Remote Sensing of Woody Shrub Cover in Desert Grasslands using Canopy Reflectance Modeling and MISR Data

Acknowledgments

Geometric-Optical Modeling of Desert Grassland Canopy Structure with MISR: The work described here is supported by NASA grant NNG04GK91G to EOS project EOS/03-0183-0465 "*Quantifying Changes in Carbon Pools with Shrub Invasion of Desert Grasslands using Multi-Angular Data from EOS Terra and Aqua*", Chopping PI; Program Manager: Dr. Garik Gutman.

Carbon Pools in Desert Grasslands from EOS MISR and MODIS

— people —

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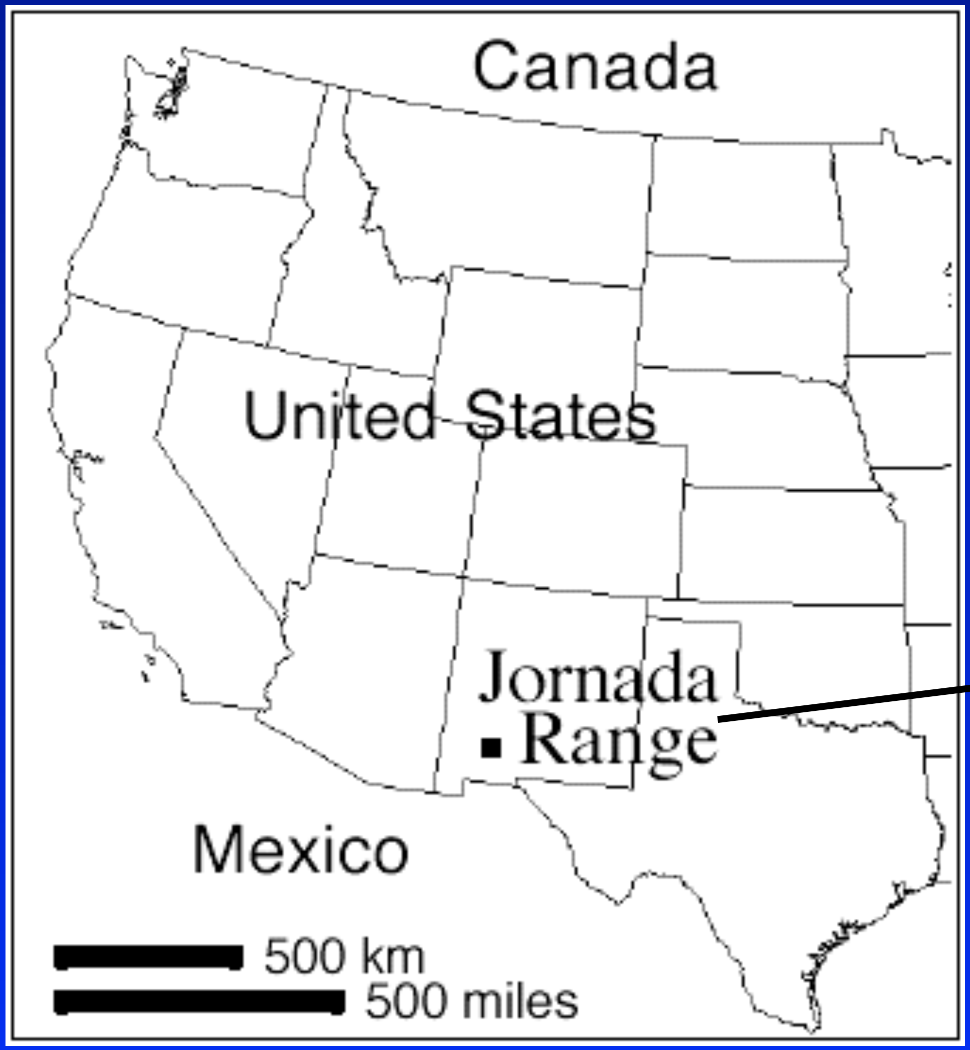
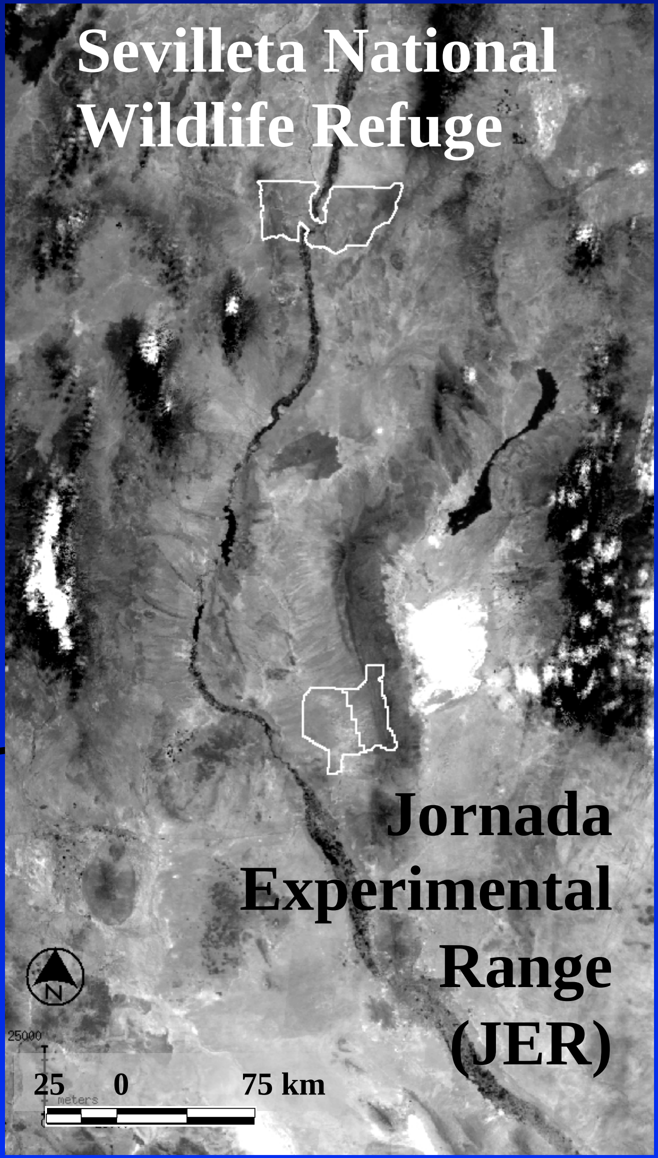
goal

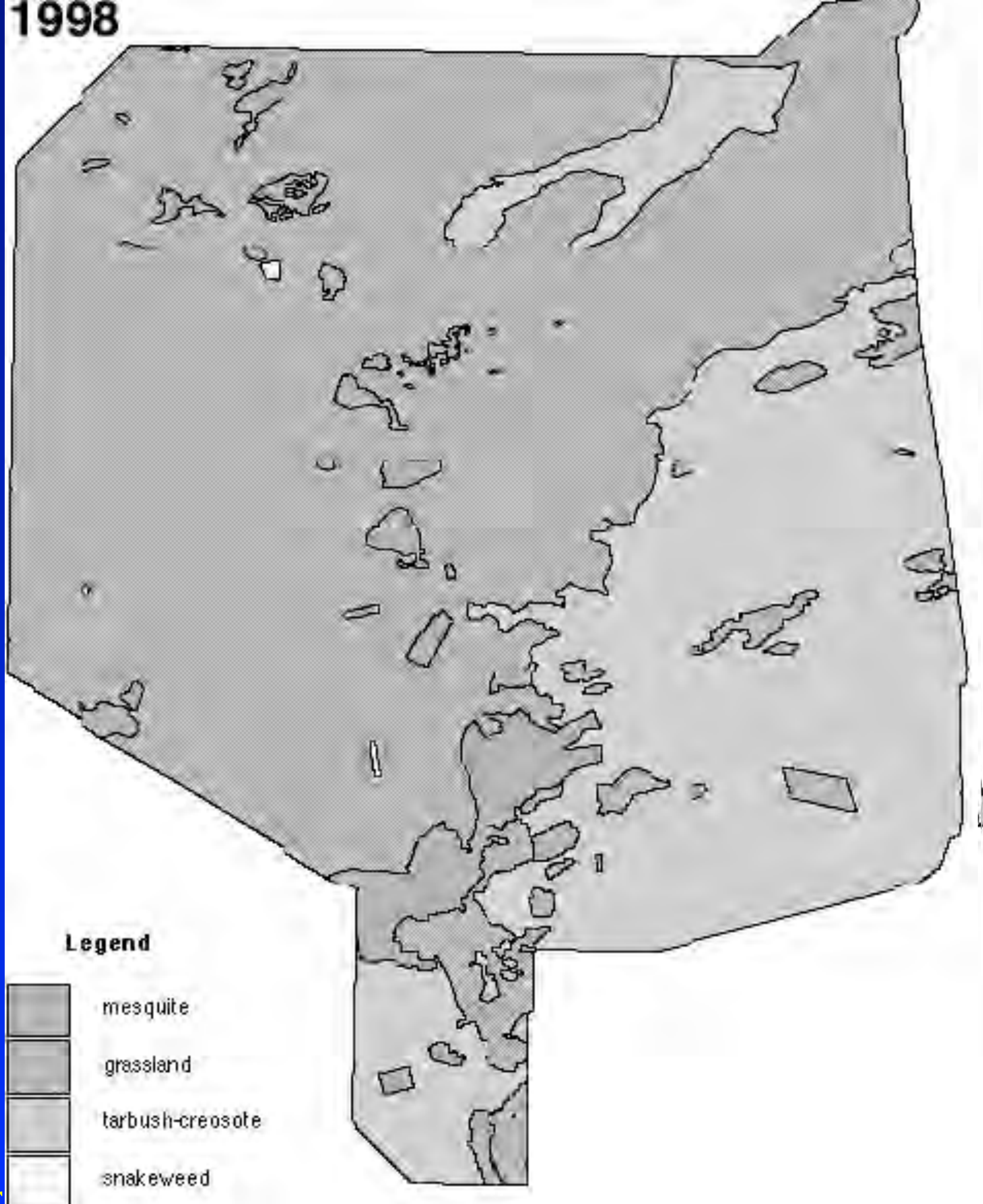
To improve estimates of C pools in desert grasslands by providing improved maps of:

- **plant community type**
- **canopy structural parameters**
- **soil/shrub/grass fractional cover**

