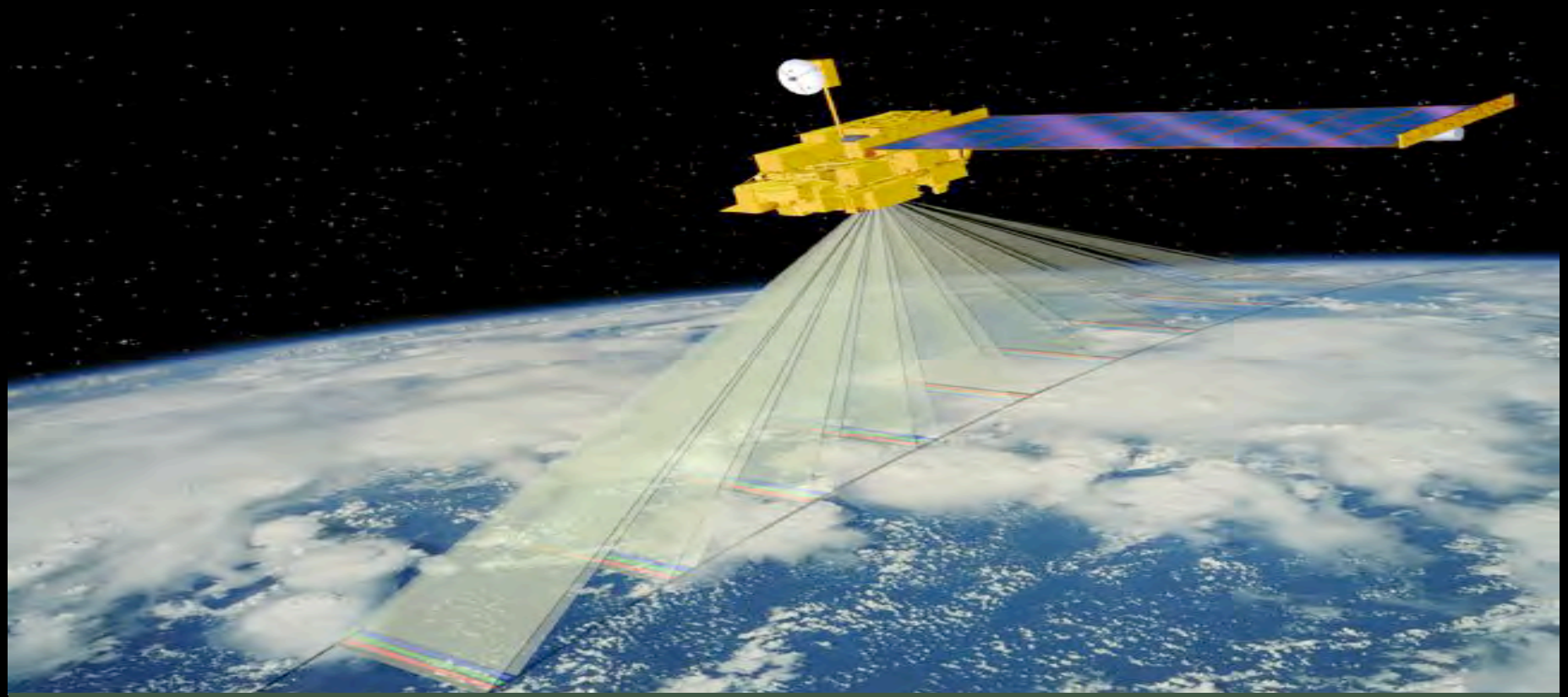
Mapping Southwestern US forest Crown Cover, Canopy Height, and Biomass with MISR



Mark Chopping, Lihong Su, Libertad Urena (Montclair State University), Gretchen Moisen (USFS); Andrea Laliberte, Albert Rango, Debra P. C. Peters (USDA, ARS); and John V. Martonchik (NASA, JPL)

MISR Data Users Science Symposium, CalTech, Pasadena, CA, December 7-8, 2006

Acknowledgments

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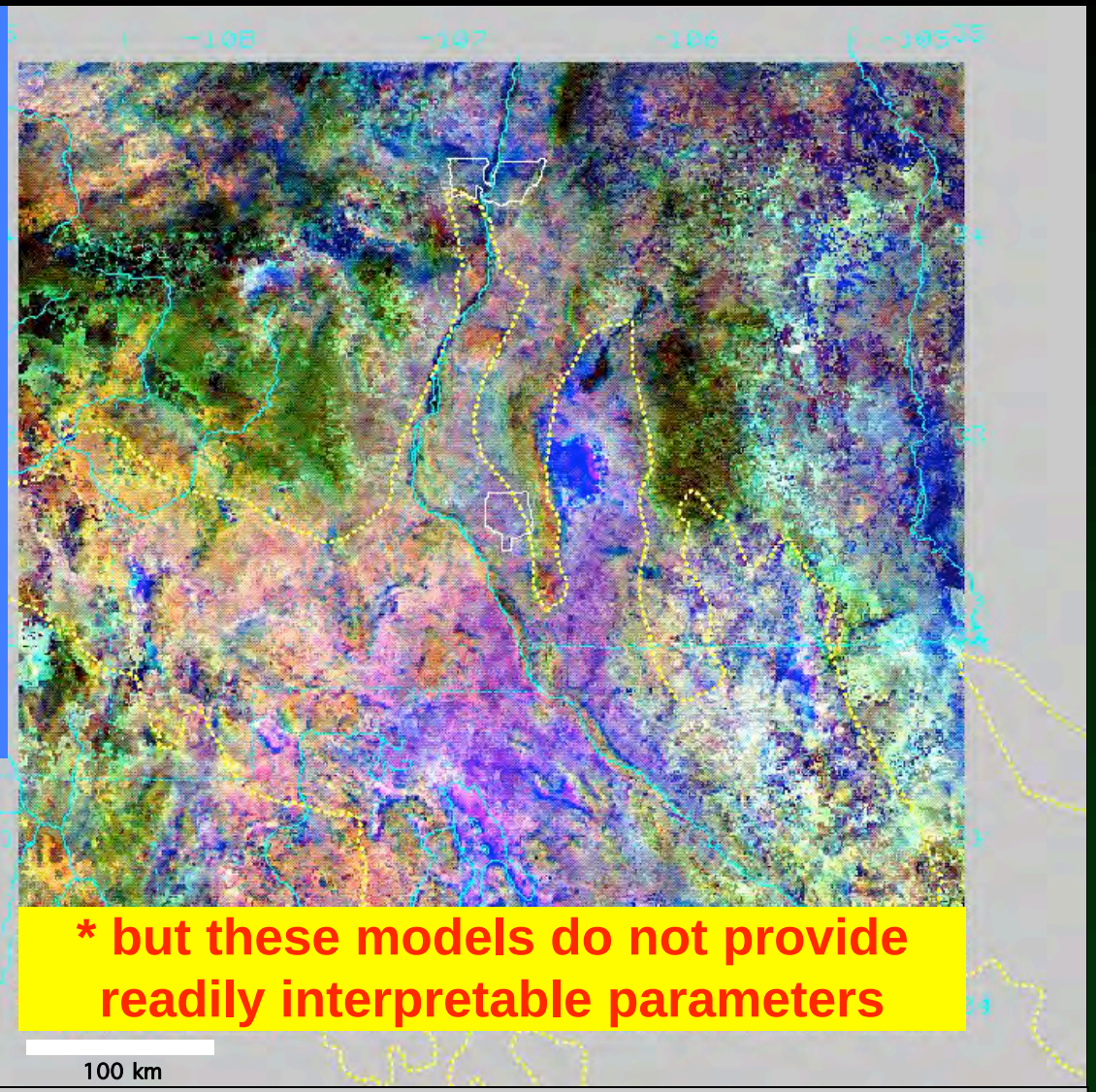
Canopy Structure from MISR

Canopy architecture and spatial heterogeneity are important parameters in forests and grasslands undergoing woody encroachment and affect carbon storage, vegetation dynamics, wildfire risk, surface roughness…

This talk reports on efforts to map southwestern forest canopy crown cover, mean height, and biomass using only MISR multi-angle reflectance factors interpreted with geometric-optical (GO) and Li-Ross models.

Multi-Angle Data are Sensitive to Canopy Structure!

In the 1980s we recognized large directional effects in AVHRR VNIR data resulting from variations in canopy structure; in the 1990s we learned how to model these* semi-empirically (Li-Ross & RPV models)



RGB= iso, geo, vol kernel weights (Li-Ross model fitted to AVHRR VIS channel data)

Canopy Structure from MISR Observations

Researchers have sought to obtain measures of canopy structure using multi-angle observations by pursuing a variety of approaches:

- ***Empirical / Data Mining / Synergistic***
- ***Radiative Transfer modeling/LUTs***
- ***Canopy Openness from MRPV-k parameter***
- ***Clumping Index***
- ***Structural Scattering Index (Li-Ross)***
- ***Geometric-Optical and Hybrid Models***

All these avenues have proved worthwhile

Focus on Canopy Structure from GO Modeling

Chopping *et al*. performed GO modeling studies at the

Plot scale*	**25 m^2**	**2003-4**
Landscape scale 1*	**> 27 km^2**	**2005**
Landscape scale 2**	**> 3,519 km^2**	**2005-6**
Regional scale***	**~ 240,000 km^2**	**2006**

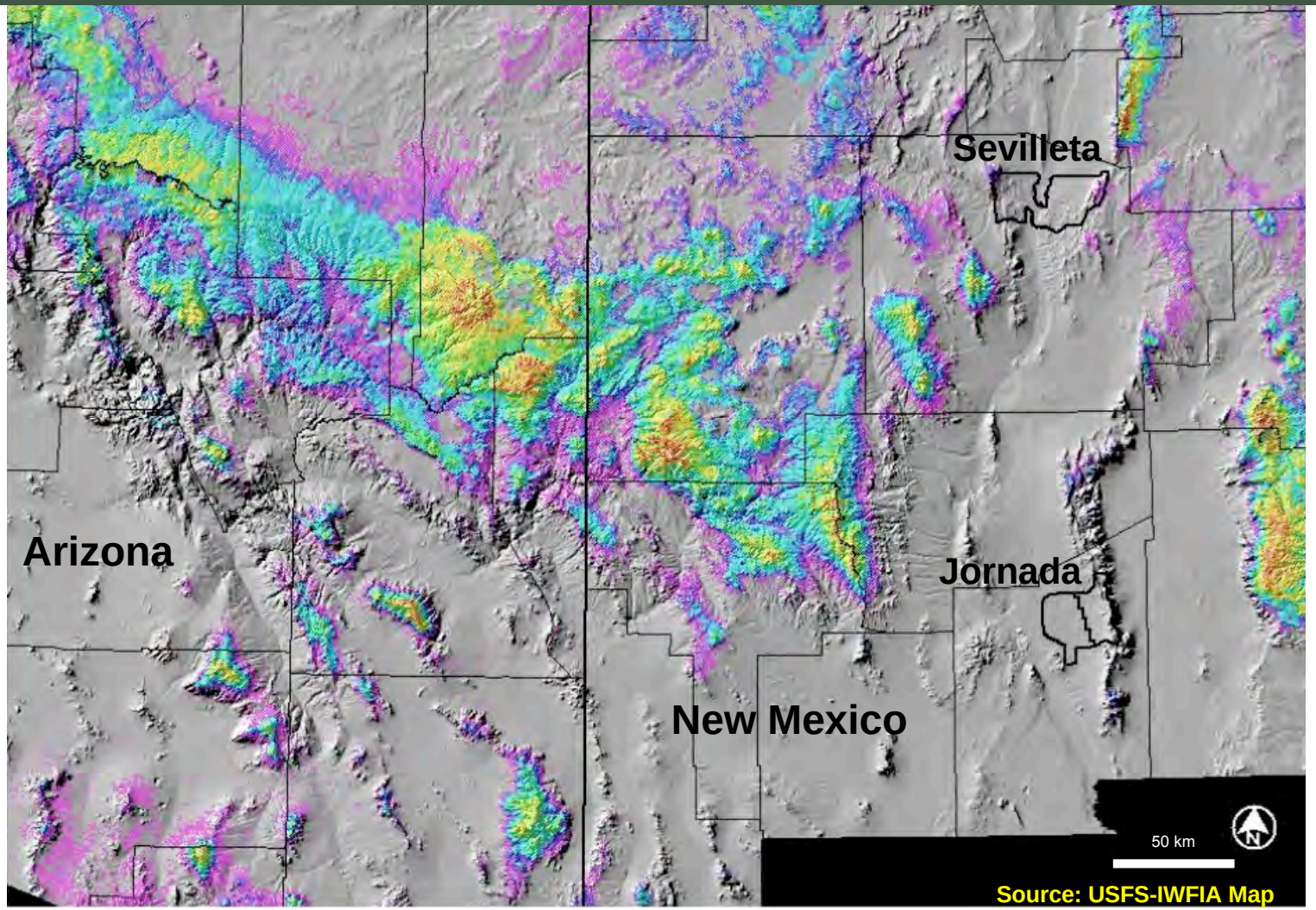
* Jornada Experimental Range, New Mexico (NM)

** plus the Sevilleta NWR

*** most of southern NM and Arizona

Other workers engaged in GO modeling with MISR and/or MODIS: Jing Chen (University of Toronto), Jiucheng Liu (Boston University)…

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



< 6 > 60

Estimated Biomass (tons/acre)

