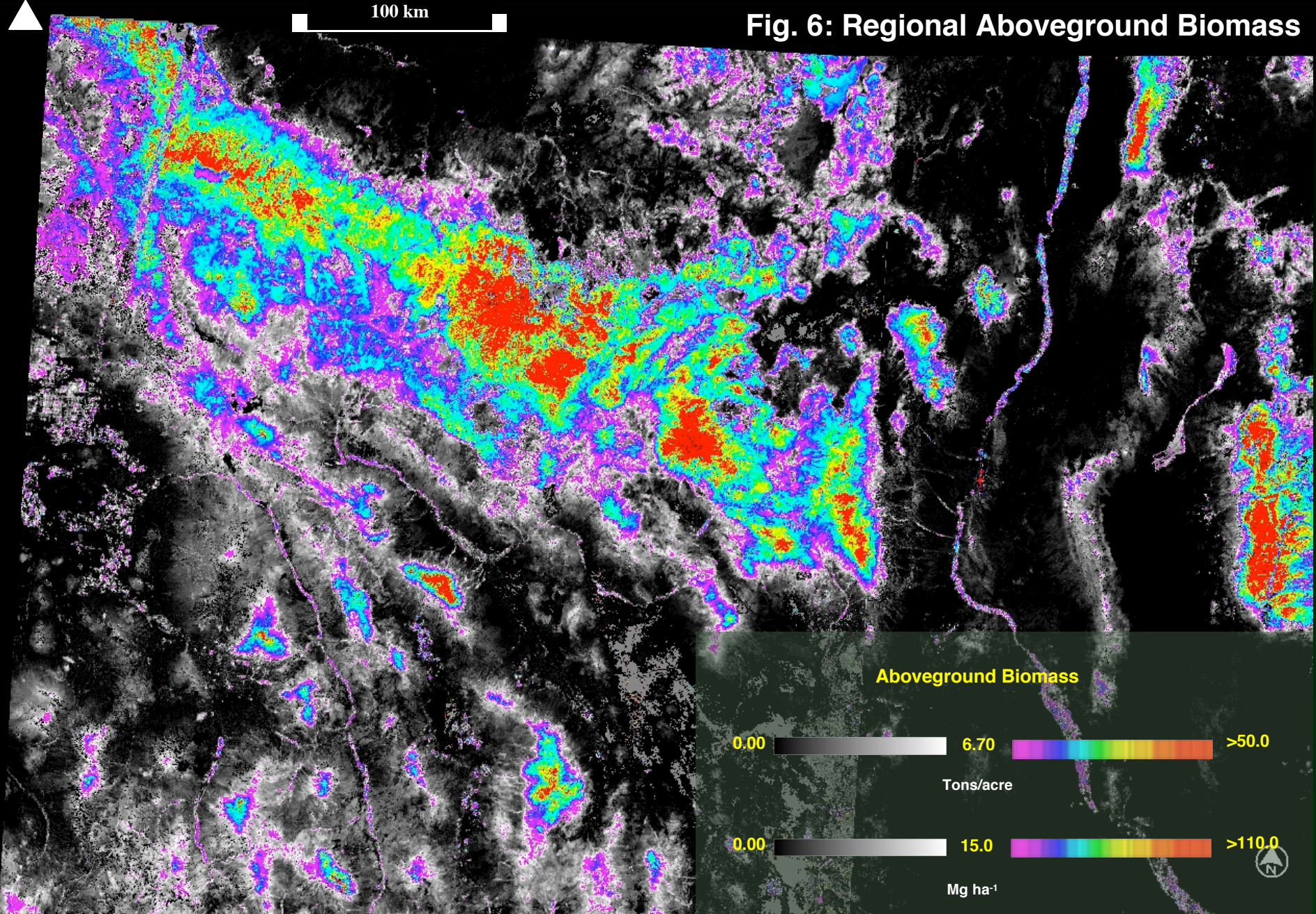


Fig. 7: Regional