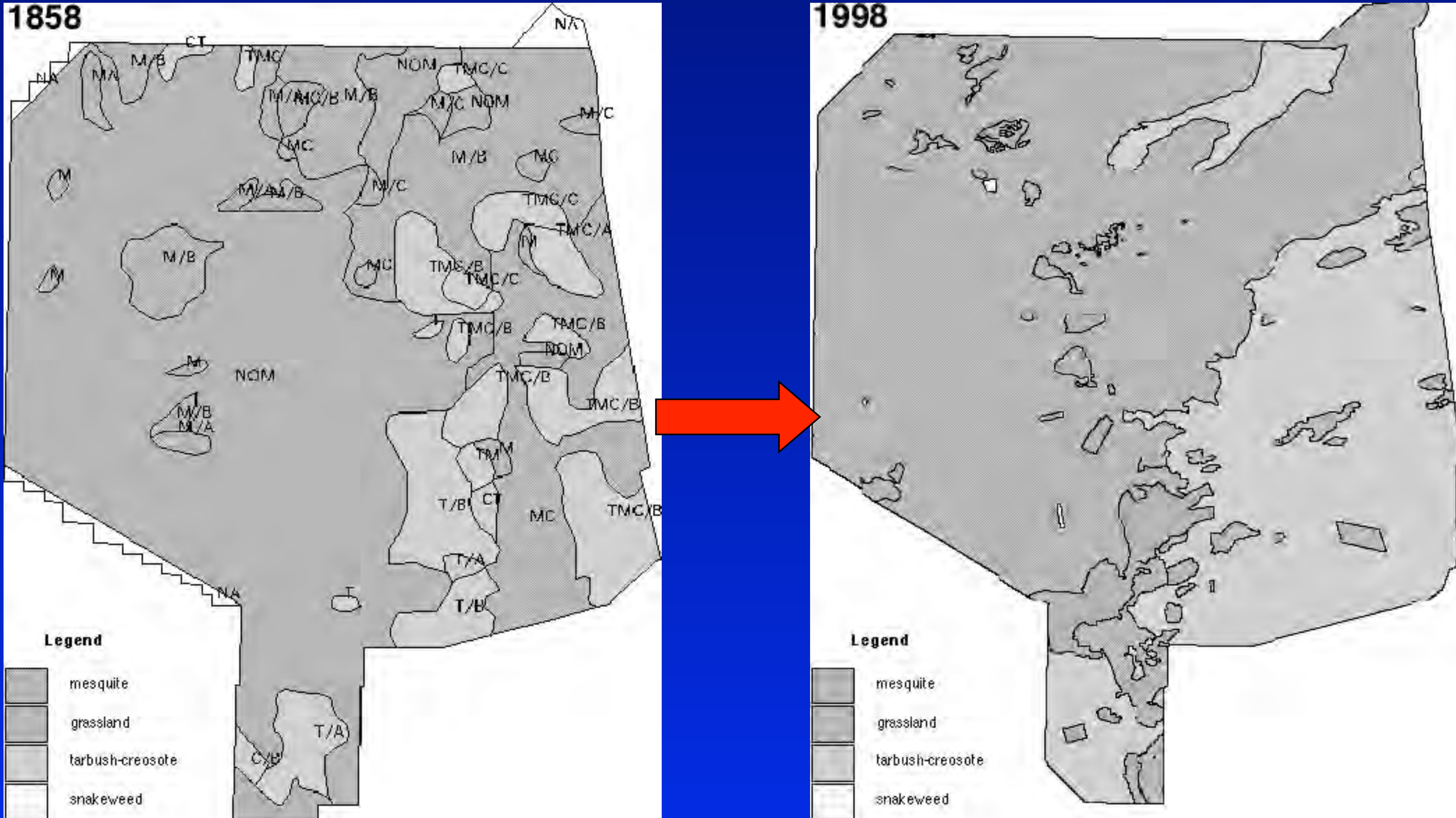
study area


Canada
United States
Jornada
Range
Mexico
500 km
500 miles


Sevilleta National
Wildlife Refuge
Jornada
Experimental
Range
(JER)
25 0 75 km



Vegetation Changes in the JER 1858-1998



Dramatic Vegetation Changes 1858-1998

Vegetation Changes in the Last 150 yrs: Space for Time Substitution

Typical Desert Grassland (SEV)

Chihuahuan and Plains Grassland (Black Grama Grasslands with Blue Grama)

Desertified Grassland (JER)

Honey mesquite (*Prosopis glandulosa*) shrub-coppice dunes

- The abundance of woody shrubs has changed and continues to change rapidly, altering C cycling patterns, albedo and energy fluxes; mapping woody plant cover is therefore of great interest.
- How to do this? Satellite remote sensing is the obvious method but often difficult.
- GO modeling is one possibility.

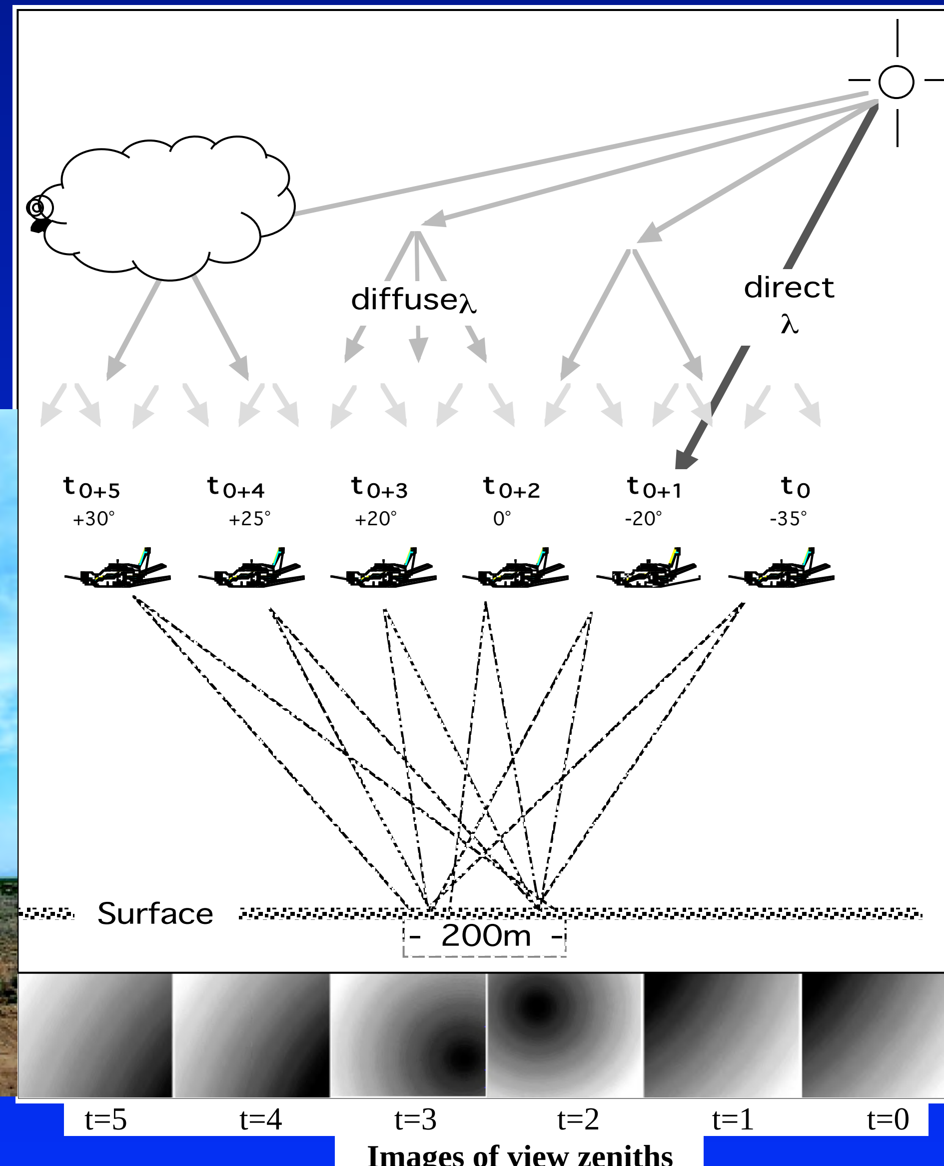
GO Modeling in Desert Grasslands

Objective:

To exploit MISR data with a Geometric-Optical model adapted to desert grasslands to retrieve canopy structure parameters (one or more)

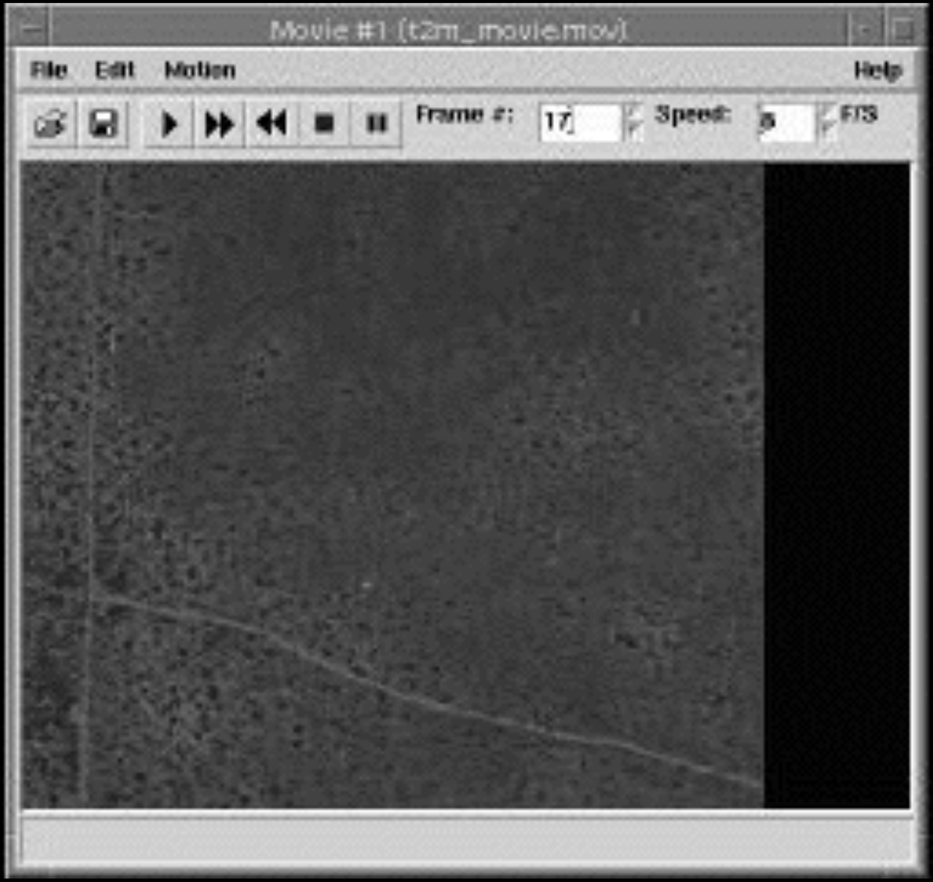
Light-Surface Interactions: BRDF

2000: we used a tilting, digital, multi-spectral camera to acquire MAO images in the Principal Plane @ 3 sun angles.