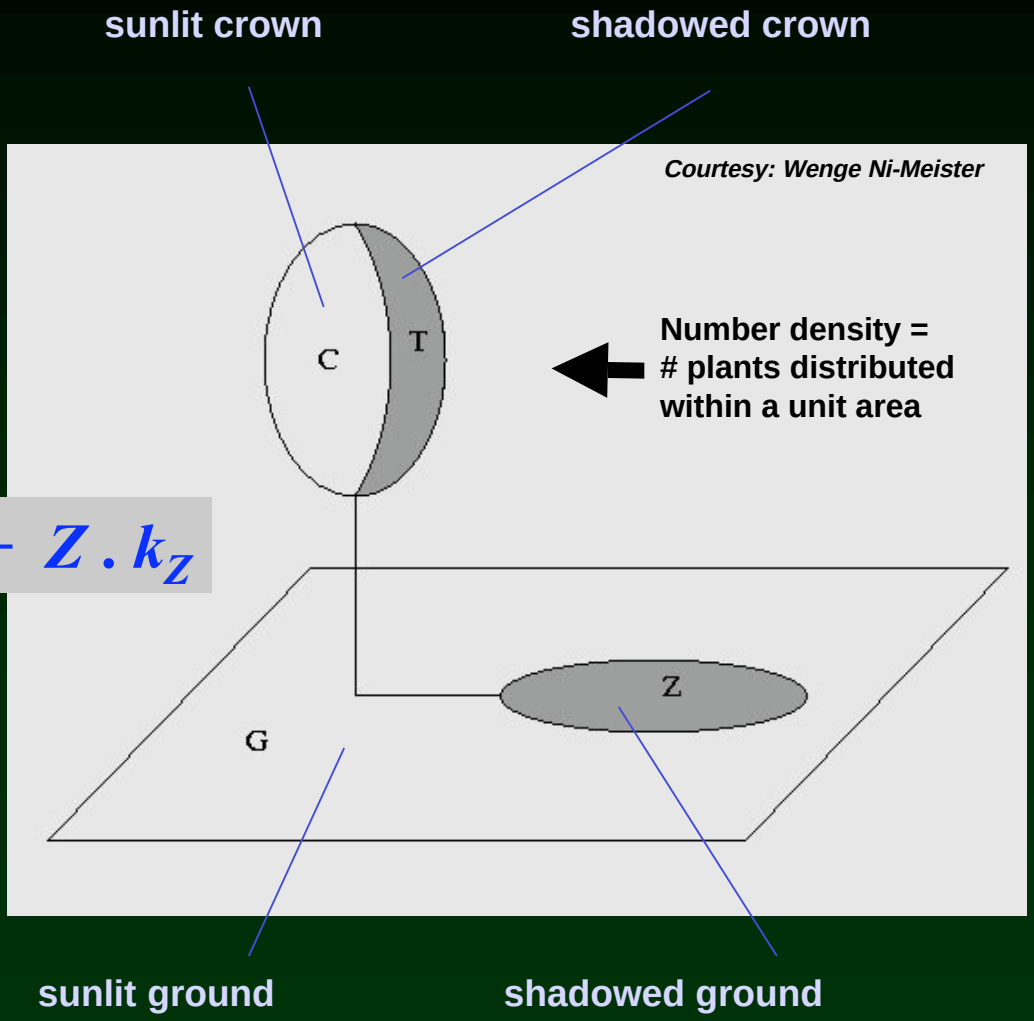
Geometric-Optical Models (Li-Strahler)

….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)

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

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

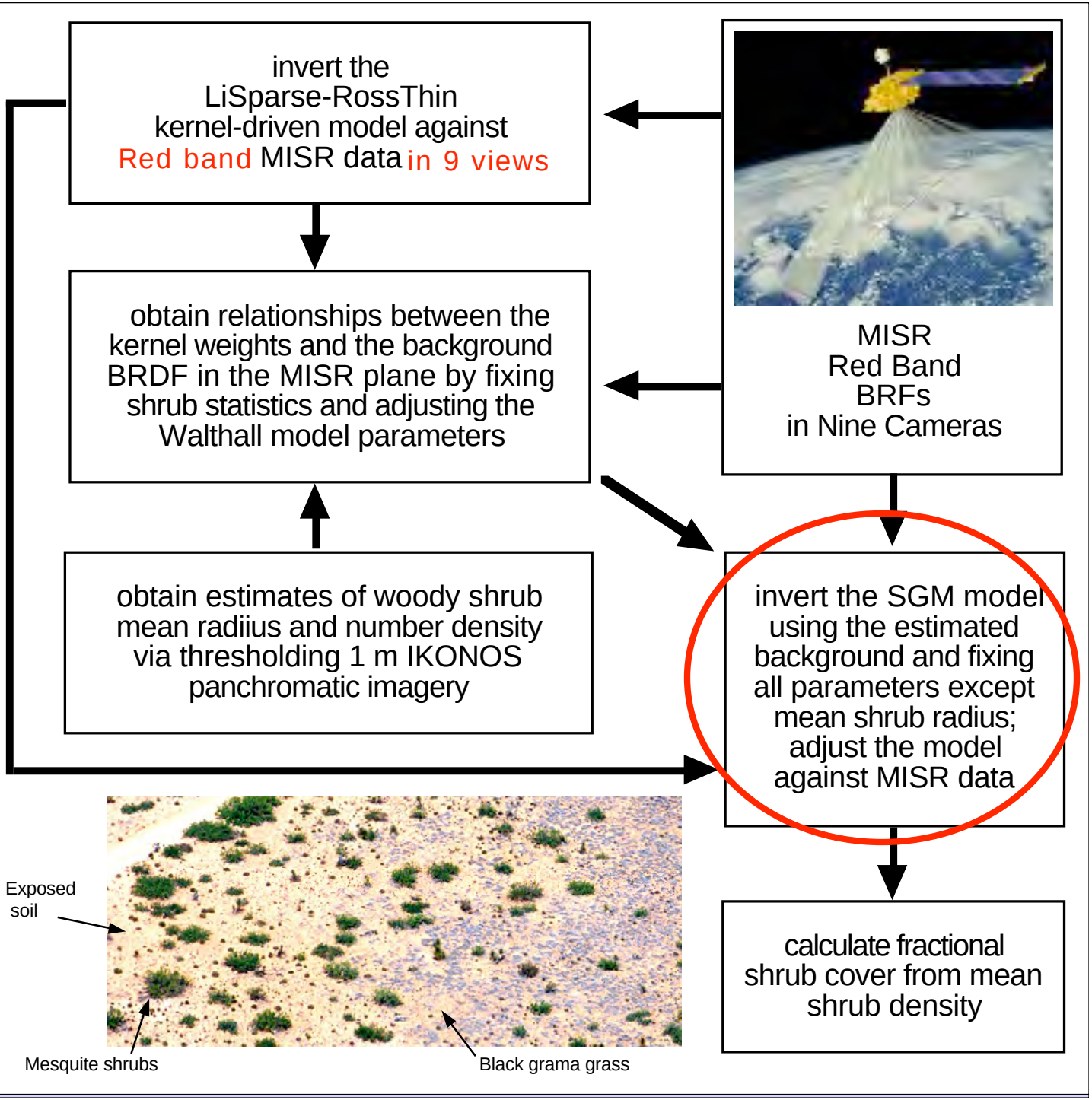


Simple Geometric-optical Model and Inversion Protocol

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

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

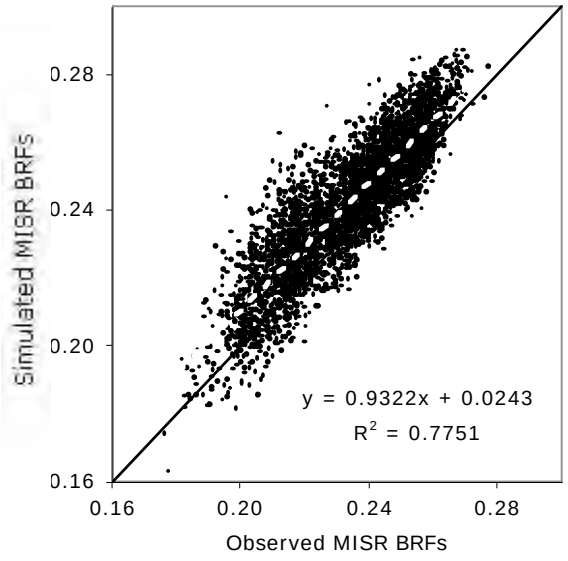
***T* and *Z* are considered black**

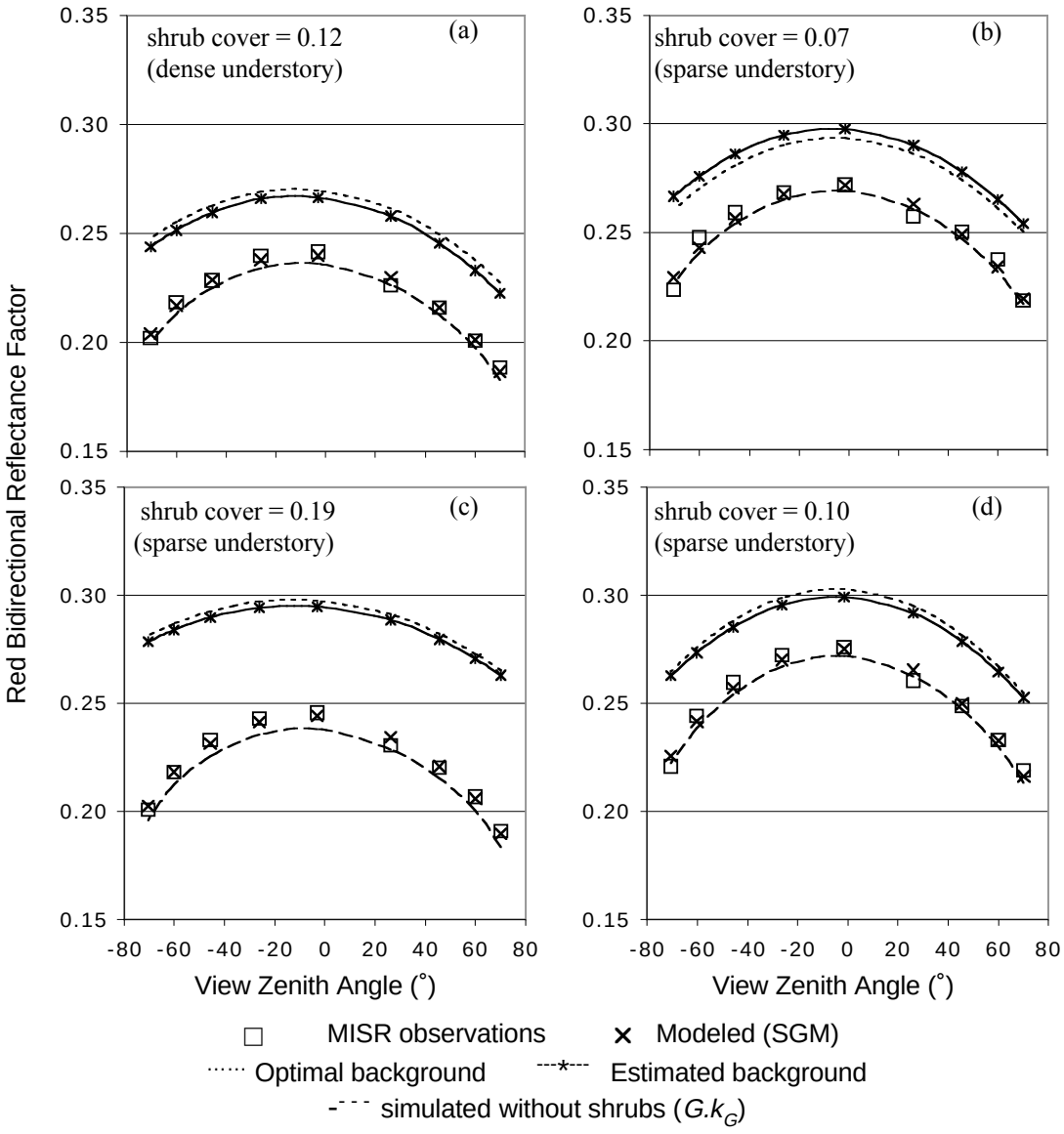


GO Model Simulations of MISR BRFs (shrubs)

Simple Geometric Model simulations, red band, mapped @ 250 m in all nine MISR cameras and for a wide range of canopy configurations.

r^2 =0.78
N = 3969
RMSE = 0.013





GO Model Inversion against MISR BRFs

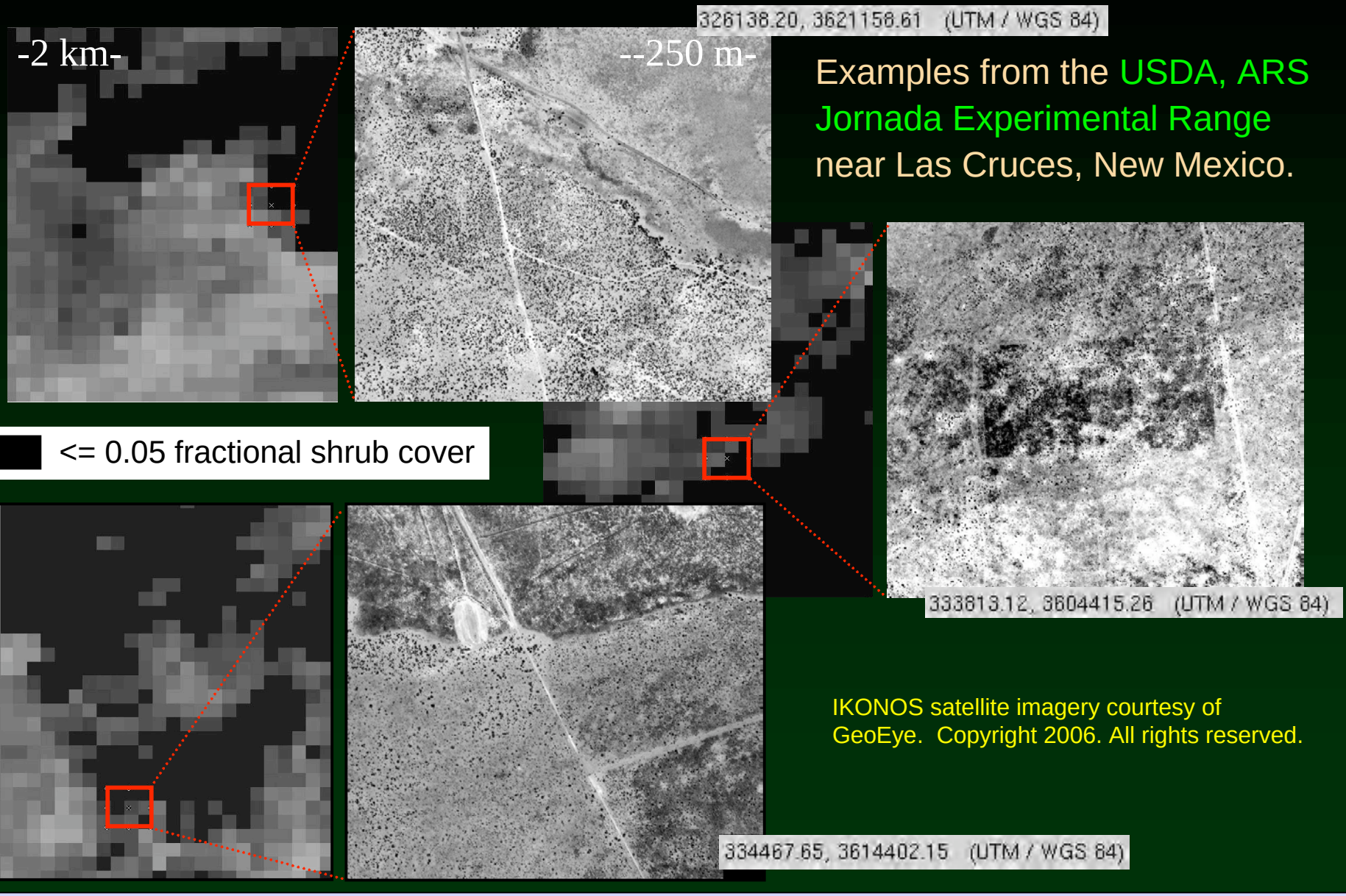
Inversion by fixing number density and retrieving mean shrub radius is saying: "Assuming that there are (e.g.), 650 plants of identical radius per 250 m^2…

What is the mean radius that provides the best match with the observed MISR data?"