Mean Canopy Height

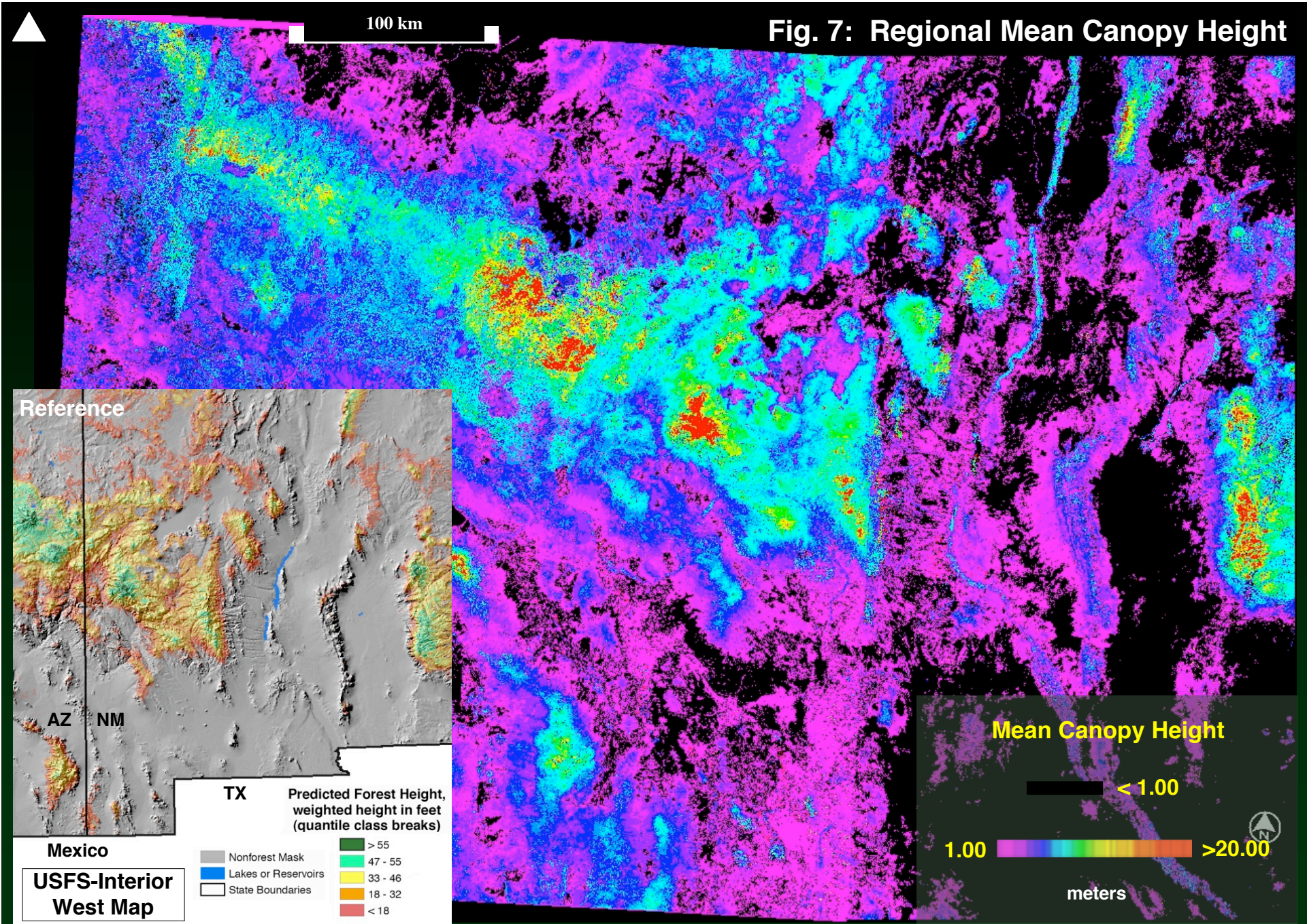