Light-Surface Interactions: BRDF

Brightness changes greatly a a function of illumination and viewing angles AND the surface (i.e. BRDF is important)



300 m

0.09 — 0.27

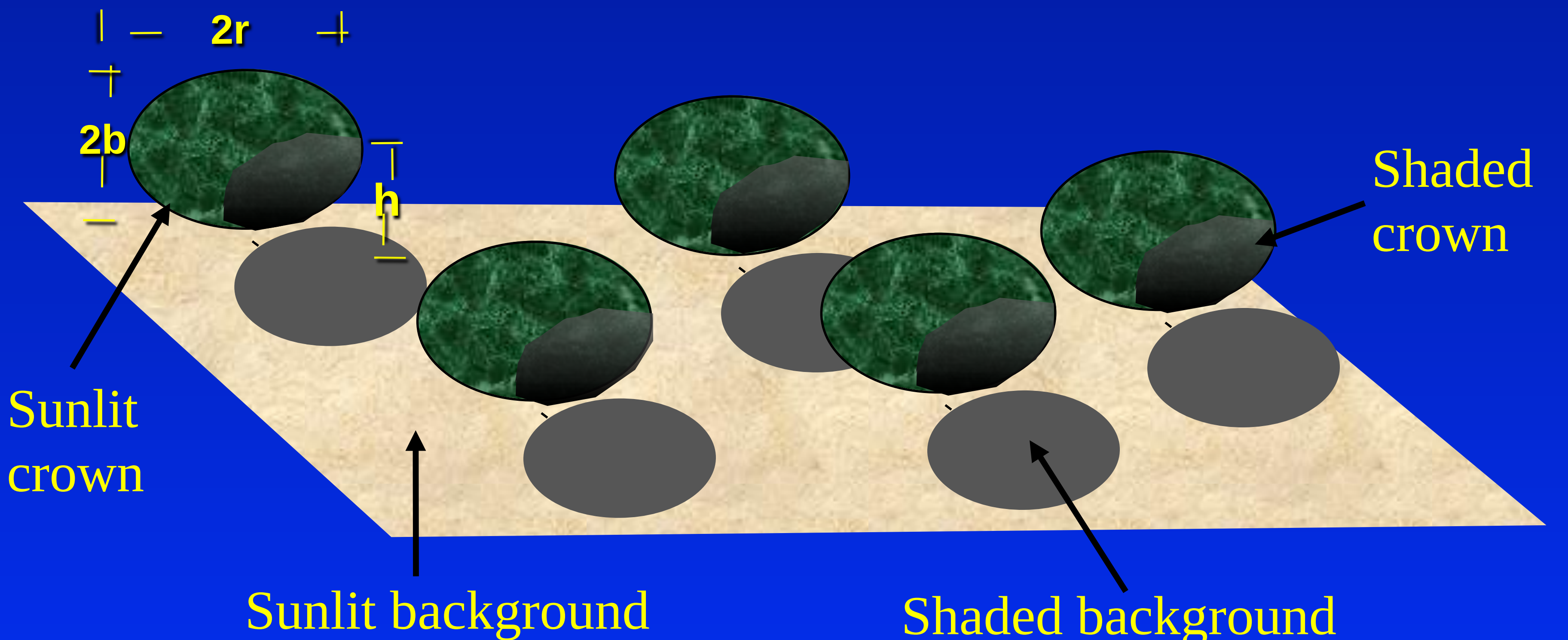
Spectral reflectance at 650 nm

BRDF Effects, Ex. in JER transition zone

Looking in the *Backscattering* direction: shadows are HIDDEN

Looking in the *Forward-scattering* direction: shadows are VISIBLE

GO models predict BRF based on the proportions of viewed and sunlit or shaded crowns and background at any angular configuration. Parameters: #density, radius, height, LAI.

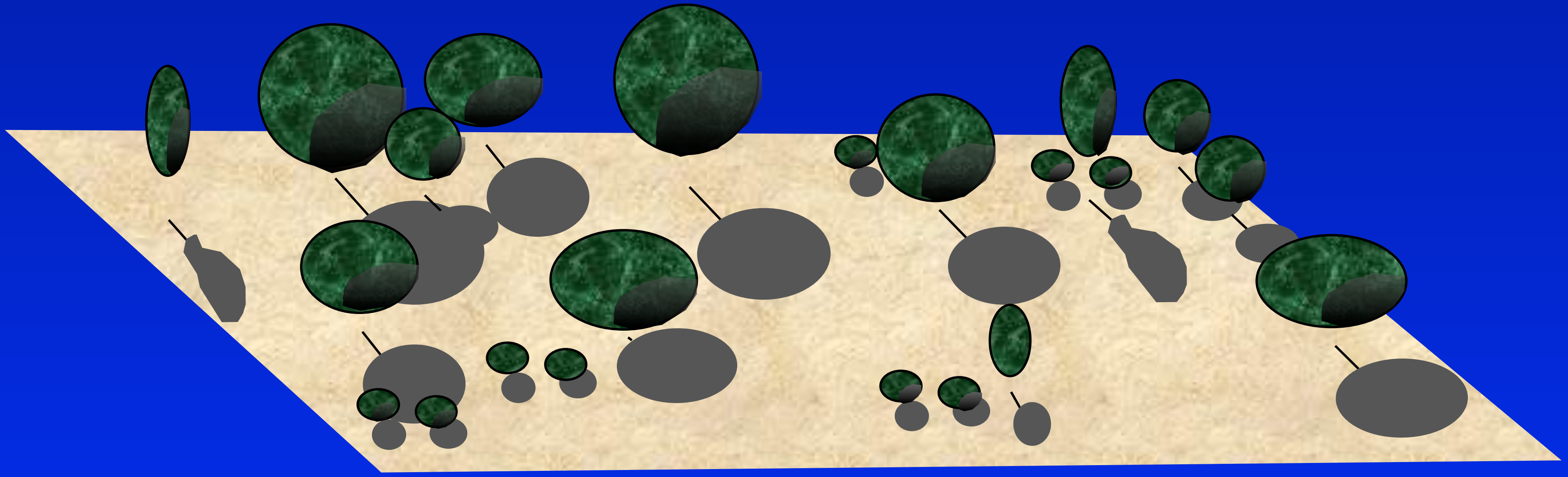


These are DISCRETE OBJECT models

How does a GO model respond to heterogeneous canopies?

-- GO models operate on mean parameter values

-- Mutual shadowing could be enhanced, depending on plant density



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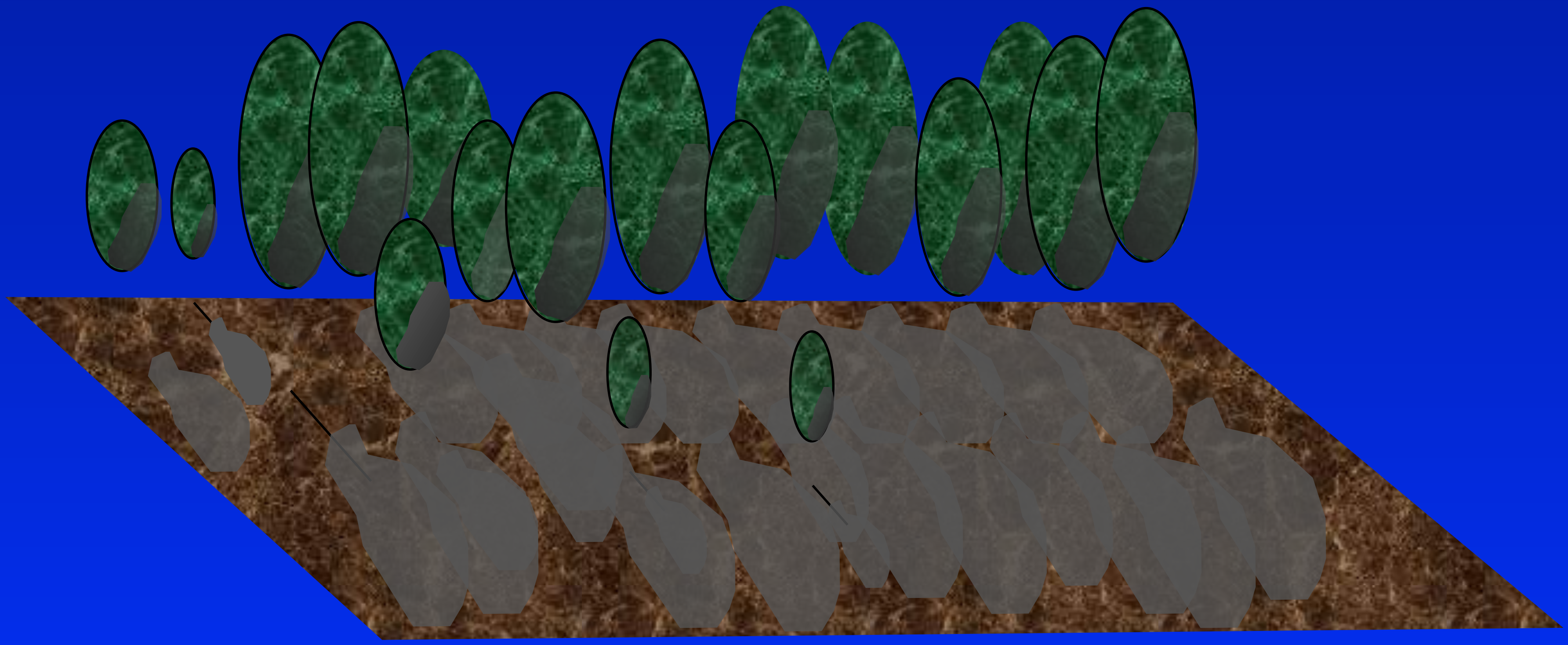
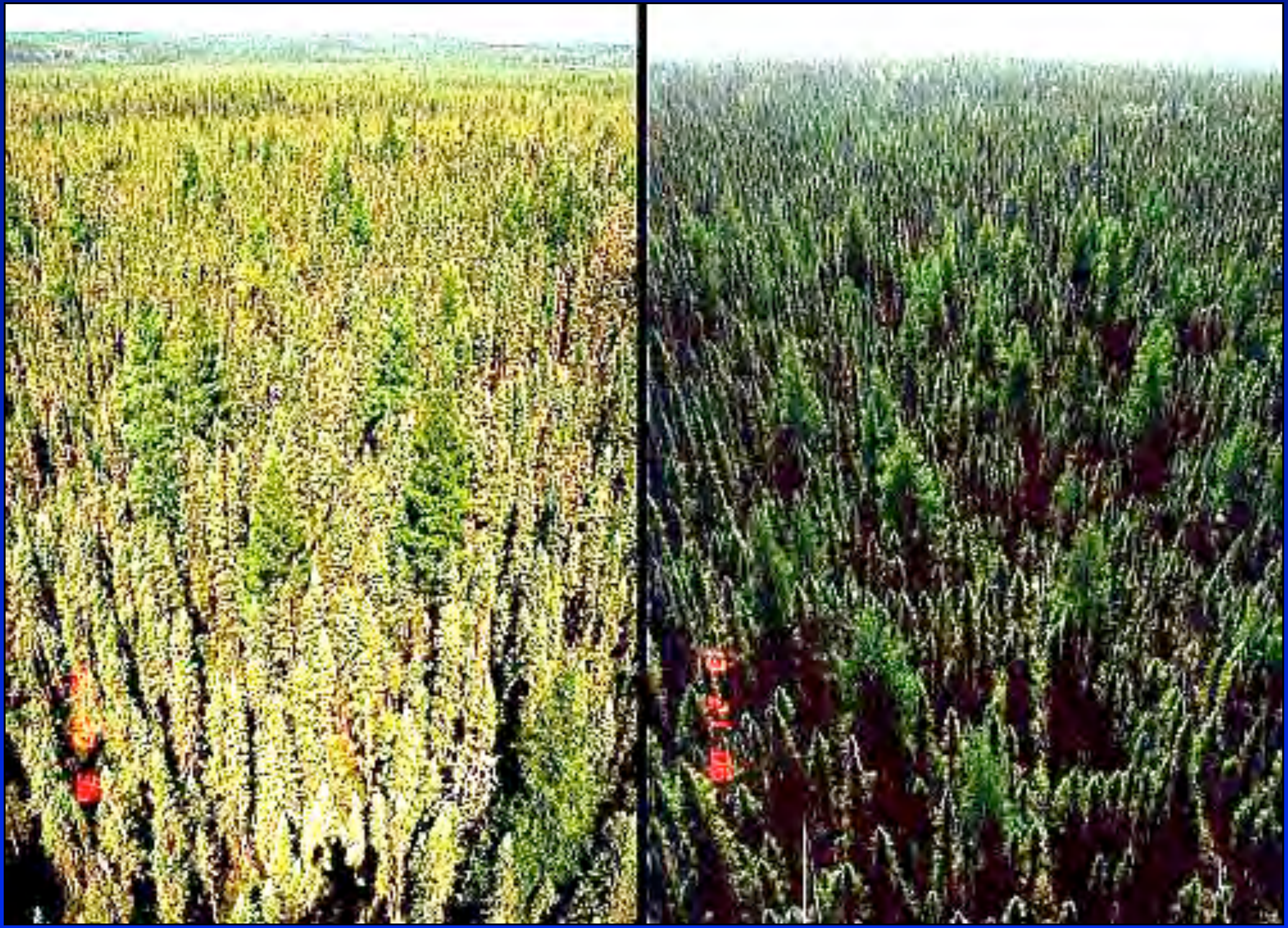
GO models work well in forested environments