This is achieved using numerical minimization with the objective function min(RMSE(modeled, observed)). The retrieved mean radius is used to calculate fractional crown cover.

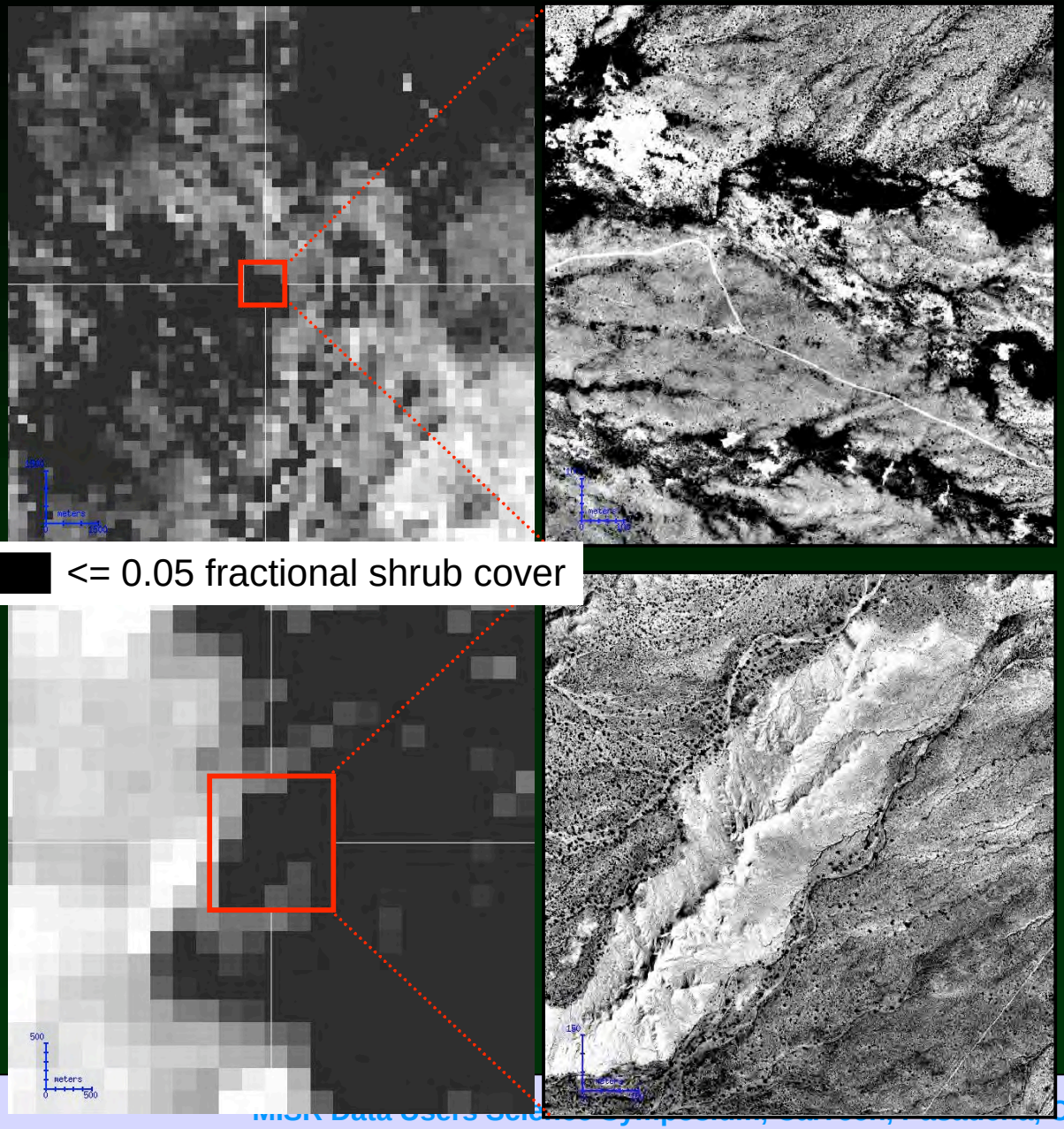
***Ditto* crown shape (*b*/*r*) with fixed canopy height (*h*/*b*).**

Comparisons of Retrievals vs Ikonos pan Images



IKONOS satellite imagery courtesy of GeoEye. Copyright 2006. All rights reserved.

Comparisons of Retrievals with 1 m Orthophotos

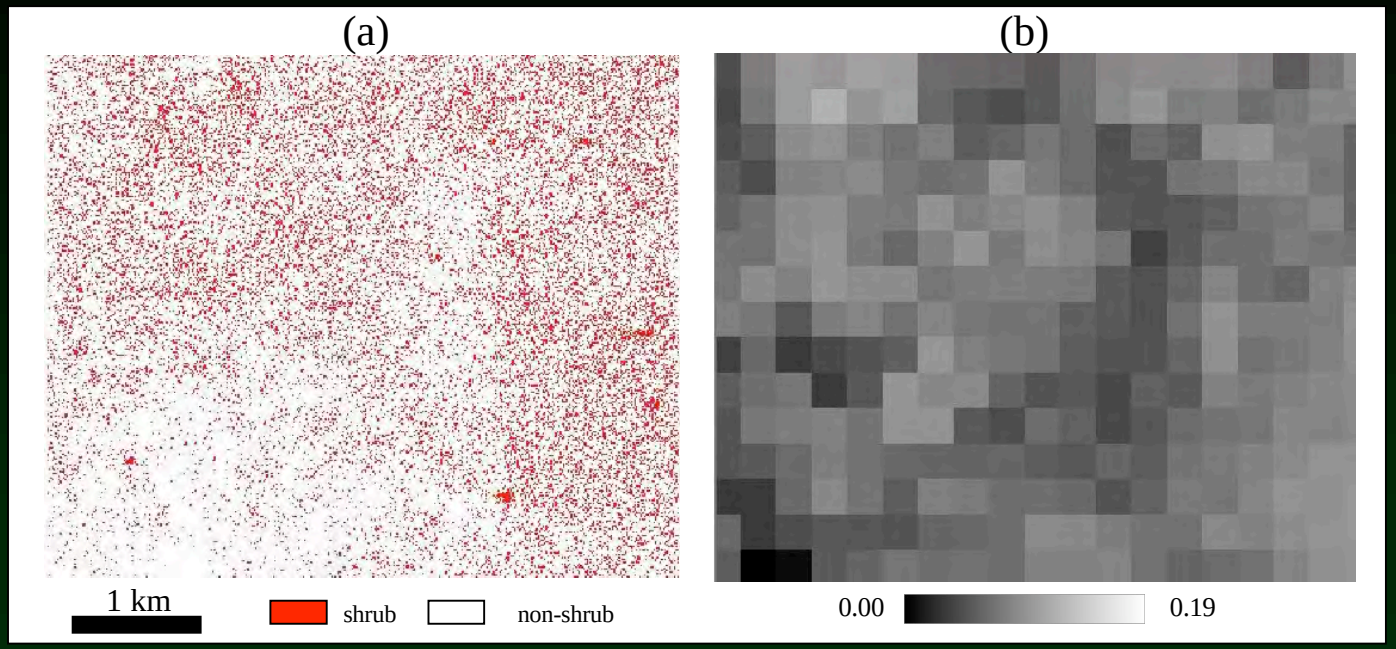


Examples from the Sevilleta National Wildlife Refuge near Socorro, New Mexico.

346233.64, 3789149.21 (UTM / WGS 84)

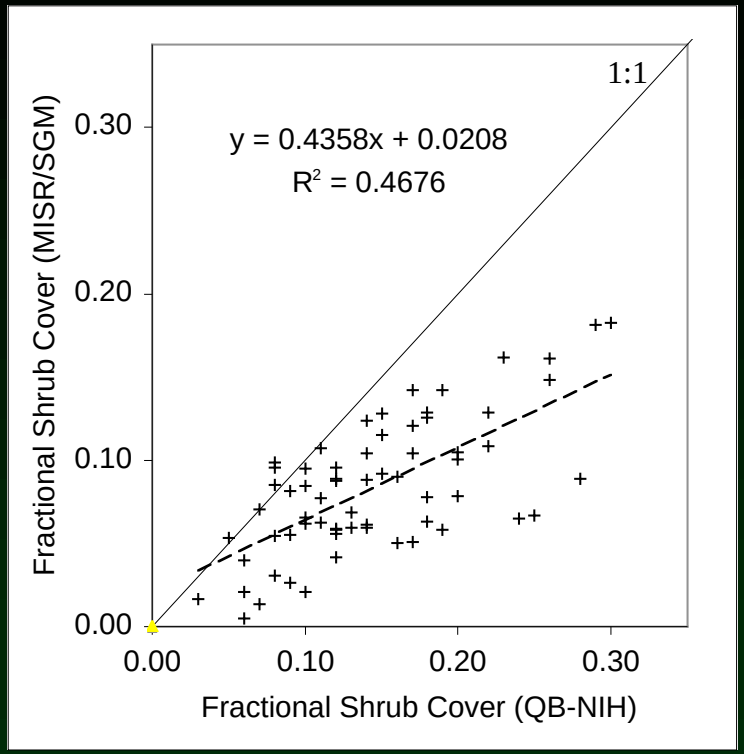
316601.99, 3794665.52 (UTM / WGS 84)

Evaluation of Retrievals vs QuickBird imagery: Pastures 8/9



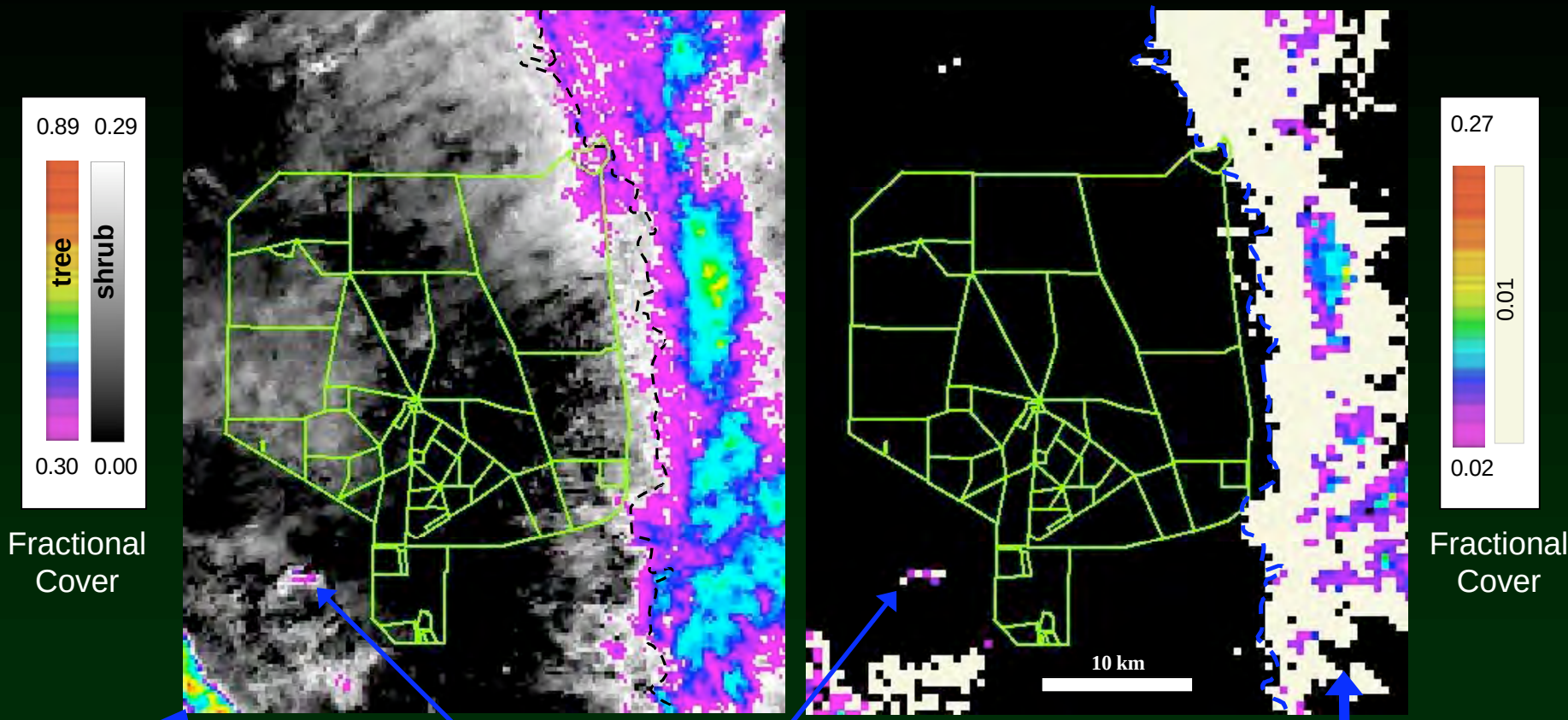
(a) QuickBird shrub map obtained using image segmentation techniques
(b) Fractional shrub cover retrieved using MISR via inversion of the GO model.