Fig. 8: Regional Forest Crown Cover

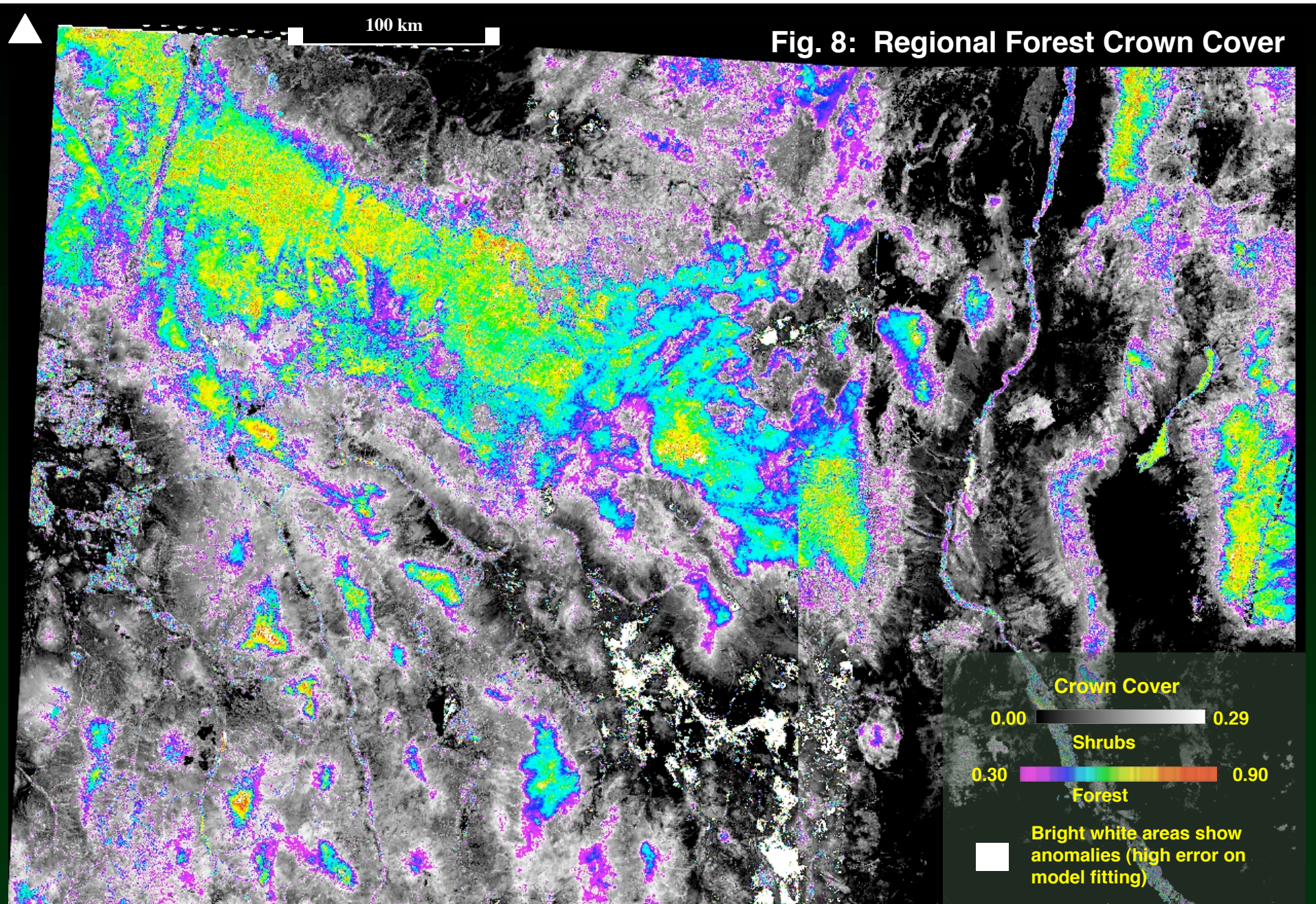
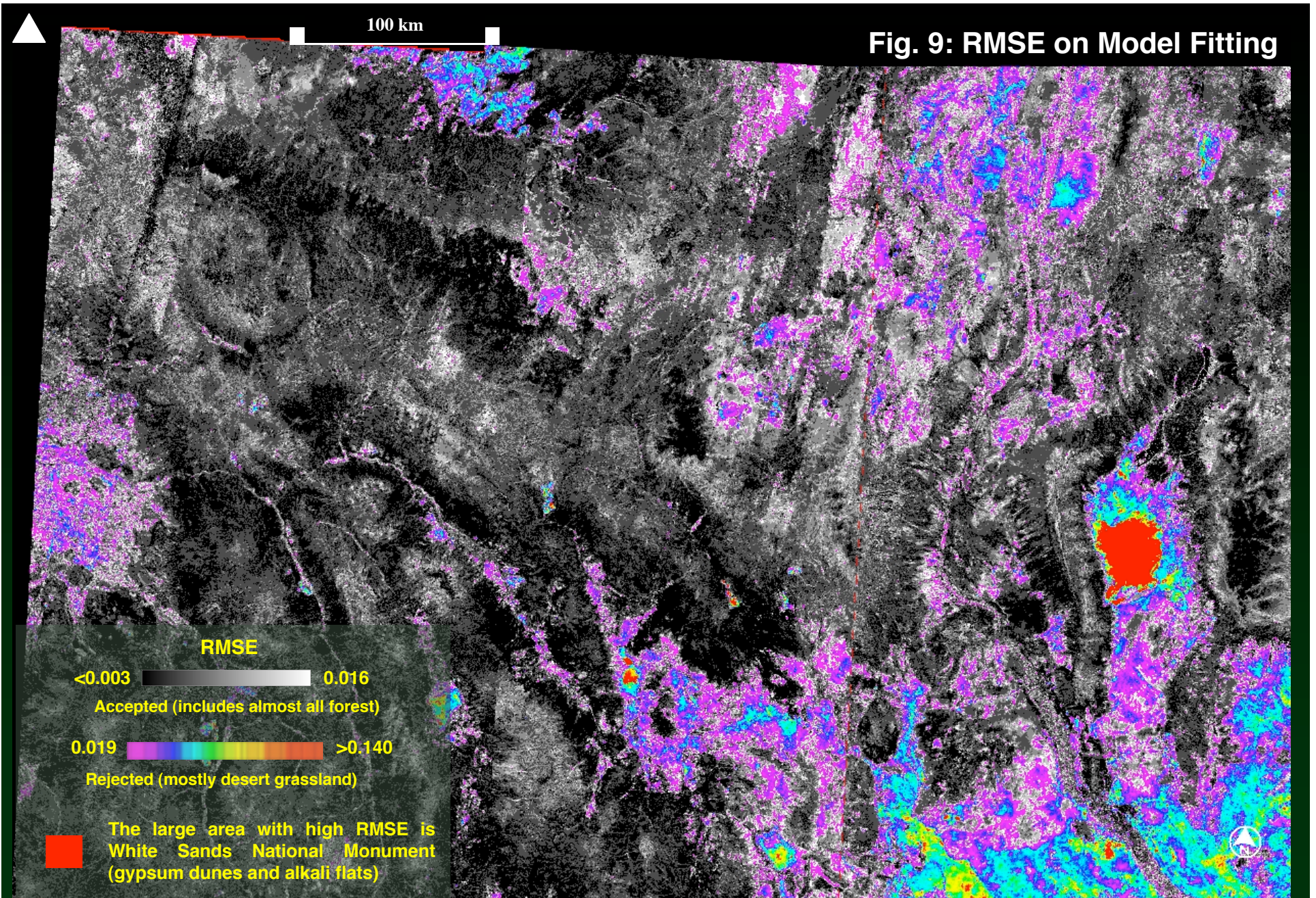