-- background proportion small relative to the upper canopy

-- backgrounds are dark with low reflectance anisotropy



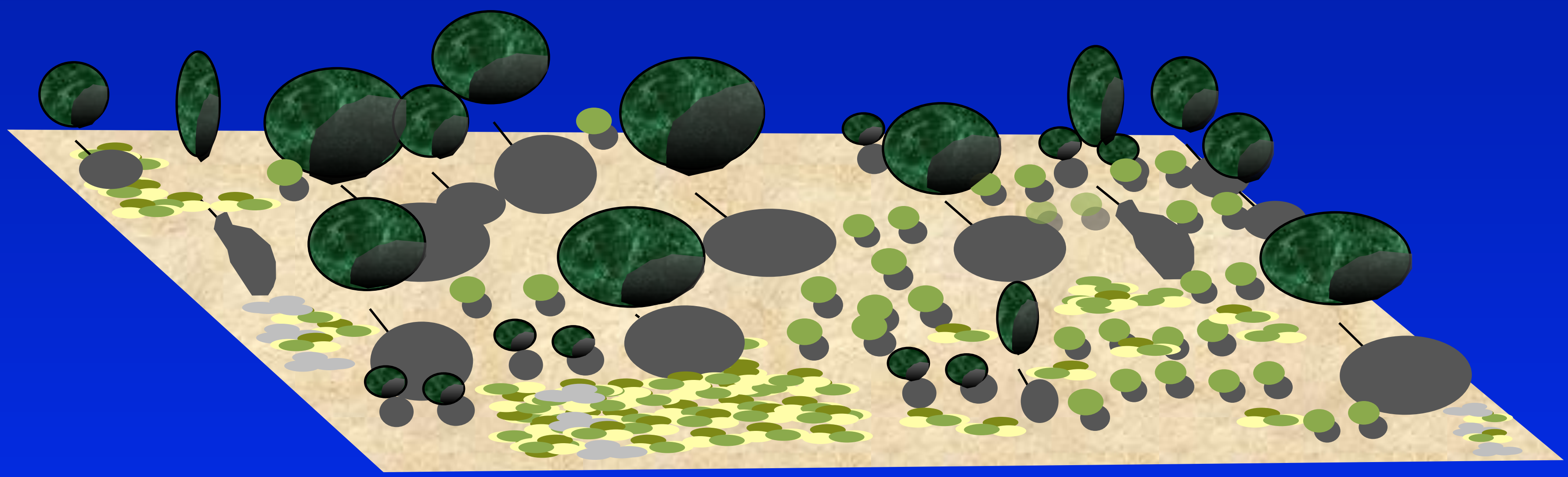
Spruce Forest: Background visible?



Looking in the *Backscattering* direction: shadows are HIDDEN

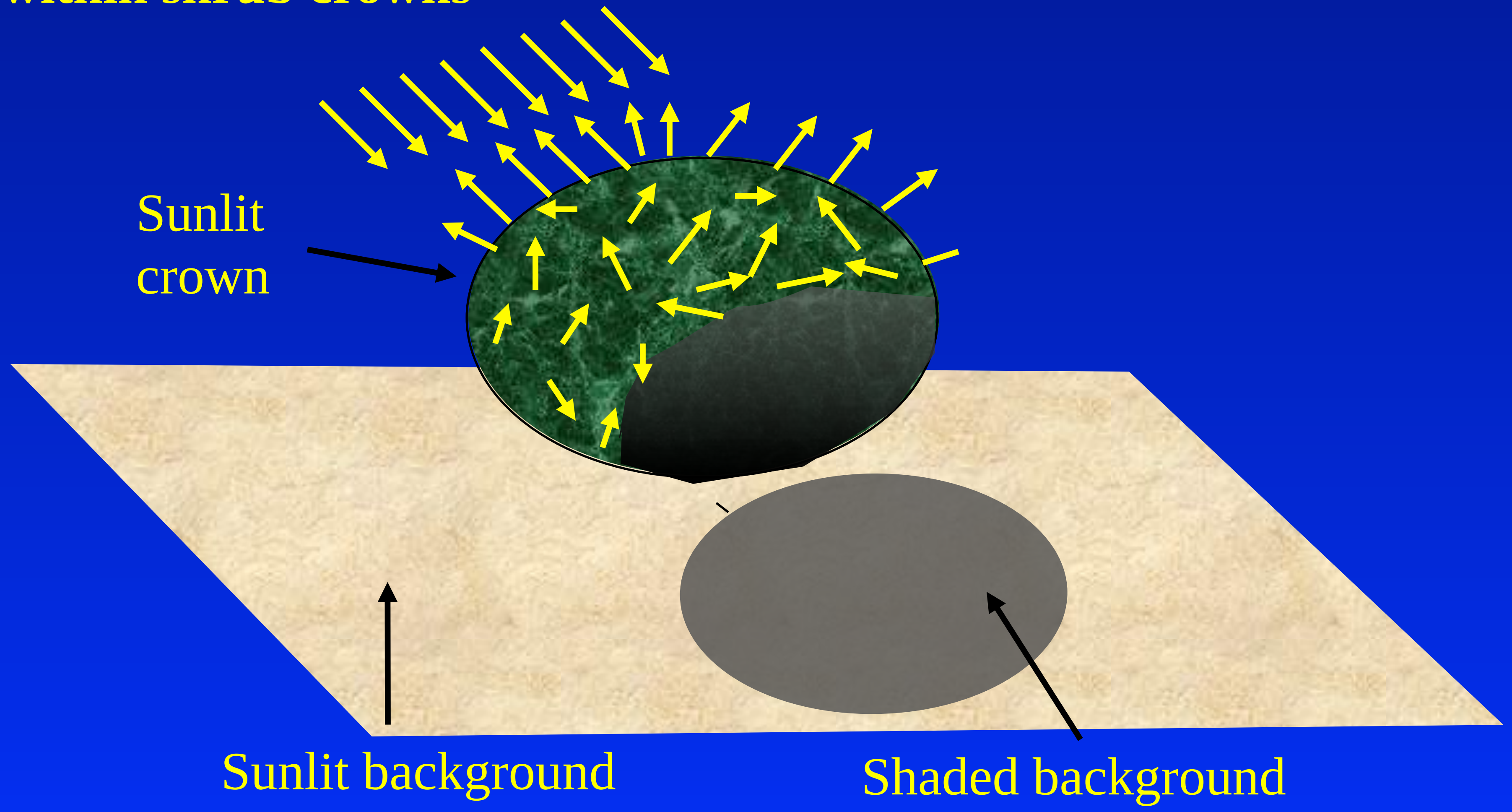
Looking in the *Forward-scattering* direction: shadows are VISIBLE

Can GO models work for very heterogeneous canopies which have a highly variable and bright background?



Note that this also assumes a flat background!