Evaluation of Retrievals vs QuickBird imagery:



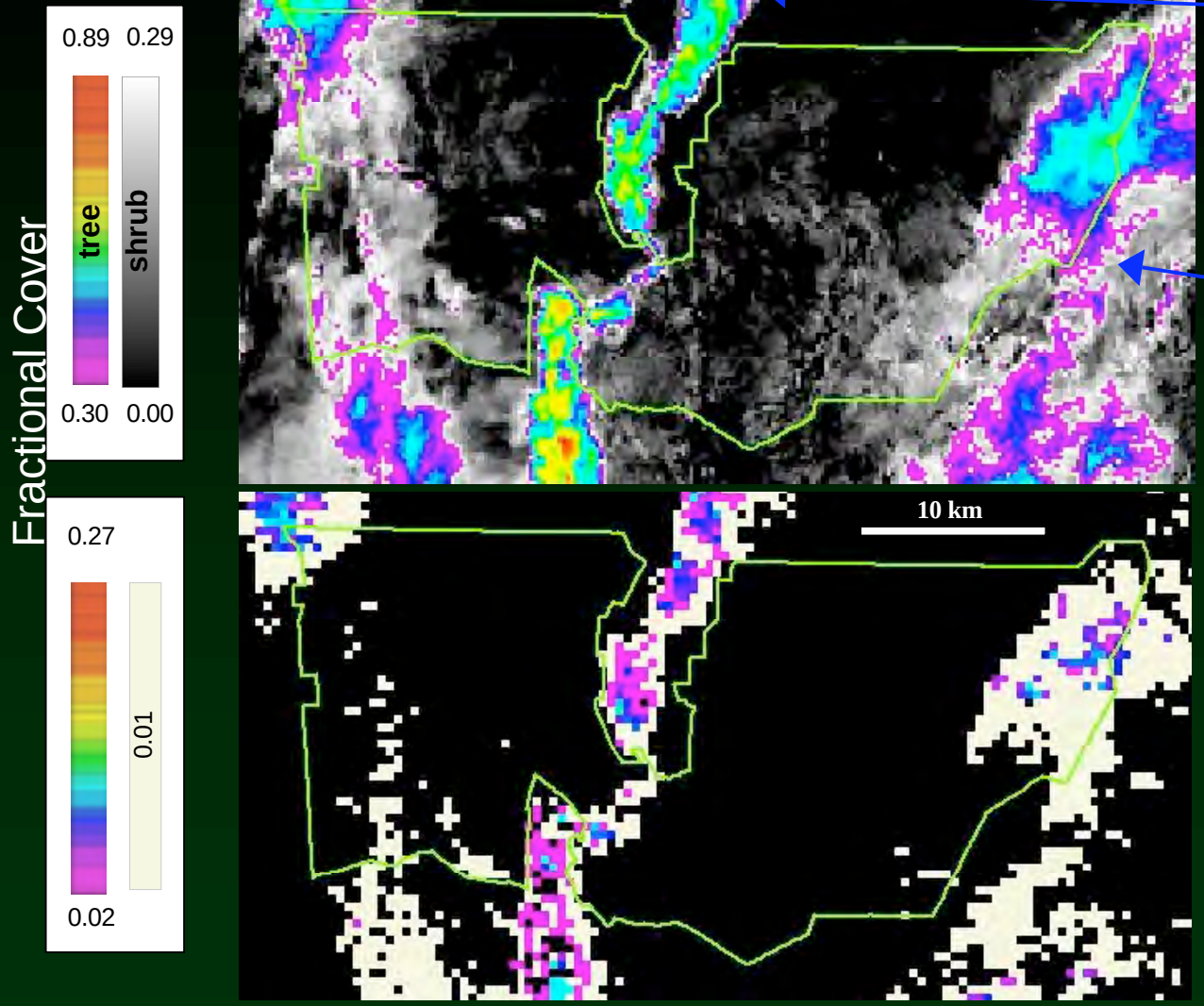
A reliable if biased relation was found between MISR/GO retrieved woody plant cover and that obtained from QuickBird imagery for areas ~10 km from the calibration sites (Chopping, Su, Laliberte, Rango, Peters, and Martonchik, Mapping woody plant cover in desert grasslands using canopy reflectance modeling and MISR data, *Geophysical Research Letters*, Vol. 33, 2006).

Comparisons of Retrievals with VCF % Tree Cover Map



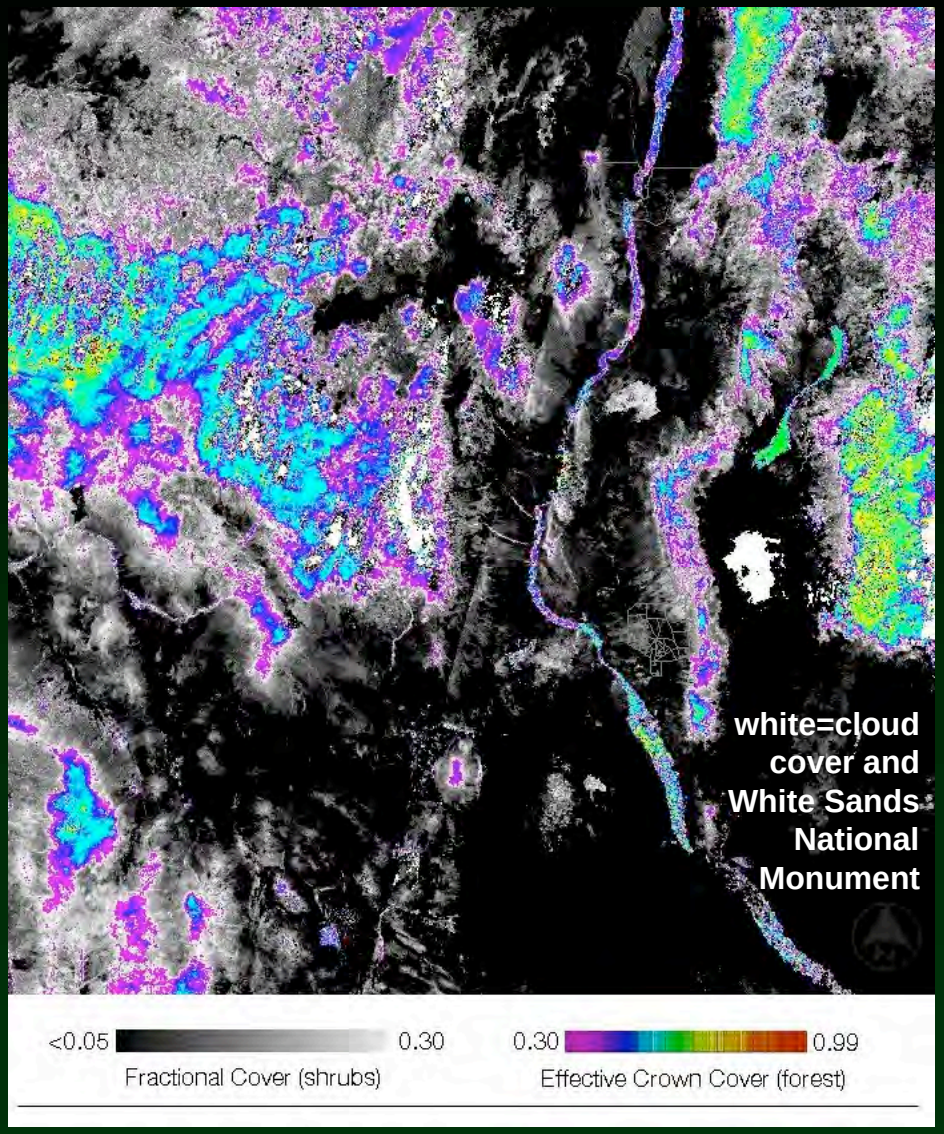
Left: MISR/GO Woody Plant Cover Right: MODIS Vegetation Continuous Fields % Tree Cover for the **USDA, ARS Jornada Experimental Range**

Comparisons of Retrievals with VCF % Tree Cover Map

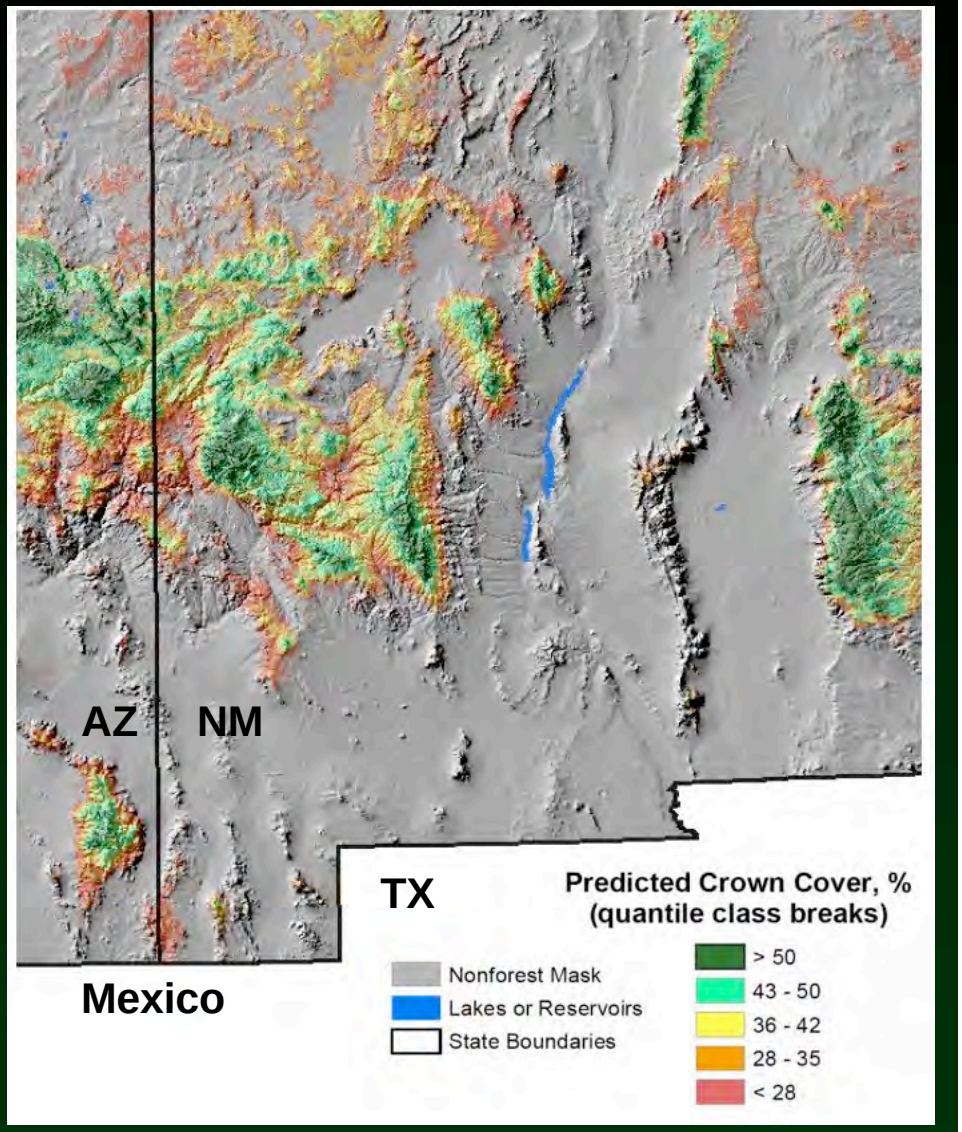


Top: MISR/GO Woody Plant Cover
Bottom: MODIS Vegetation Continuous Fields % Tree Cover for the **Sevilleta National Wildlife Refuge** near Socorro, NM

Comparisons of Retrievals with USFS IW-FIA Map (Cover)