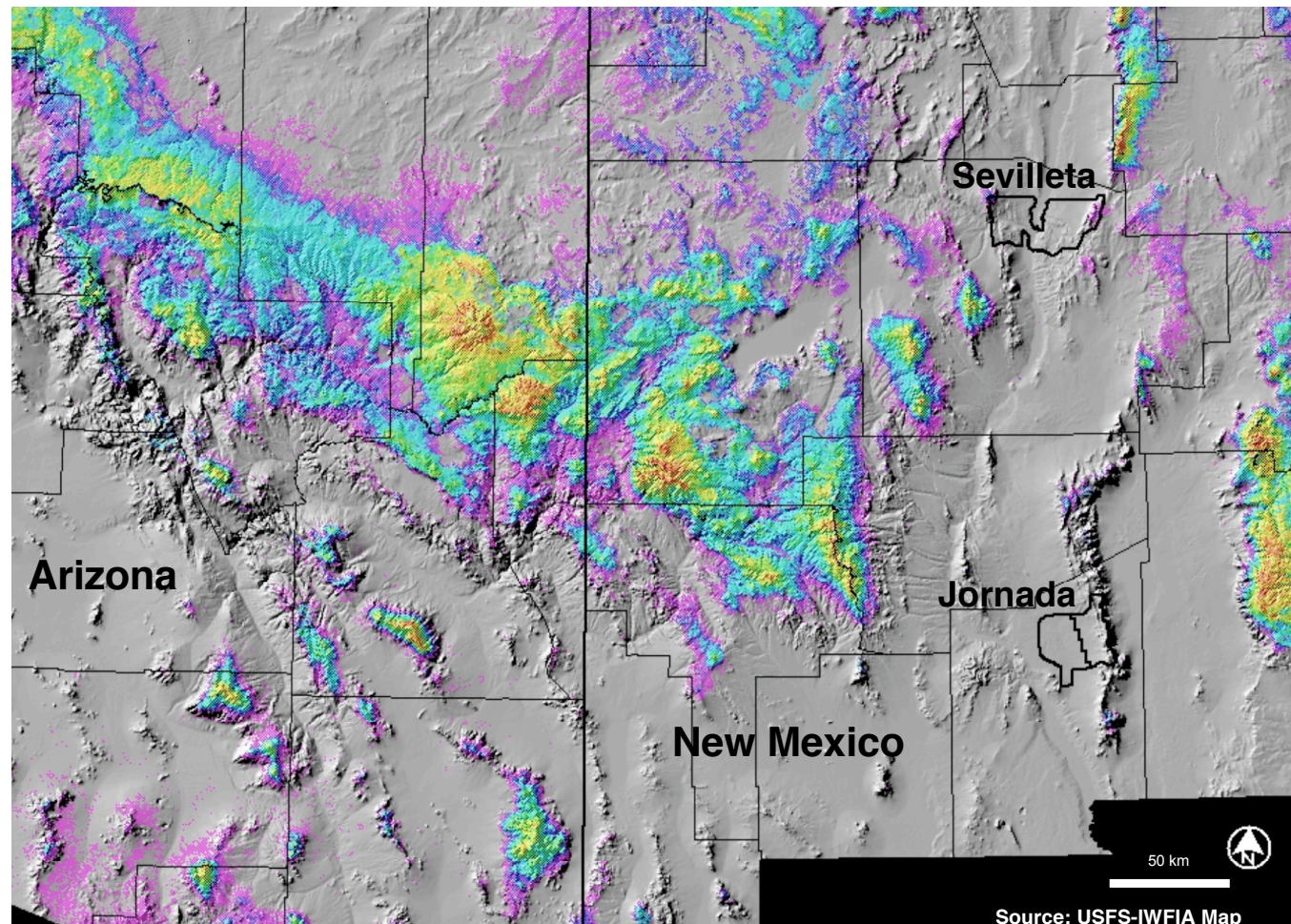