We can handle foliage density by considering volume scattering within shrub crowns



Knowledge of the DESERT background BRDF is essential: there is a lot of bright “background”

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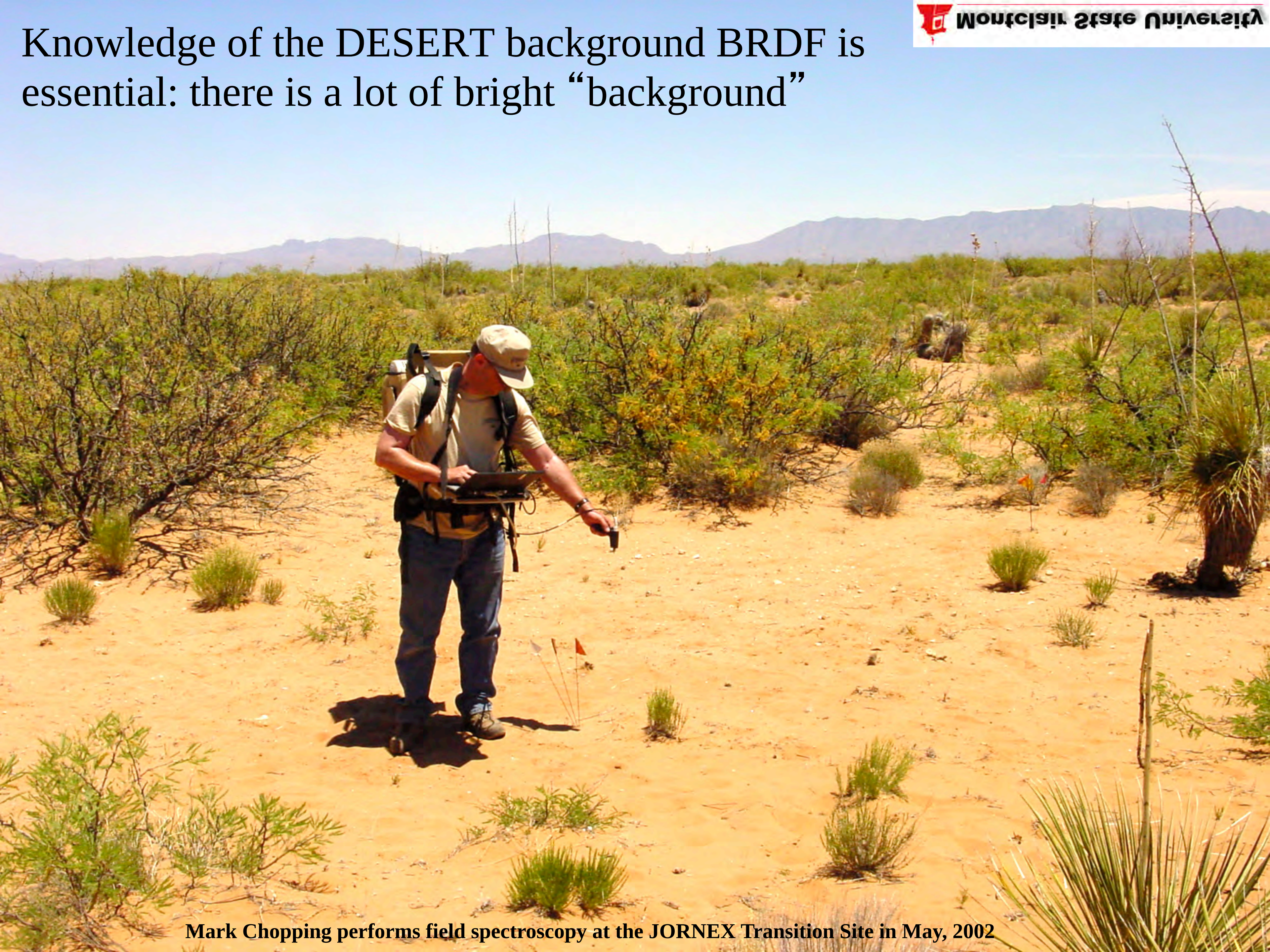

Mark Chopping performs field spectroscopy at the JORNEX Transition Site in May, 2002

Mesquite Dunes- sparse, clumped

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At the Jornada Range, airplane pilots follow flight-line markers during remote-sensing flyovers. Here, Mark Chopping secures a marker in place.

community types --> BG

Sometimes the BG is uniform… and sometimes NOT!

Creosotebush shrubland (JER)

Tarbush Shrubland (JER)

The desert background reflectance is controlled by the understory

Photo courtesy USDA-ARS Photo Unit (Scott Bauer)

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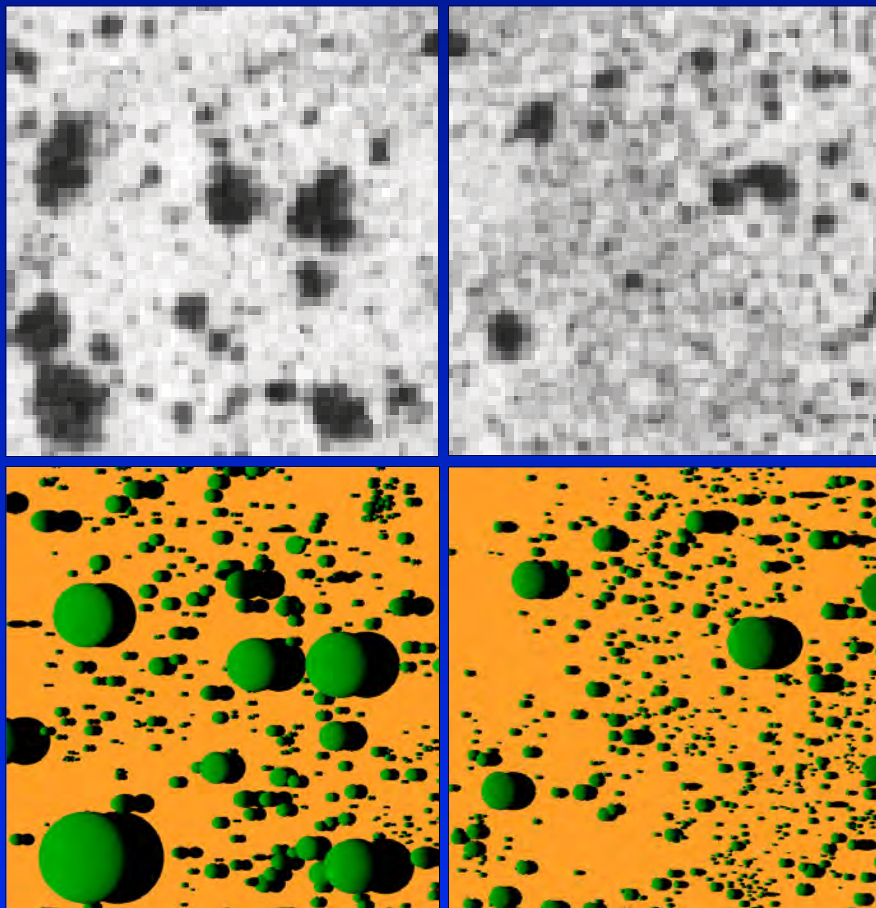
The Simple Geometric Model (SGM)

- designed for invertibility, so has to be simple, with a small # of adjustable parameters
- Developed from kernel-driven models; uses the principles of Boolean geometry, pretty much GOMS + Ross volume scattering
- Parameters are mean plant # density, radius, height, shape, and a soil-understory BRDF (Walthall)
- Tested vs. observations and radiosity model driven with field measurements.

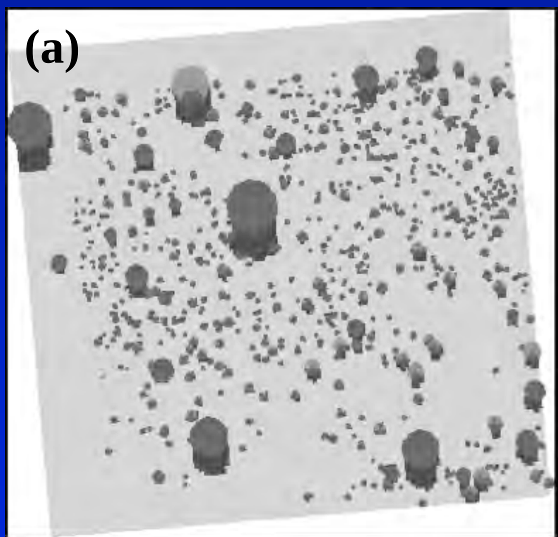
CHRIS/Proba Principal Investigator Meeting April 28, 2004

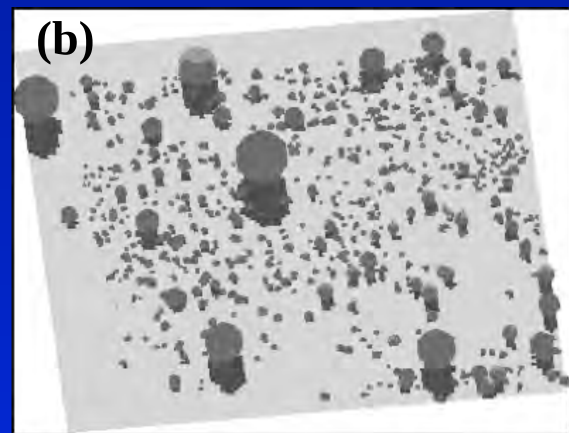


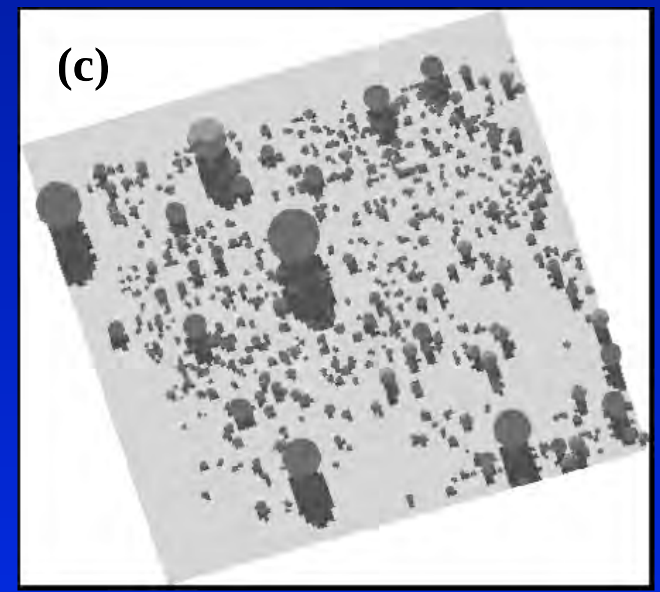
Top: Aerial photographs for sparse and dense 25 m^2 plots. Note the fuzzy areas.