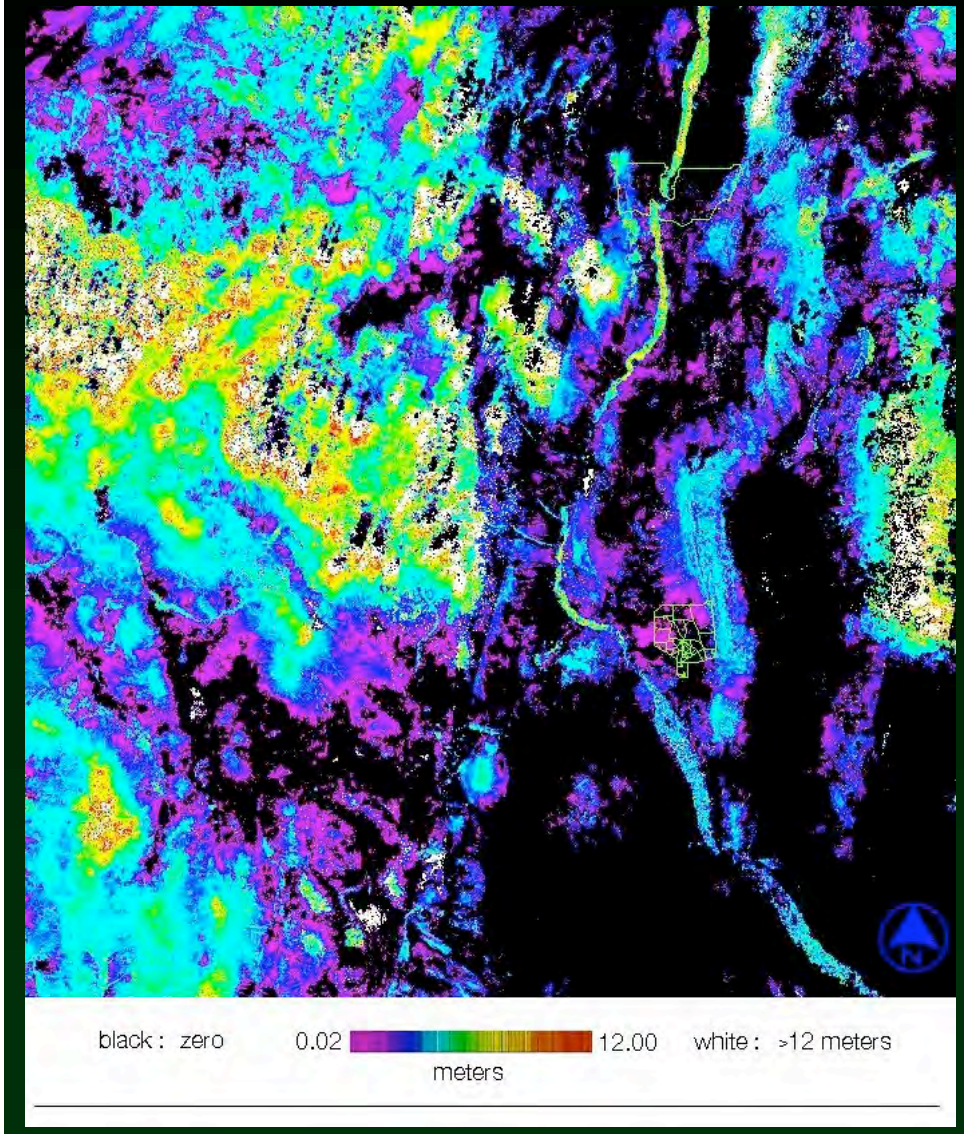


MISR/GO Canopy Cover

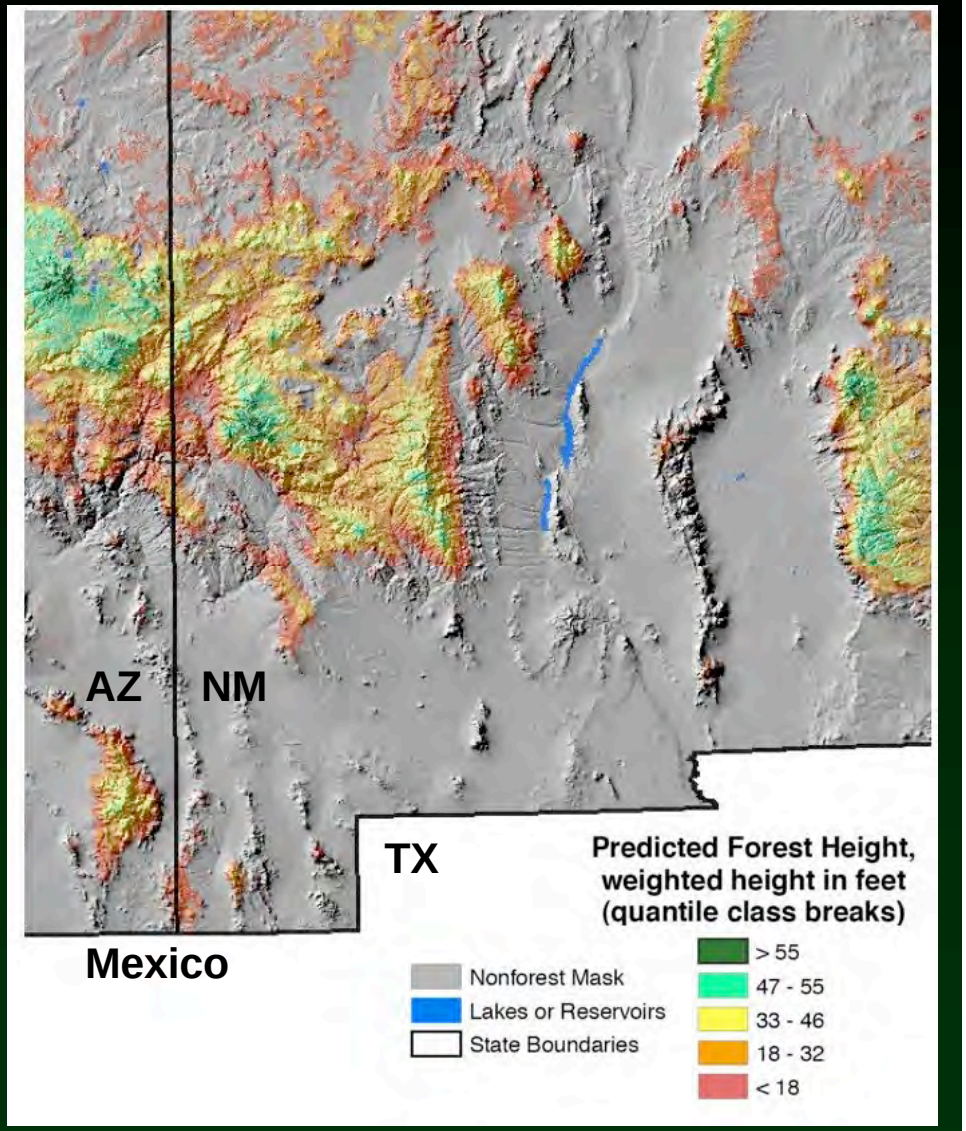


Forest Inventory Analysis Canopy Cover

Comparisons of Retrievals with USFS IW-FIA Map (Height)



MISR/GO Mean Canopy Height

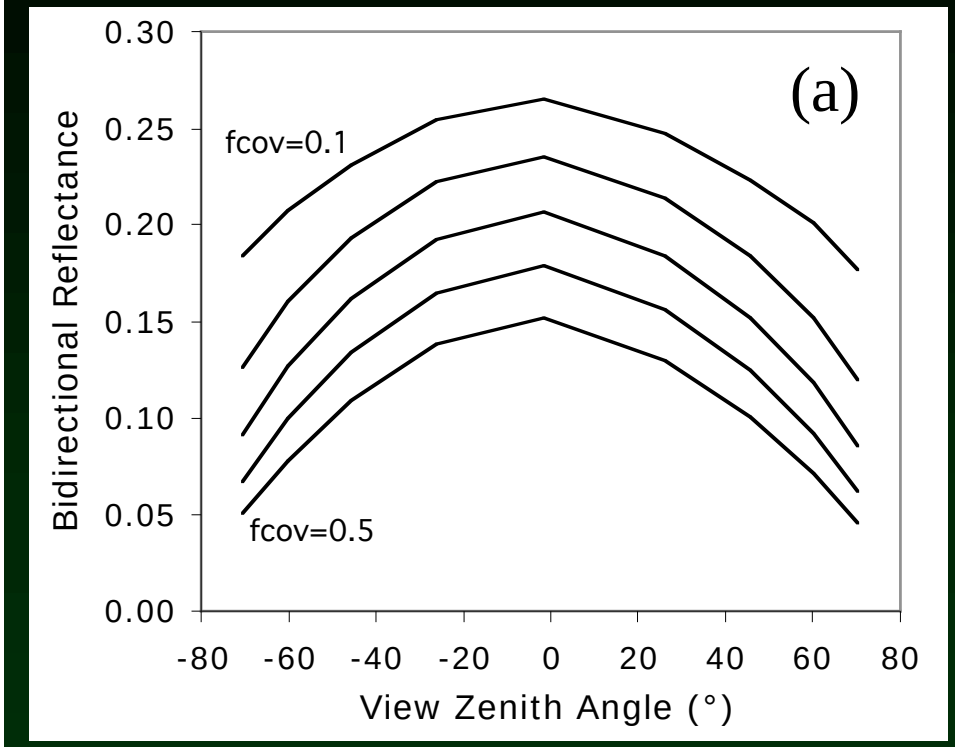


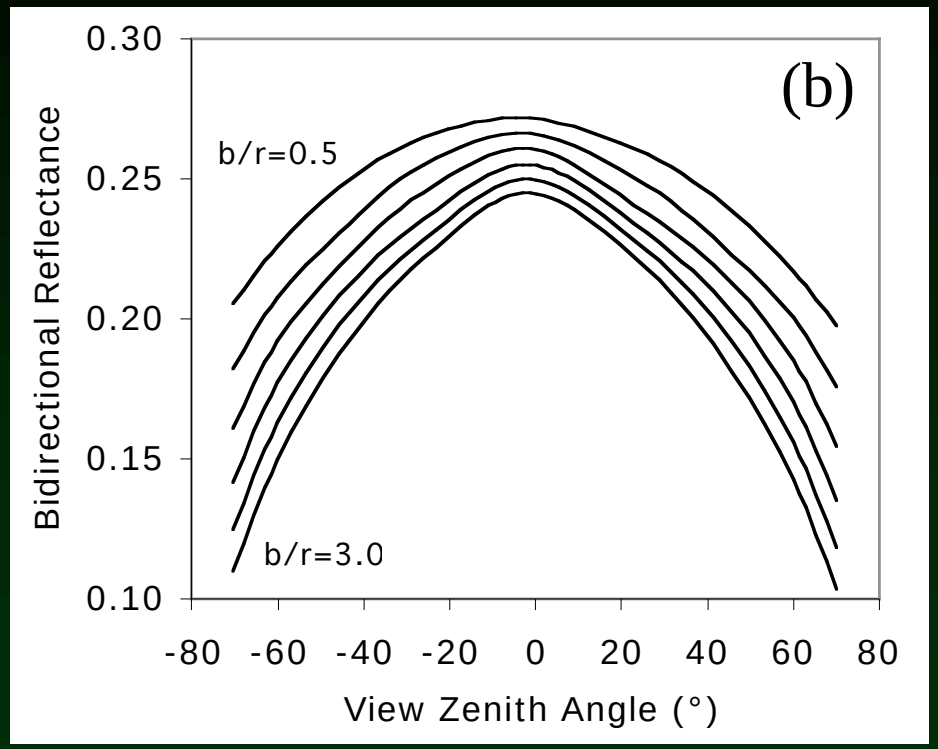
Forest Inventory Analysis Canopy Height

If we have *r* and *b/r*, and *h/b* is fixed, we can obtain *h*

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

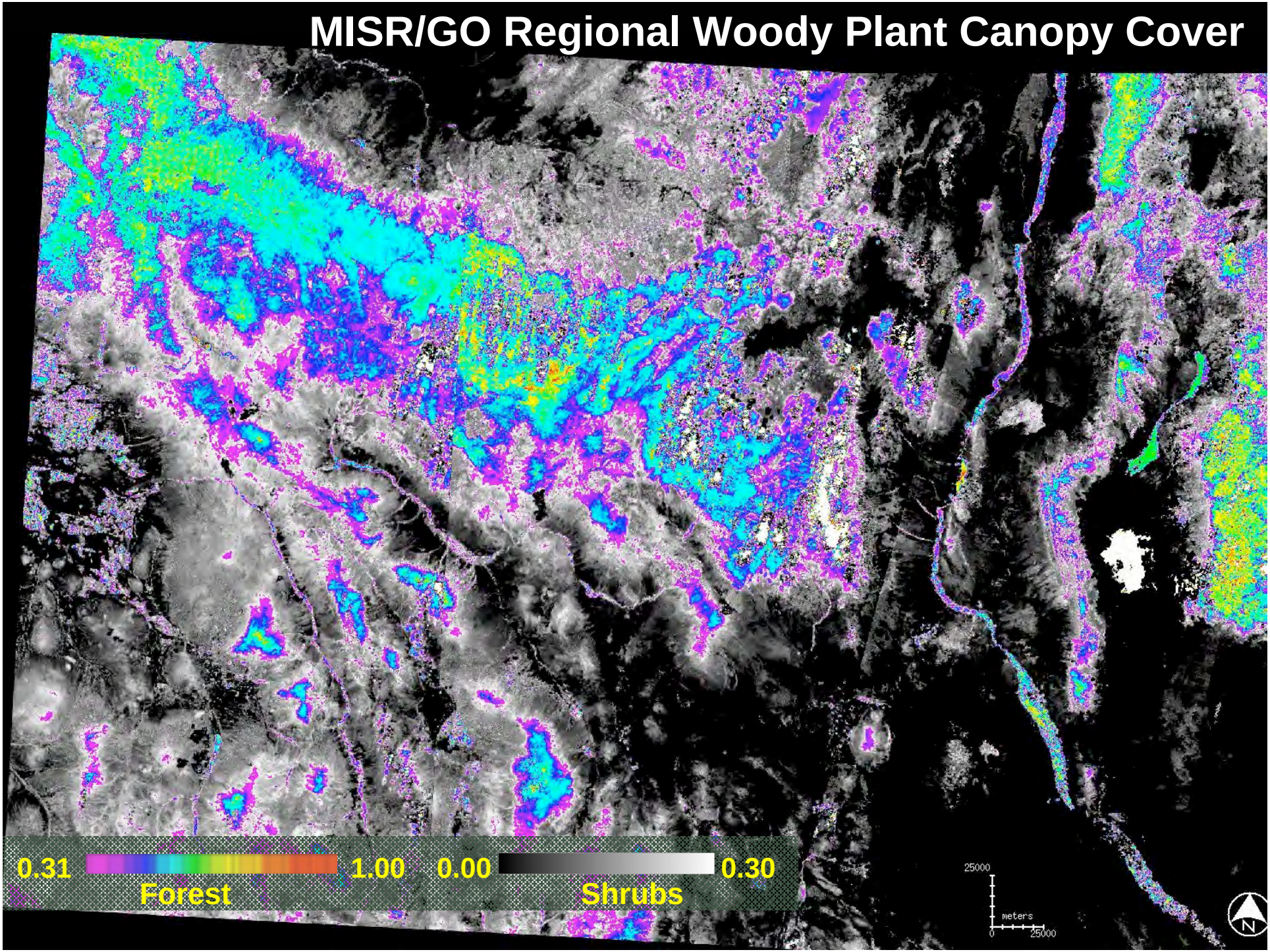
Canopy height is from *b/r* with fixed *h/b* (sensitive to BRF shape)