Fig. 9: RMSE on Model Fitting






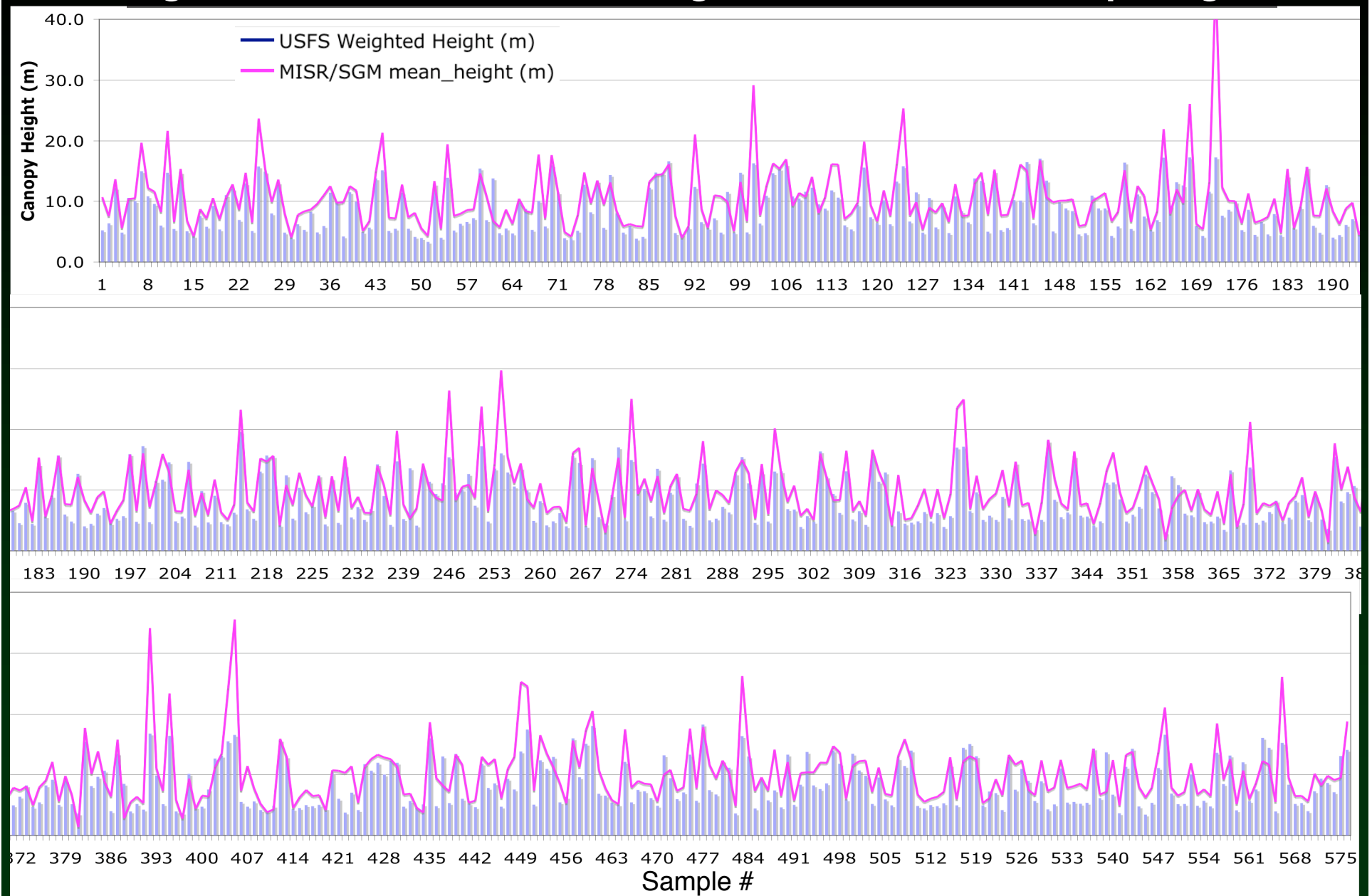
< 6  > 60
 Estimated Biomass (tons/acre)

Fig 10: Reference: USDA Forest Service map showing estimated forest biomass for the Interior 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). Light lines indicate county boundaries.

Figure 11. Plot of Retrieved Height vs USFS IW-FIA Map Height



Large area mapping of southwestern forest crown cover, canopy height, and biomass using MISR: Results

Table I: Error Analysis

	Fractional crown cover (dimensionless)	Mean canopy height (meters)	Woody Biomass (tons acre ⁻¹) (Mg ha ⁻¹)	
Mean Relative Error (%)	3.0	2.8	2.8	-
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	-

Large area mapping of southwestern forest crown cover, canopy height, and biomass using MISR: Conclusions

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.



<http://www-misr.jpl.nasa.gov/>

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