Bottom: large and small shrubs modeled as spheroids showing shadowing (based on airphoto and field-measured maps of all plants except grasses)

Views of dense snakeweed plot generated at various angular configurations by the Radiosity Graphics Method

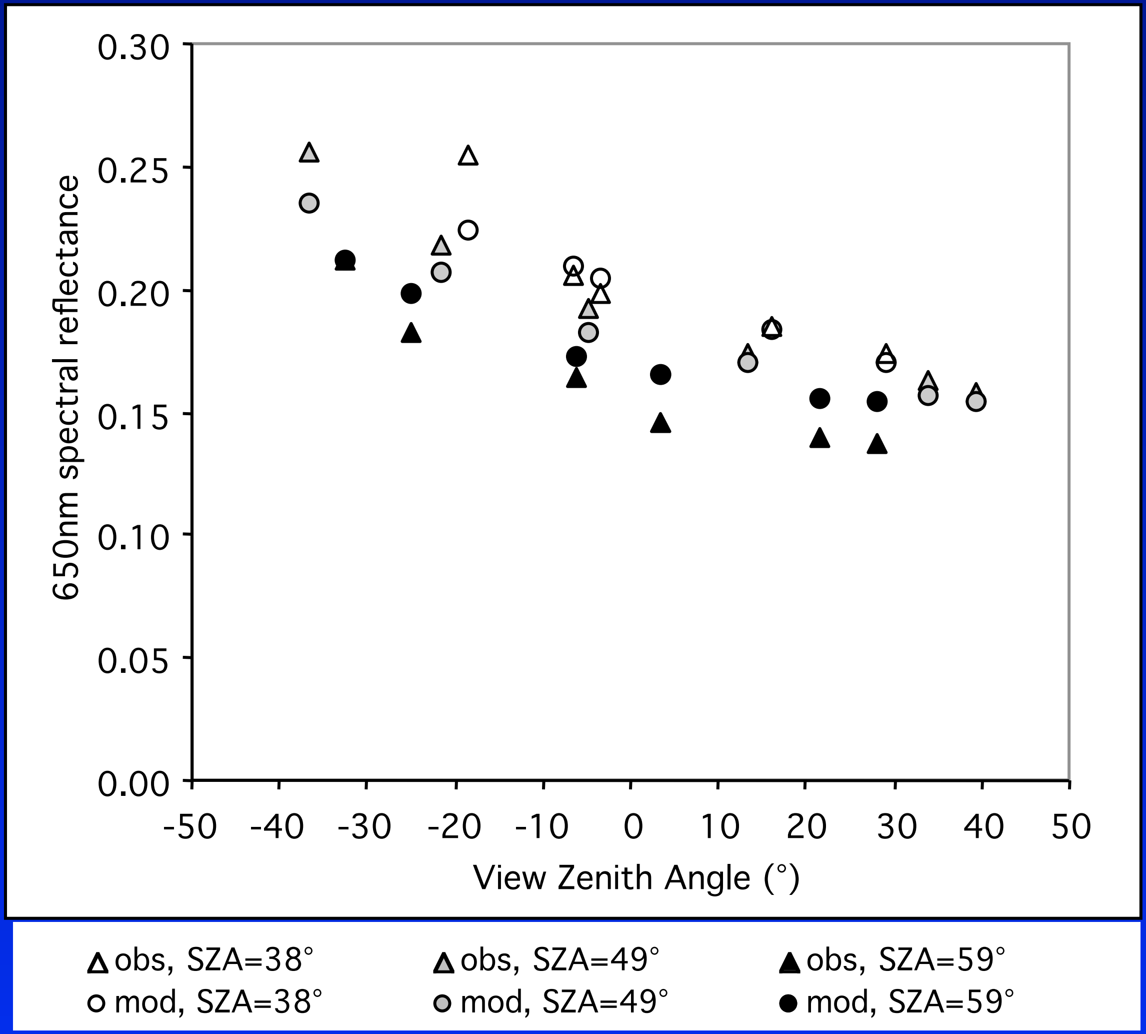






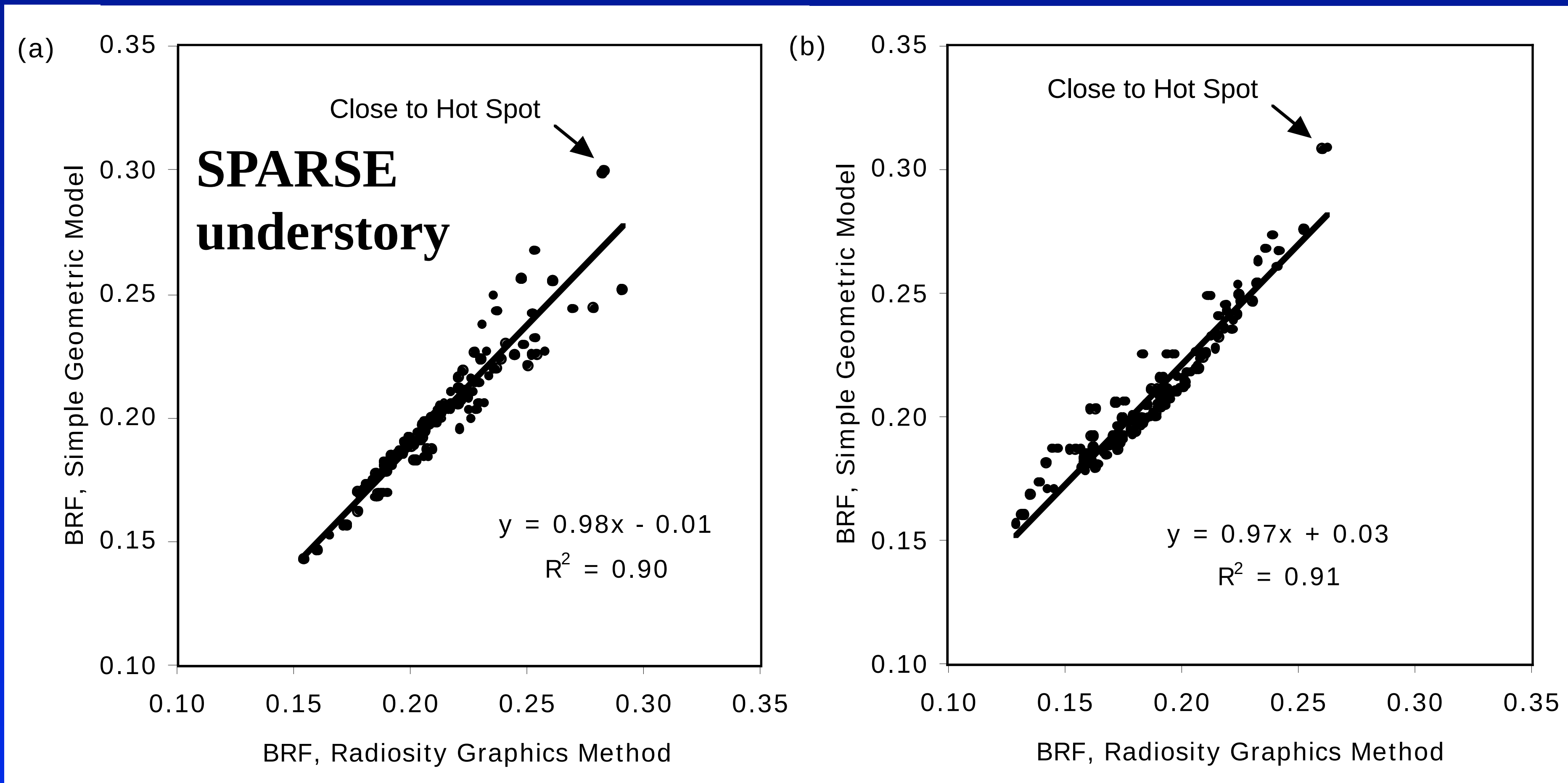
	- - - - - - - Acquisition Angles (°) - - - - - -			
	Solar Zenith	Solar Azimuth	Viewing Zenith	Viewing Azimuth
(a)	37.50	0.00	14.06	175.10
(b)	49.00	0.00	40.20	173.80
(c)	59.25	0.00	23.63	162.90

BRDF / GO CR Modeling



Modeled (mod) and Observed (obs) Multiangular reflectance factors at three solar zeniths, RMSE=0.014, R^2=0.93, shrub width=0.5m, density=0.1025, height=1.374m, LAI=0.9

BRDF / GO CR Modeling



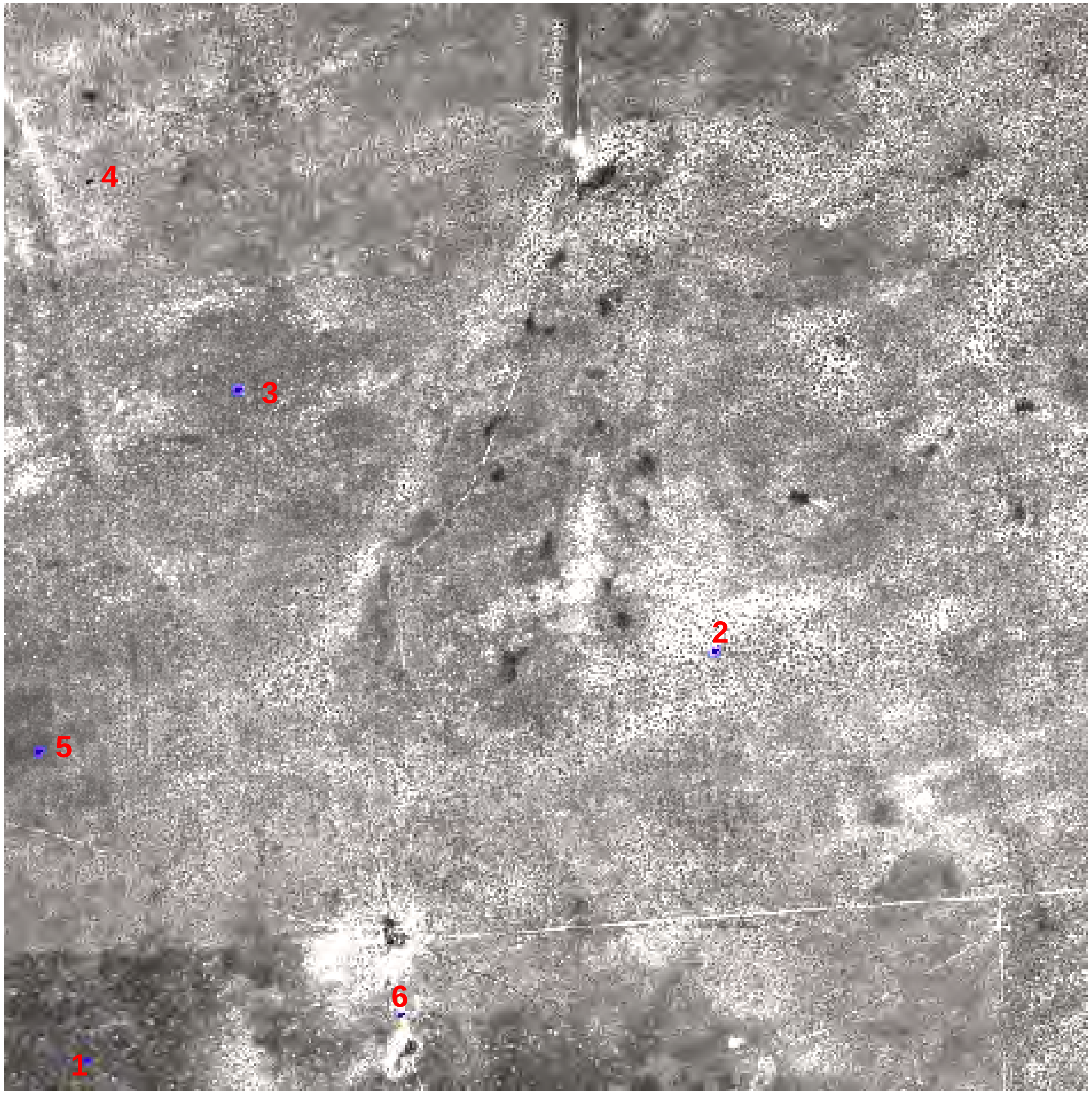
So, we can model the response for selected sites but not across the landscape:

--why not?