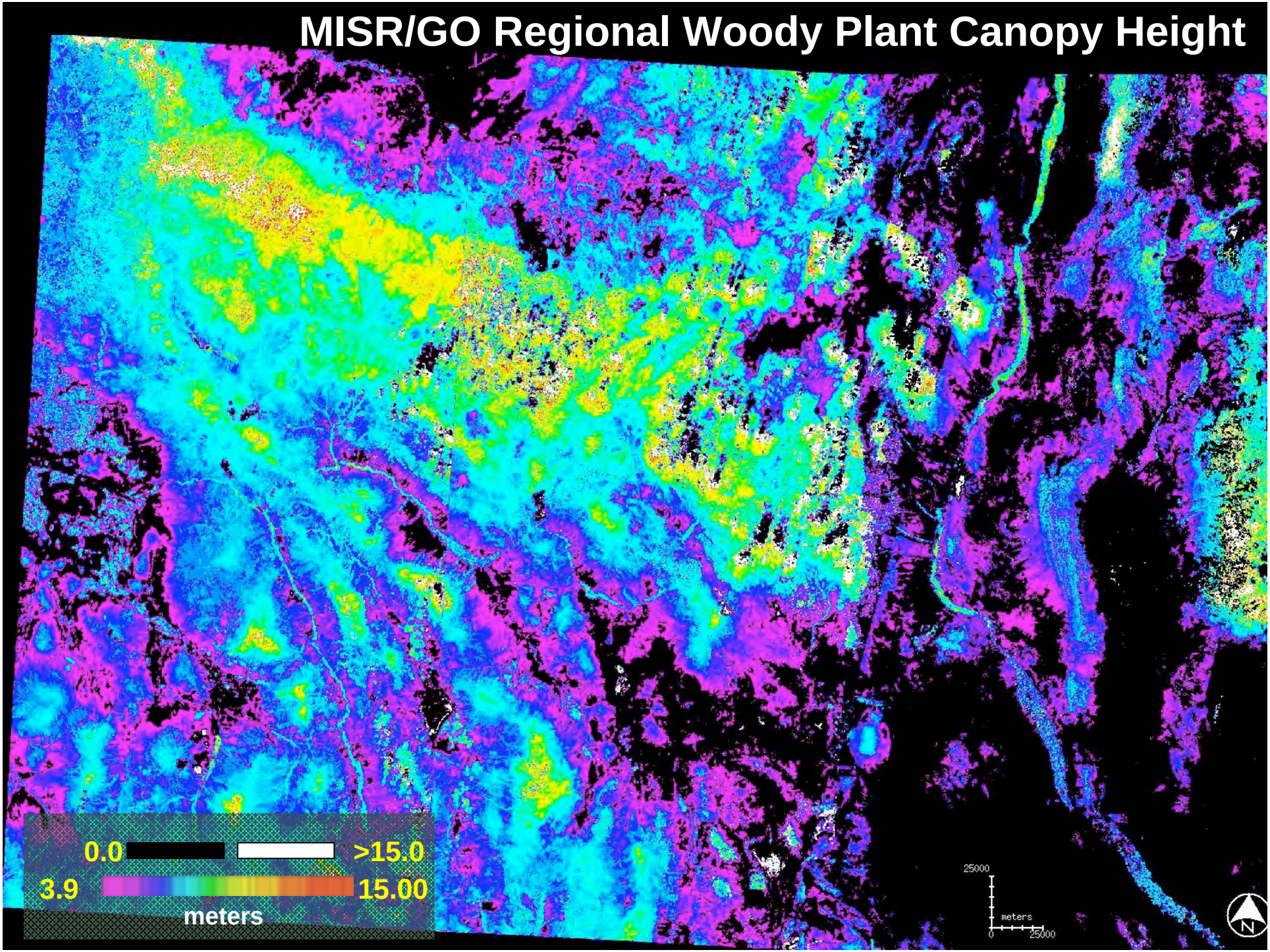


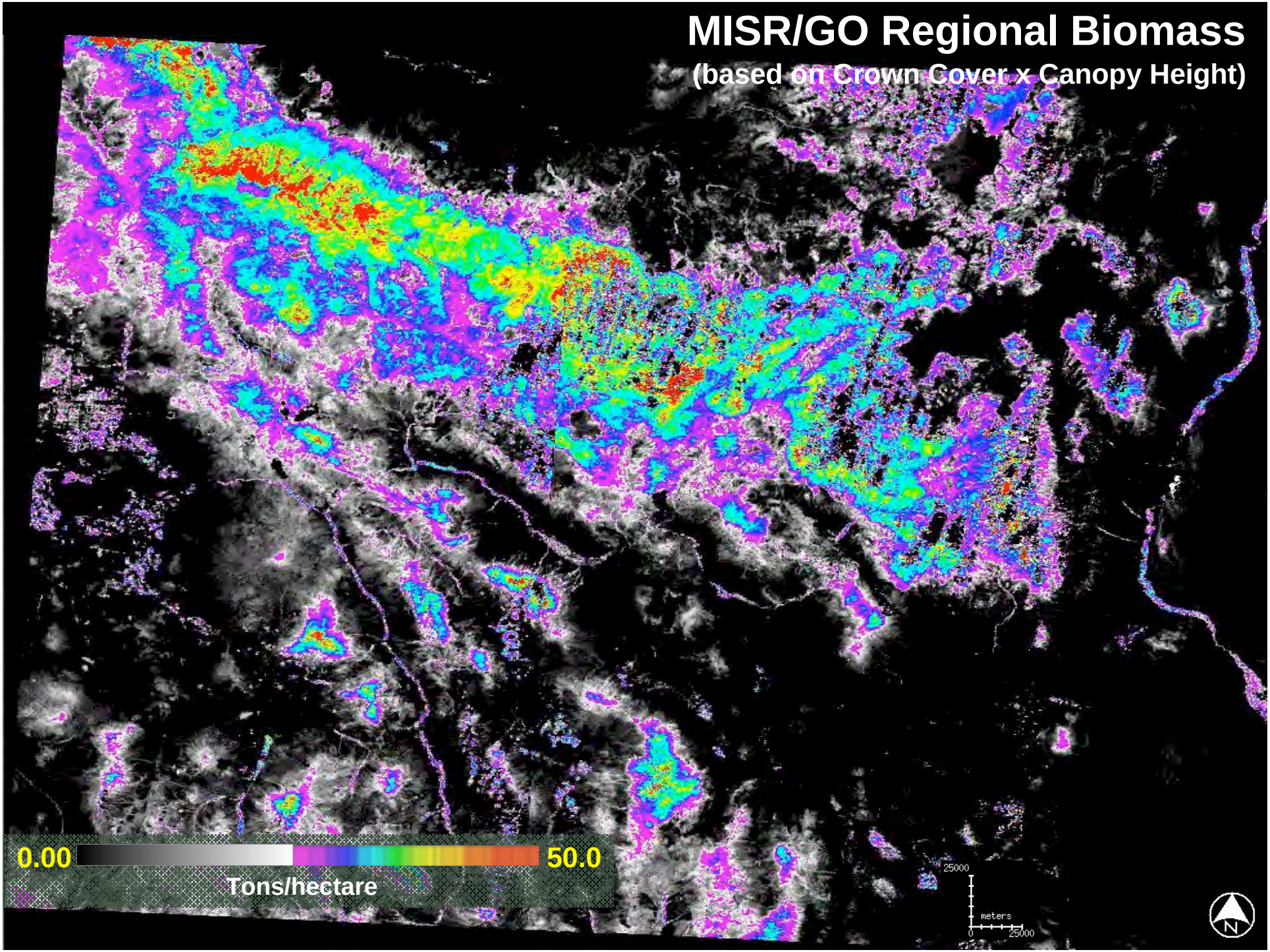
The azimuthal plane corresponds to the MISR viewing plane

Effects of changing (a) fractional crown cover with fixed λ and maintaining canopy height at 3.0 m (b) crown shape (*b/r*), maintaining *h/b* fixed at 2.00.

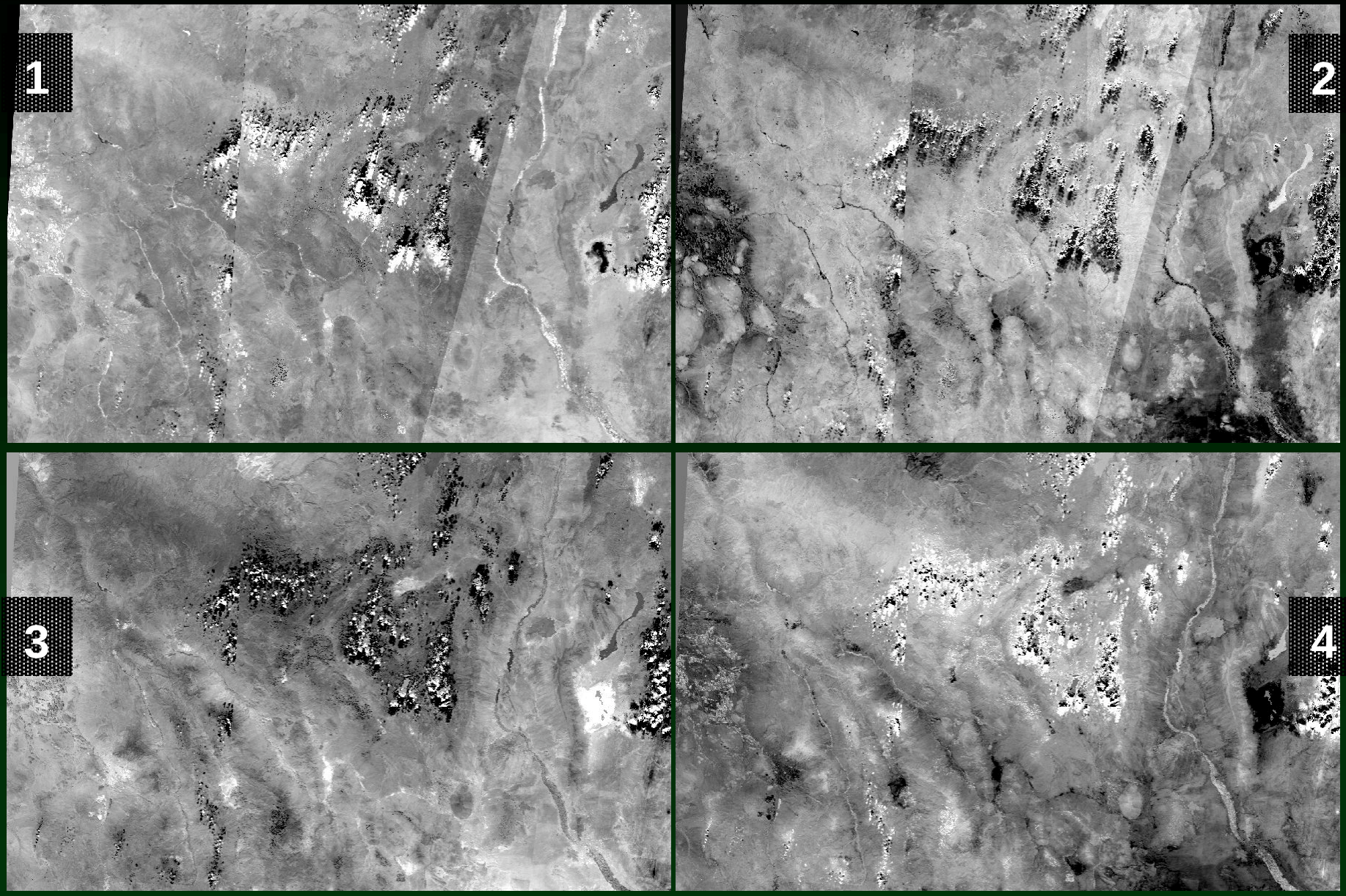

MISR/GO Regional Woody Plant Canopy Cover
0.31
Forest
1.00
0.00
Shrubs
0.30
25000
meters
0
25000
N

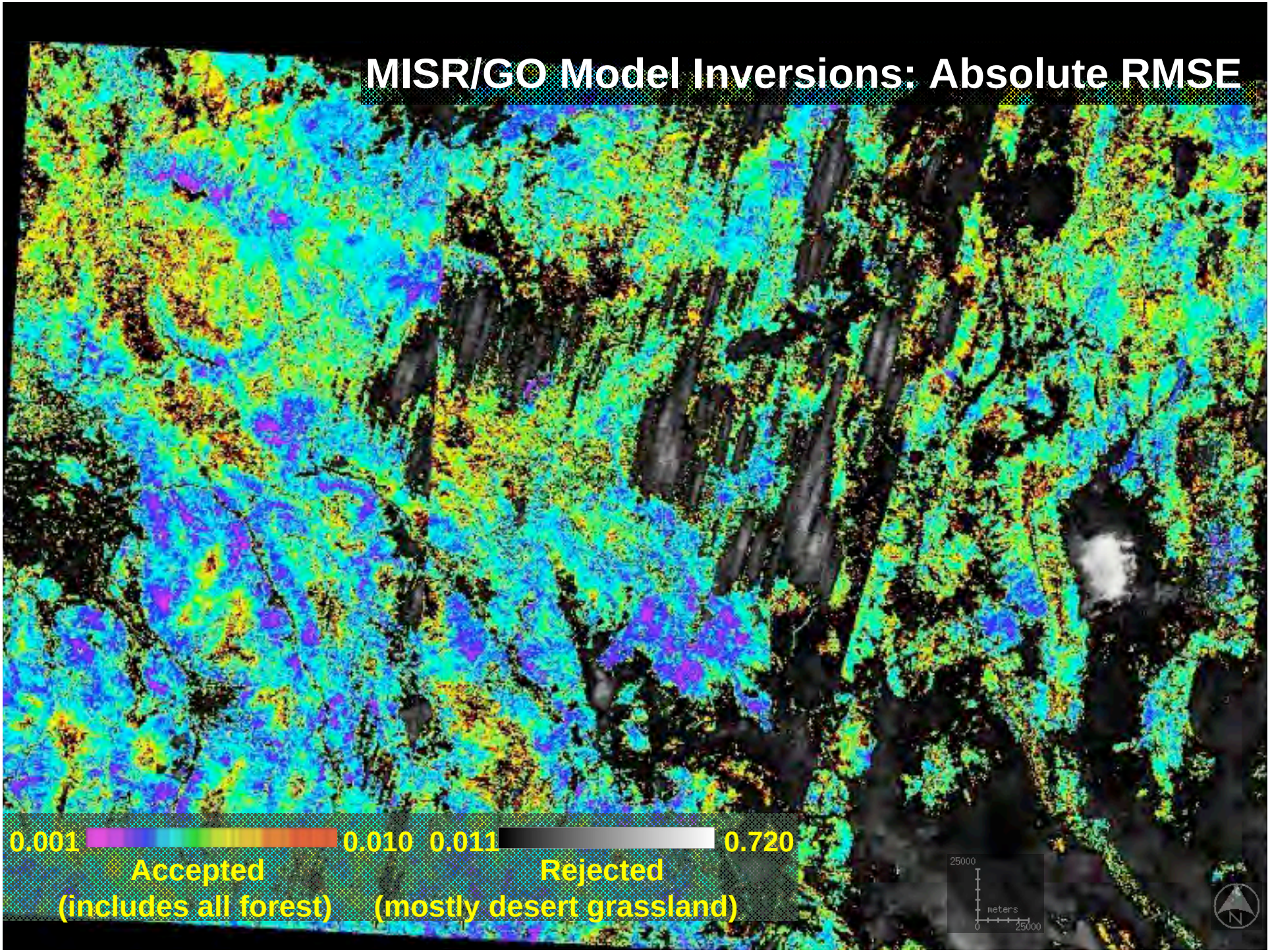
MISR/GO Regional Woody Plant Canopy Height