Reference tarps used for calibration

The problem: *the BG BRDF*

Application of GO models is difficult in arid environments as the magnitude and anisotropy of the remotely-sensed signal is dominated by the "background" comprised of varying proportions of 1. soil and 2. understory elements (grasses, litter, annuals, forbs). The Challenge is to find a way of obtaining the background BRDF in order to isolate the effects of the larger canopy elements, e.g., to estimate shrub crown cover.



IKONOS Panchromatic Image

05/23/01 Sites are indicated in RED

600 m

N

The problem: *understory*

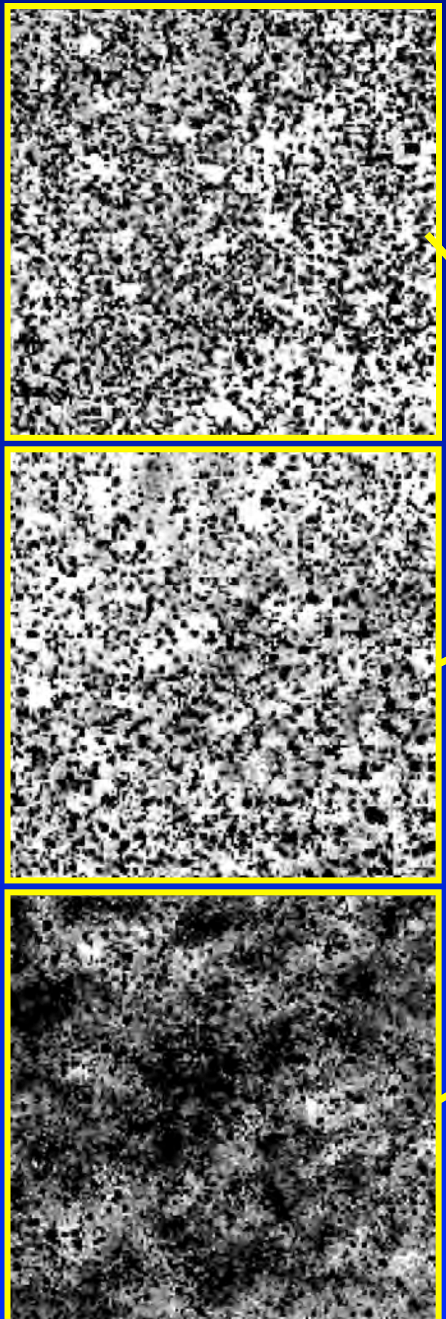
We looked at this by studying the soil-understory behavior at a number of Selected Sites:

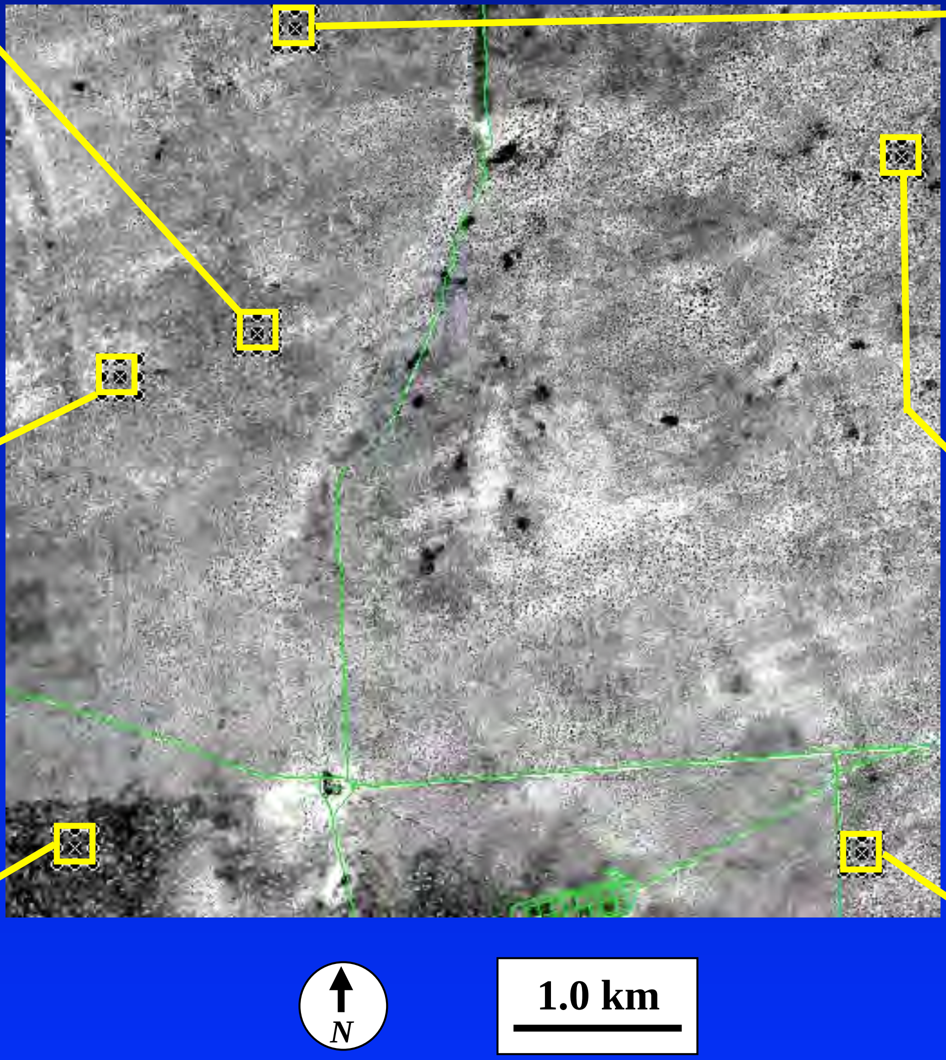
1. **grama grass with some PRGL (mesquite)**
2. **large PRGL on sand**
3. **small PRGL on dense understory**
4. **small PRGL on sparse understory**

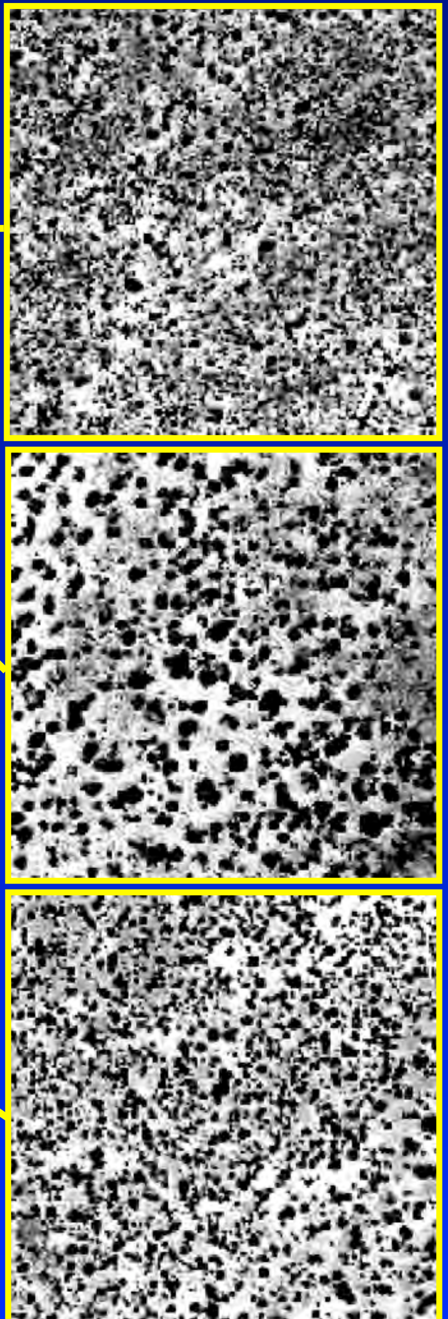
5 small PRGL on dense understory(2)