MISR/GO Regional Biomass
(based on Crown Cover x Canopy Height)
0.00
50.0
Tons/hectare
25000
meters
0
25000
N

MISR/GO: Walthall_1 = Background = ~Understory

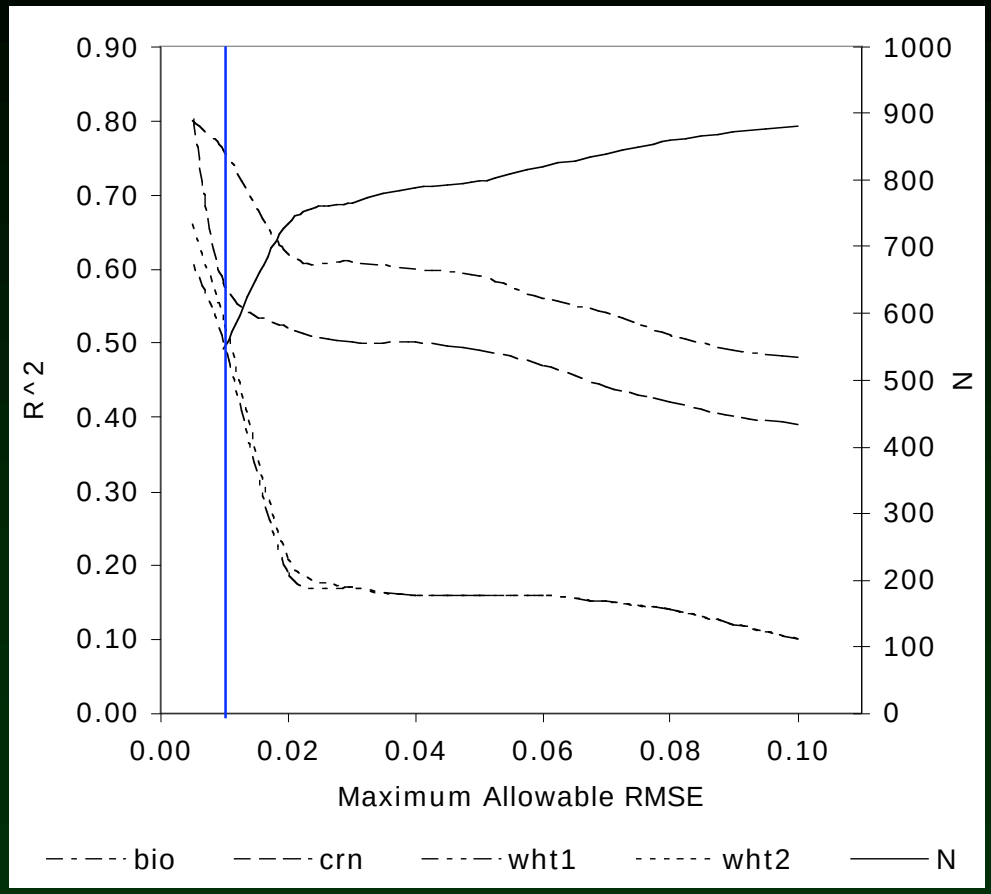



MISR/GO Model Inversions: Absolute RMSE
0.001
0.010
0.011
0.720
Accepted
(includes all forest)
Rejected
(mostly desert grassland)
25000
meters
0
25000
N

MISR/GO: Validation Data Filtering

Validation was against 1063 randomly selected points over forest (USFS definition). A threshold of RMSE < 0.01 was used to filter the data set, retaining 547 points.

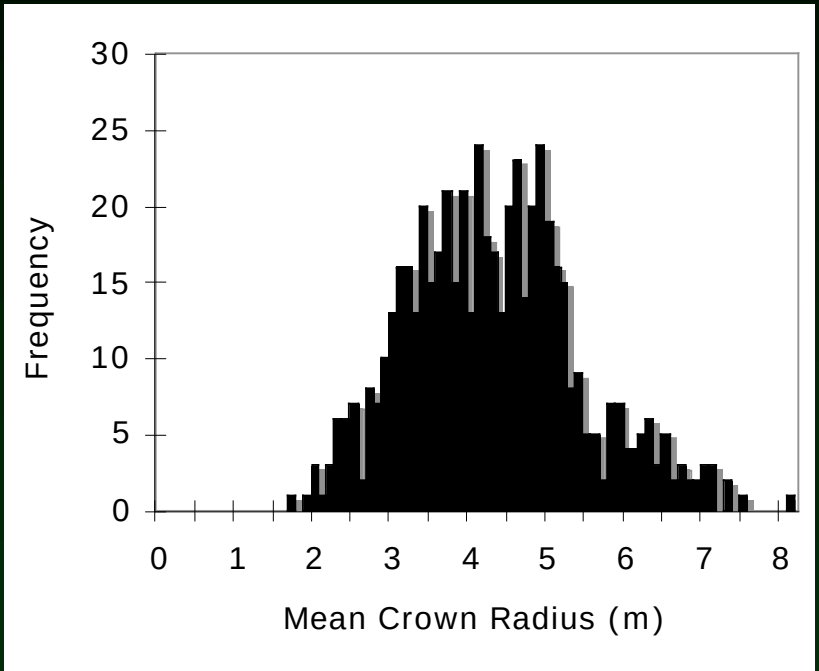
Correlation as a Function of RMSE

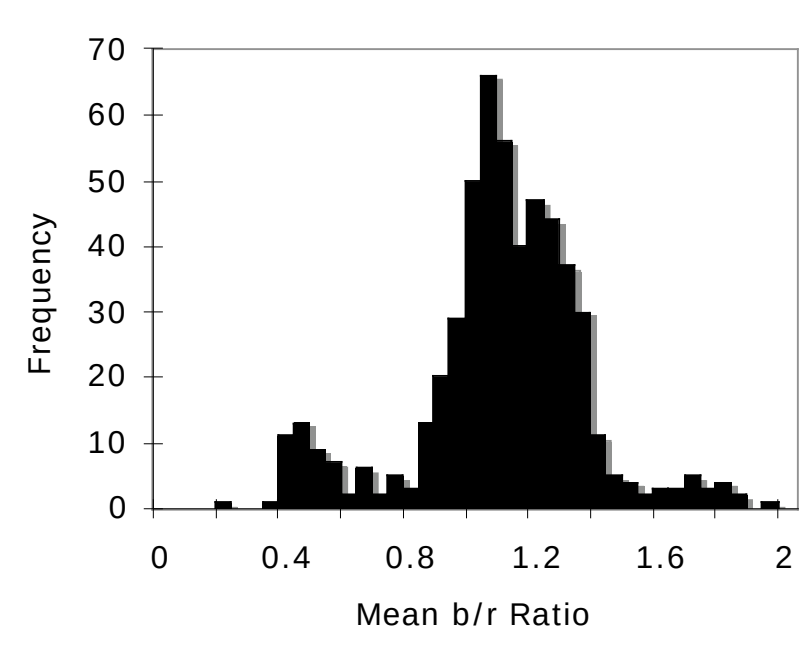


bio: biomass crn: crown cover
wht1 and wht2: weighted canopy height

MISR/GO Forest Structure Mapping:

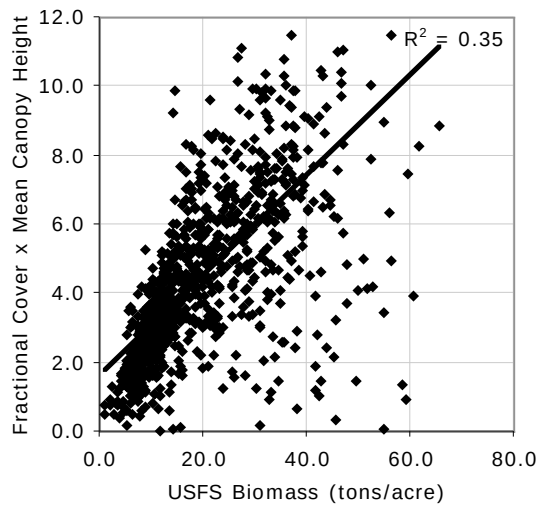
Directly retrieved model parameters (N=547)



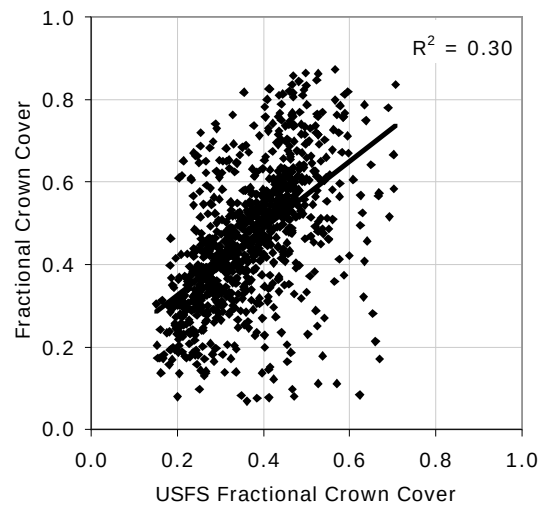


MISR/GO Forest Structure Mapping: First-order Validation

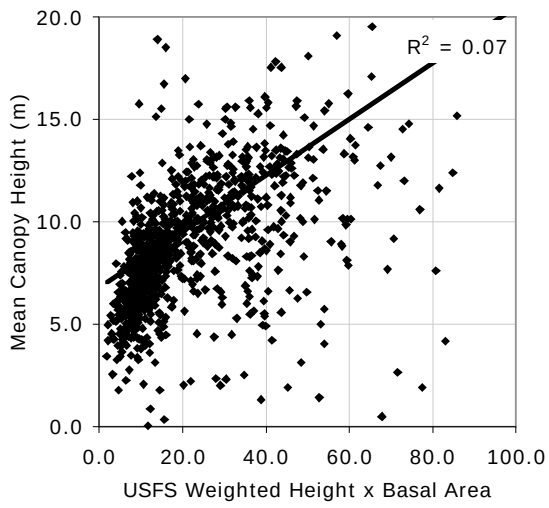
(a)



(b)

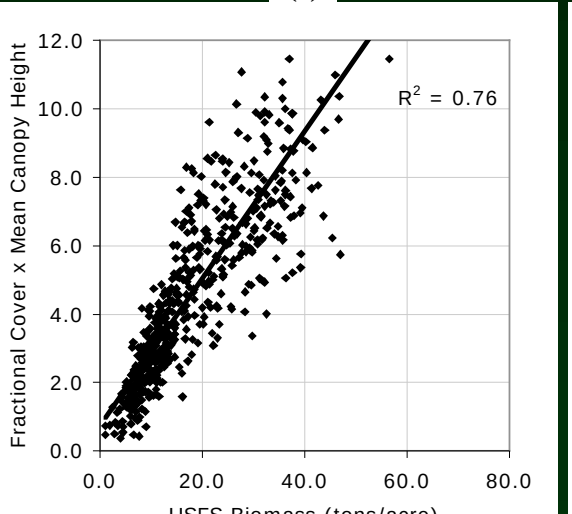


(c)

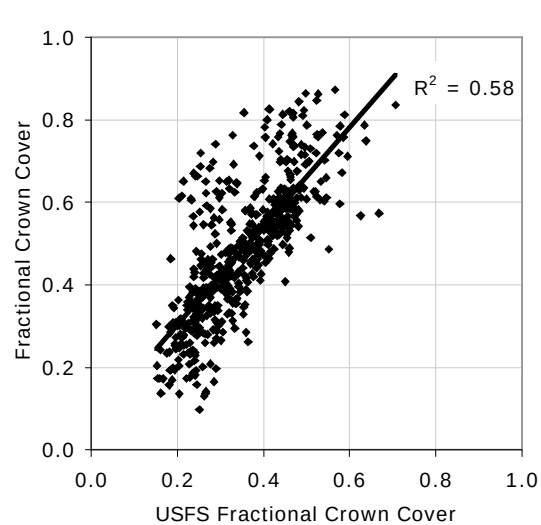


With no filtering, N = 1063

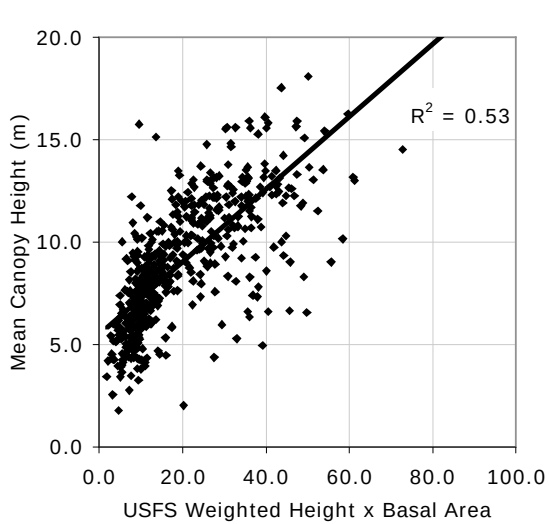
(d)



(e)



(f)



With data filtered for RMSE < 0.01, N = 547

MISR Data Users Science Symposium, CalTech, Pasadena, CA, December 7-8, 2006

MISR/GO: +MODIS?

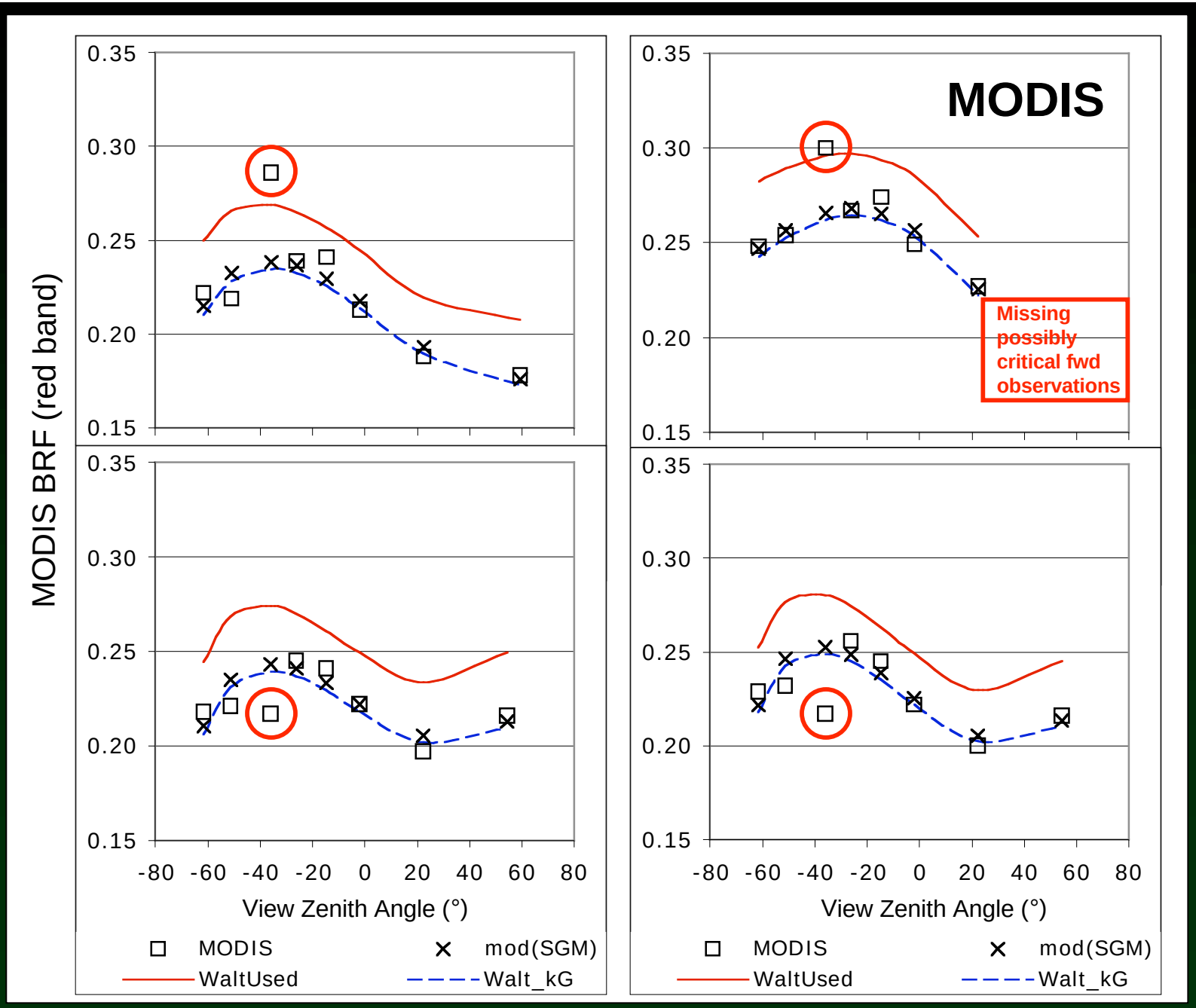
- Can we use MODIS with MISR, as MODIS views closer to the principal plane at these latitudes and thus should have a stronger directional signal?

- Difficulties:

  1. Combining data from different planes enhances radiative products (albedo, BRDF) but is problematic when estimating the background signal (estimated better in a single plane)

  2. Precision and consistency of MODIS BRFs (MOD09). See the next slide.

MISR/GO: +MODIS?



Houston, we have a problem:
one of our orbits is missing...
(not an artifact of differences in Rel. Azimuth)

MISR/GO Validation Plan

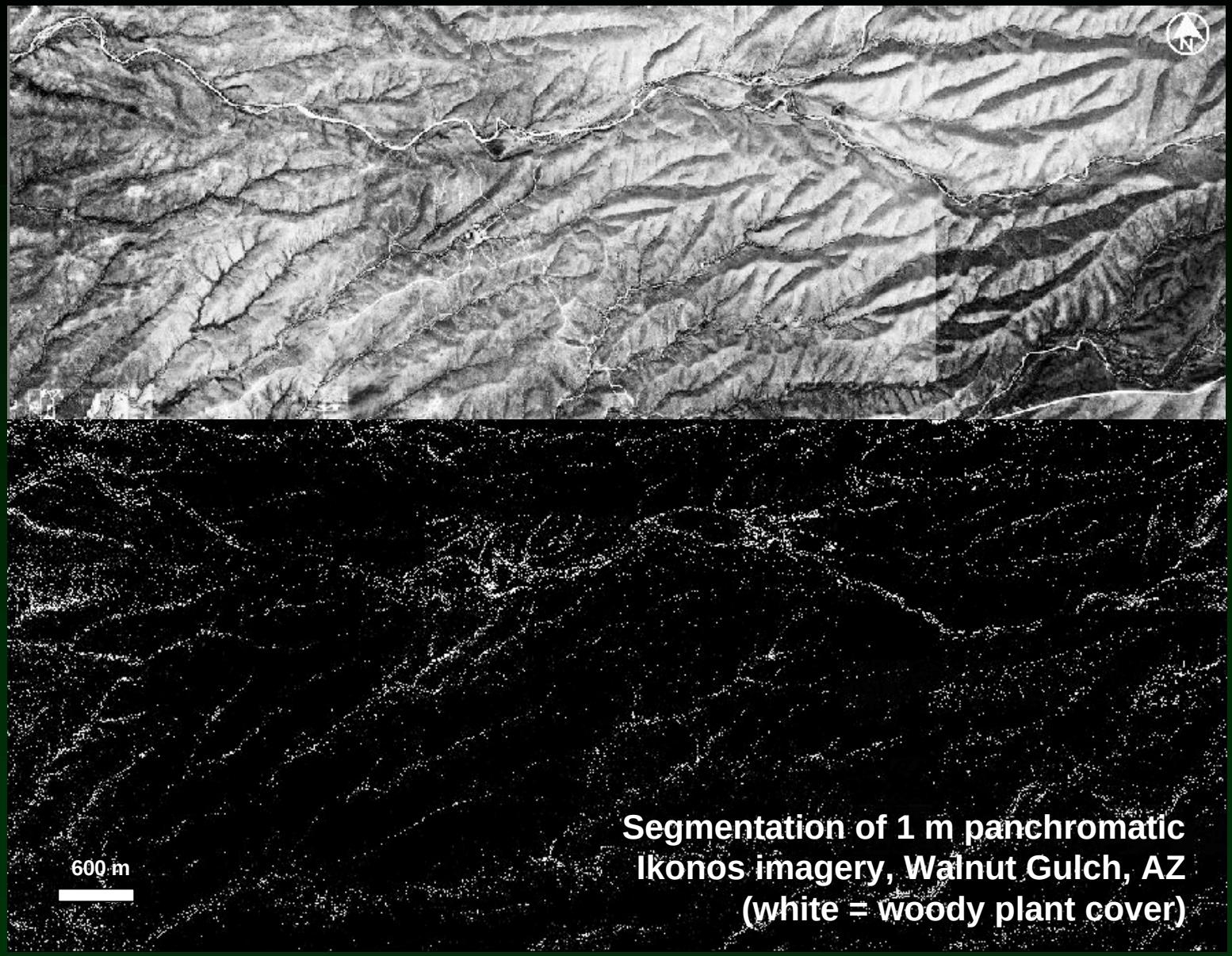
- **Woody plant cover for 4 sites:**

  1. **Jornada Experimental Range (NM)**
  2. **Sevilleta National Wildlife Refuge (NM)**
  3. **Walnut Gulch Experimental Watershed (AZ)**
  4. **Santa Rita Experimental Range**

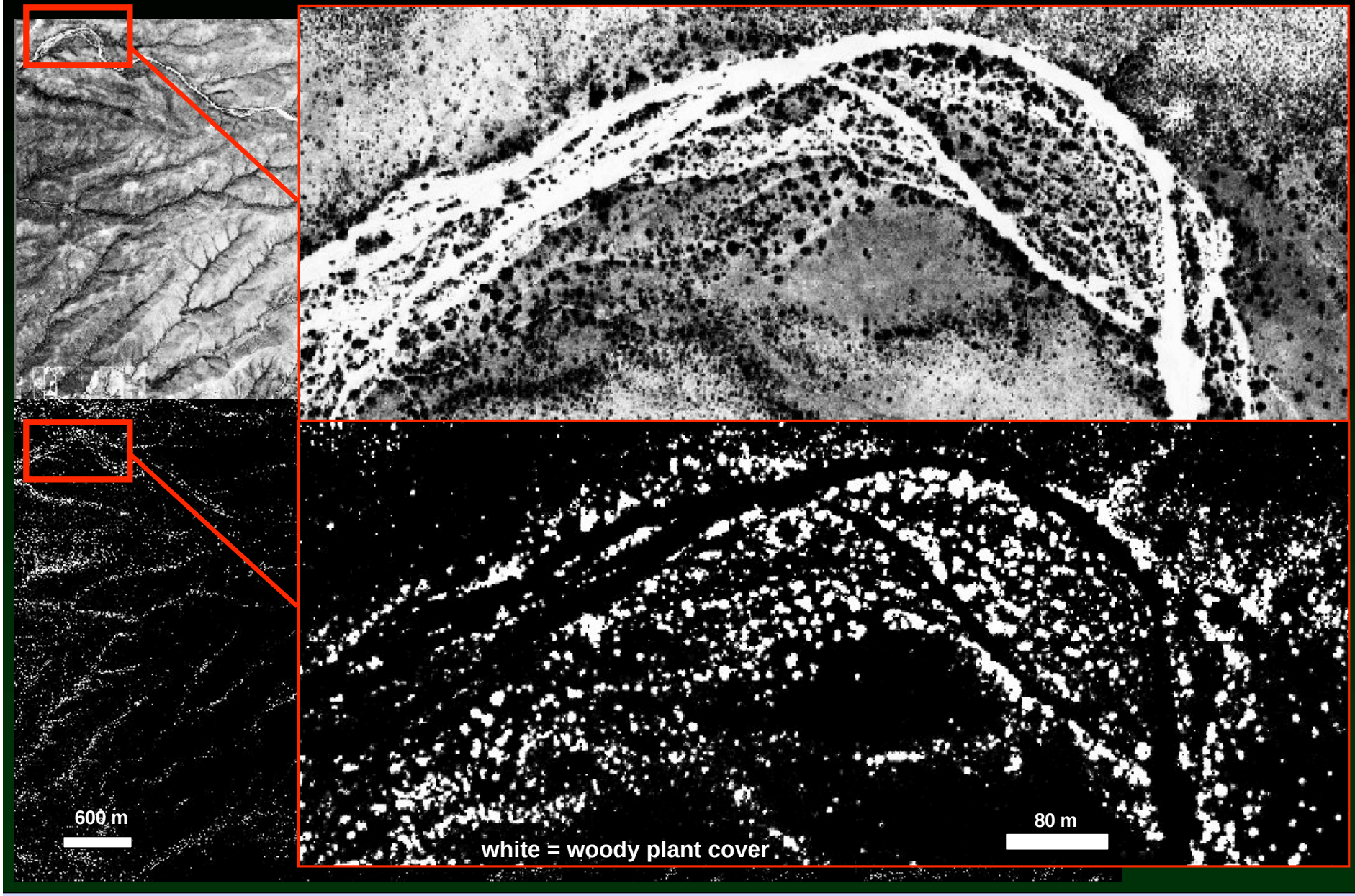
- **These provide the primary validation data for our current EOS project (C pools in desert grasslands); obtained via segmentation algorithms.**

- **Also (forest):**
  - **USFS FIA Plot data**
  - **SWReGAP data**
  - **Lidar-derived canopy height (avaliable?)**

MISR/GO: Further Calibration/Validation…



MISR/GO: Further Calibration/Validation…



MISR/GO: Conclusions 1/2

- These results are to our knowledge unique in the moderate resolution remote sensing world: reasonable crown cover, canopy height, and biomass estimates from a single instrument with no external data inputs (apart from the background calibration). Internal parameters are consistent; understory density is estimated; accuracy is a monotonic function of RMSE.

- Main caveat: The Li-Ross ⟷ background relationship was calibrated on only 19 sites in the Jornada Experimental Range. However, extrapolation error appears much lower than might have been expected.

Conclusions 2/2

- We have made significant progress towards exploiting the structural information content of MISR data. Empirical methods give the best results but models with greater explanatory power are gaining (bottom-up approach).
- We can assess the quality of our retrievals: accuracy improves with increasingly stringent thresholds on RMSE on model fitting (and we can check internal parameters).
- Multi-angle data provide a way to separate the background and upper canopy contributions, enabling the inversion of GO models for crown cover, mean canopy height and woody biomass over large areas.
- Retrieval of canopy structure measures is more challenging for shrubs than for forest (no surprise perhaps).
- further validation being pursued for grassland and forest (replicate, replicate, replicate).

Future work…

Where to go from here? Things to investigate:

- Cause of error: model inadequacies or BG estimates?
- More and better calibration/validation data (FIA plot data)
- Recalibrate the BG regression with data from larger area
- Check fire location/dates: test before/after fire
- Trends through time? Larger area? (requires resources!)
- Investigate the effects of BG extrapolation error
- Correct problems at edge of the MISR swath (how?)
- Restrict to 7 cameras?
- Larger |#| of validation points (increase significance)

That’s all folks!
http://csam.montclair.edu/~chopping/wood