6. **mixed area near WestWell**

Canopy Configurations

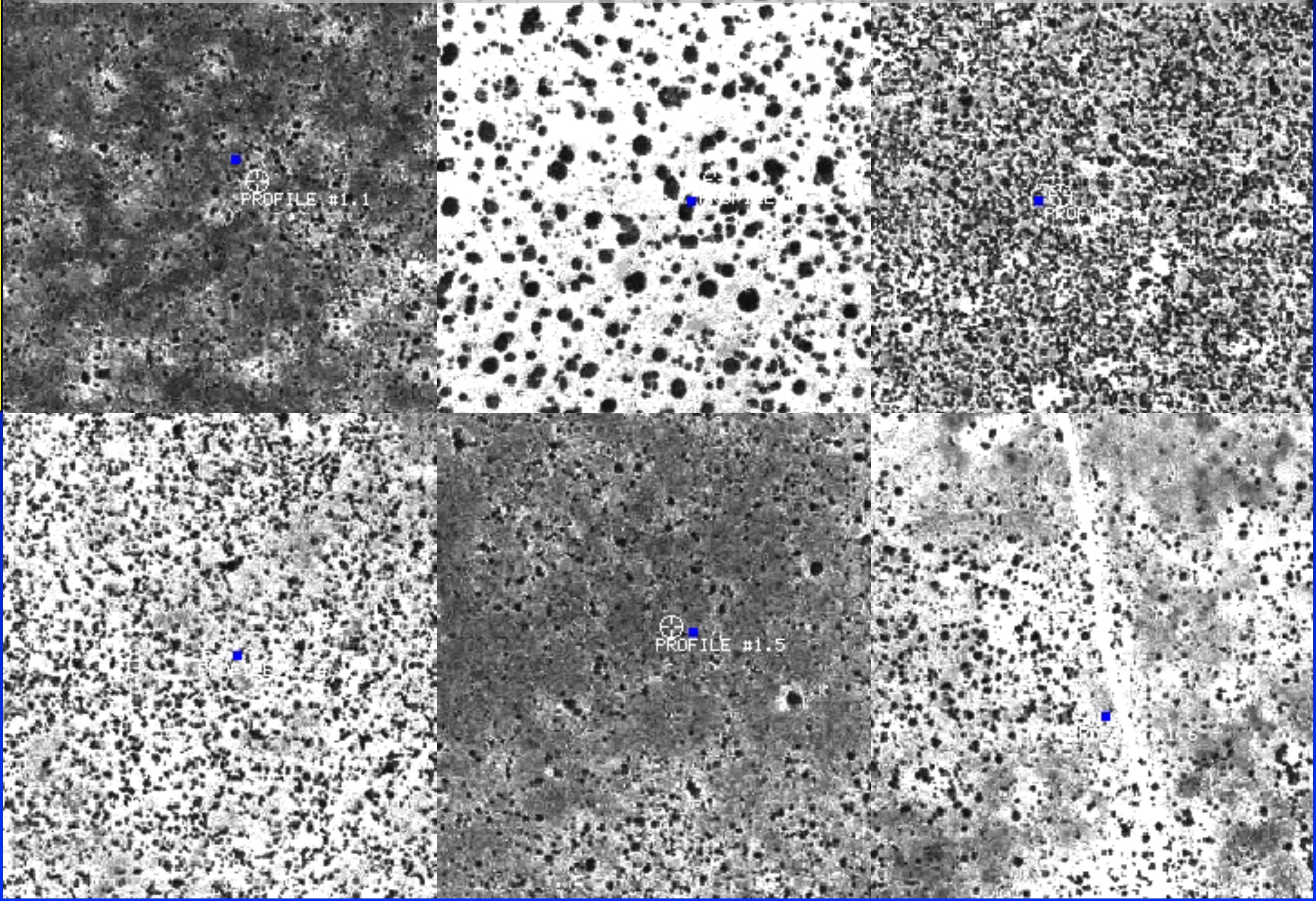




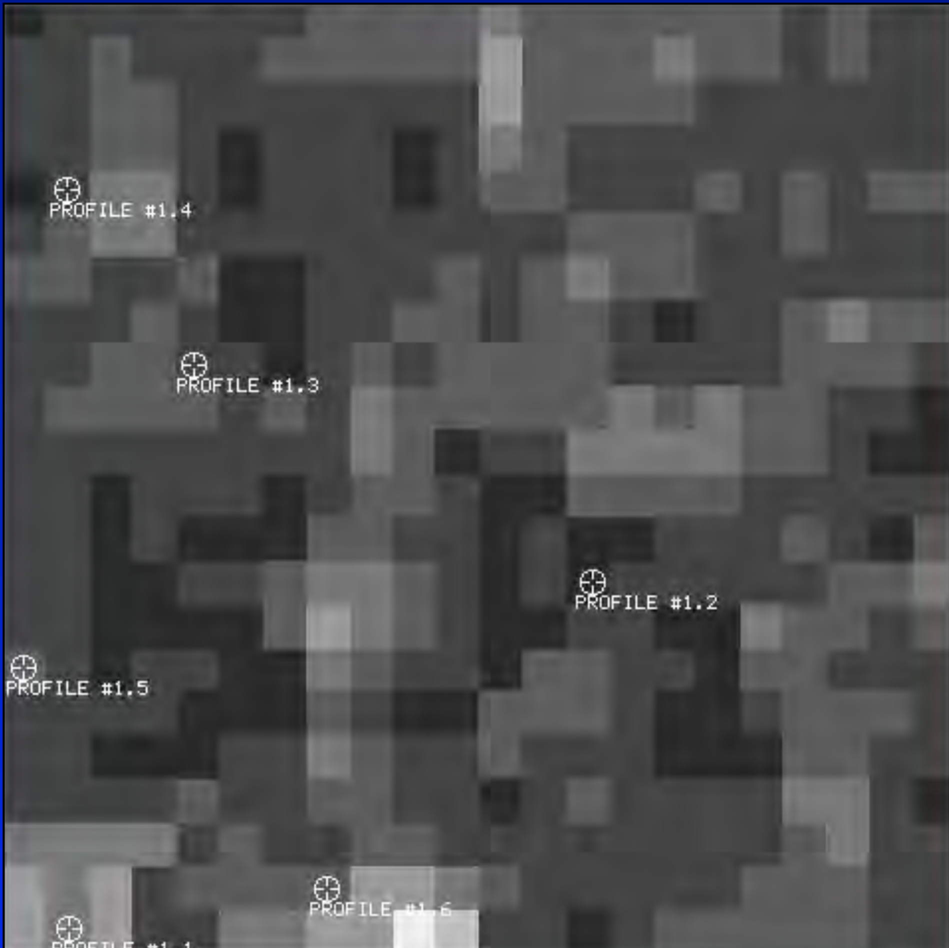


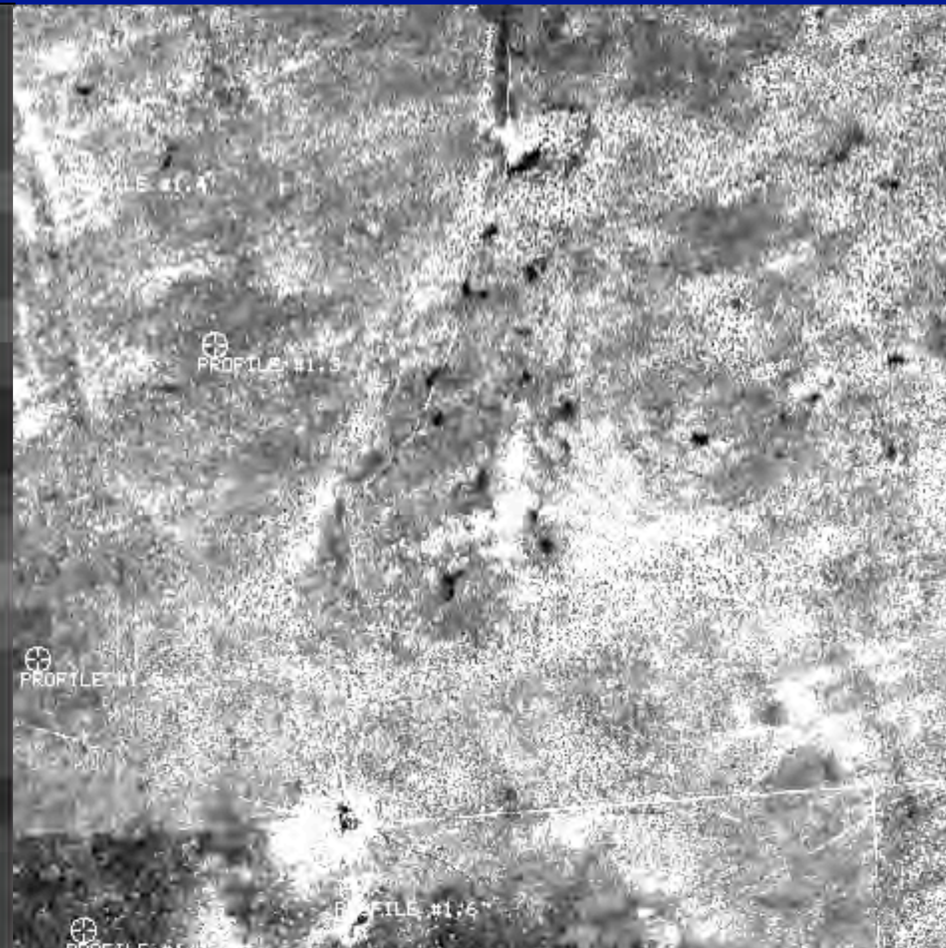
Closer still (IKONOS 1 meter pan images)

250 meters



We noticed that vol scattering correlates…





MISR Volume Scattering (brighter = greater volume scattering)

IKONOS Pan Image

This accords with physical principles

Modeled vs. Observed MISR Red BRFs Using vol kernel weight as BG predictor

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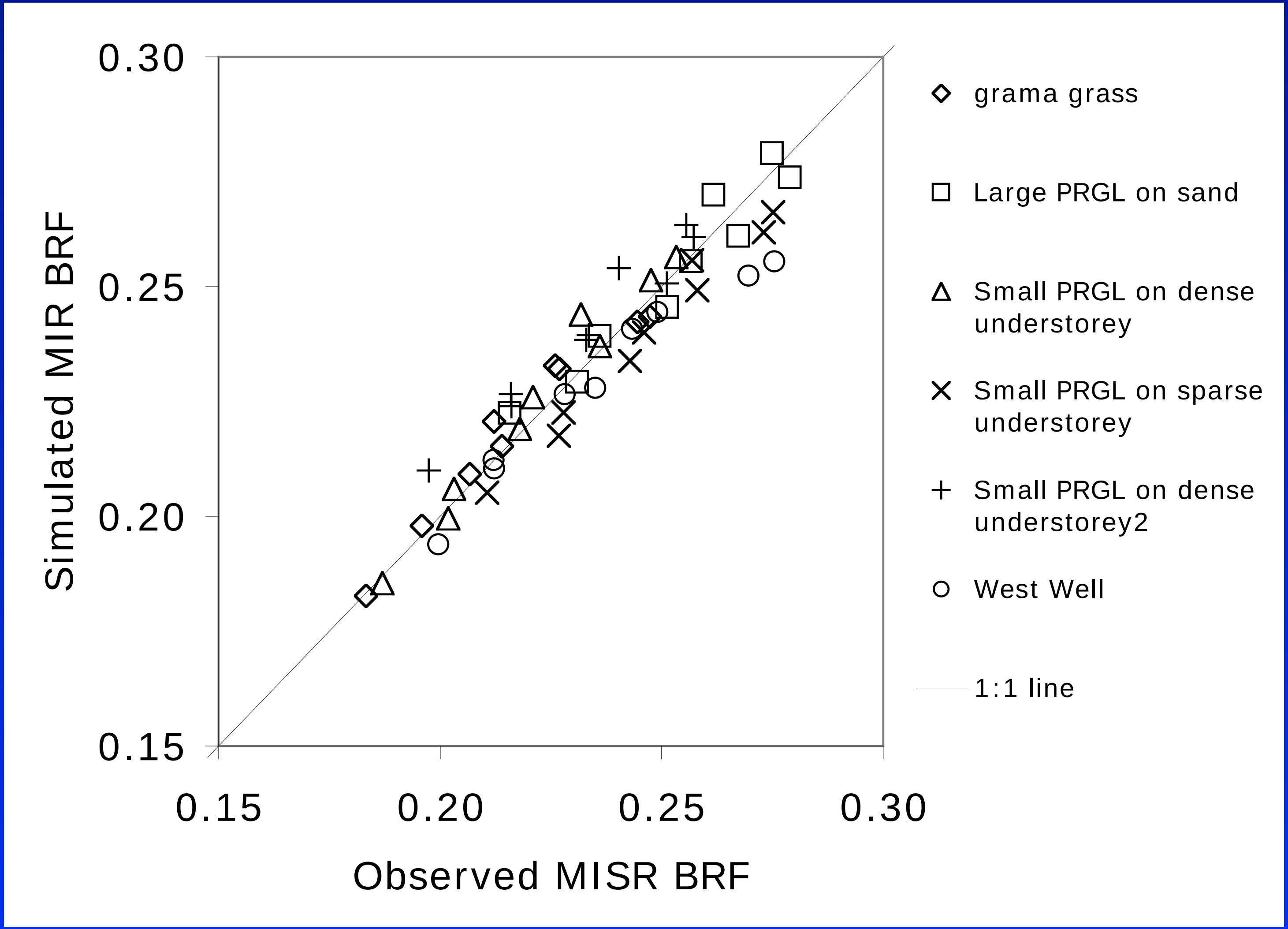
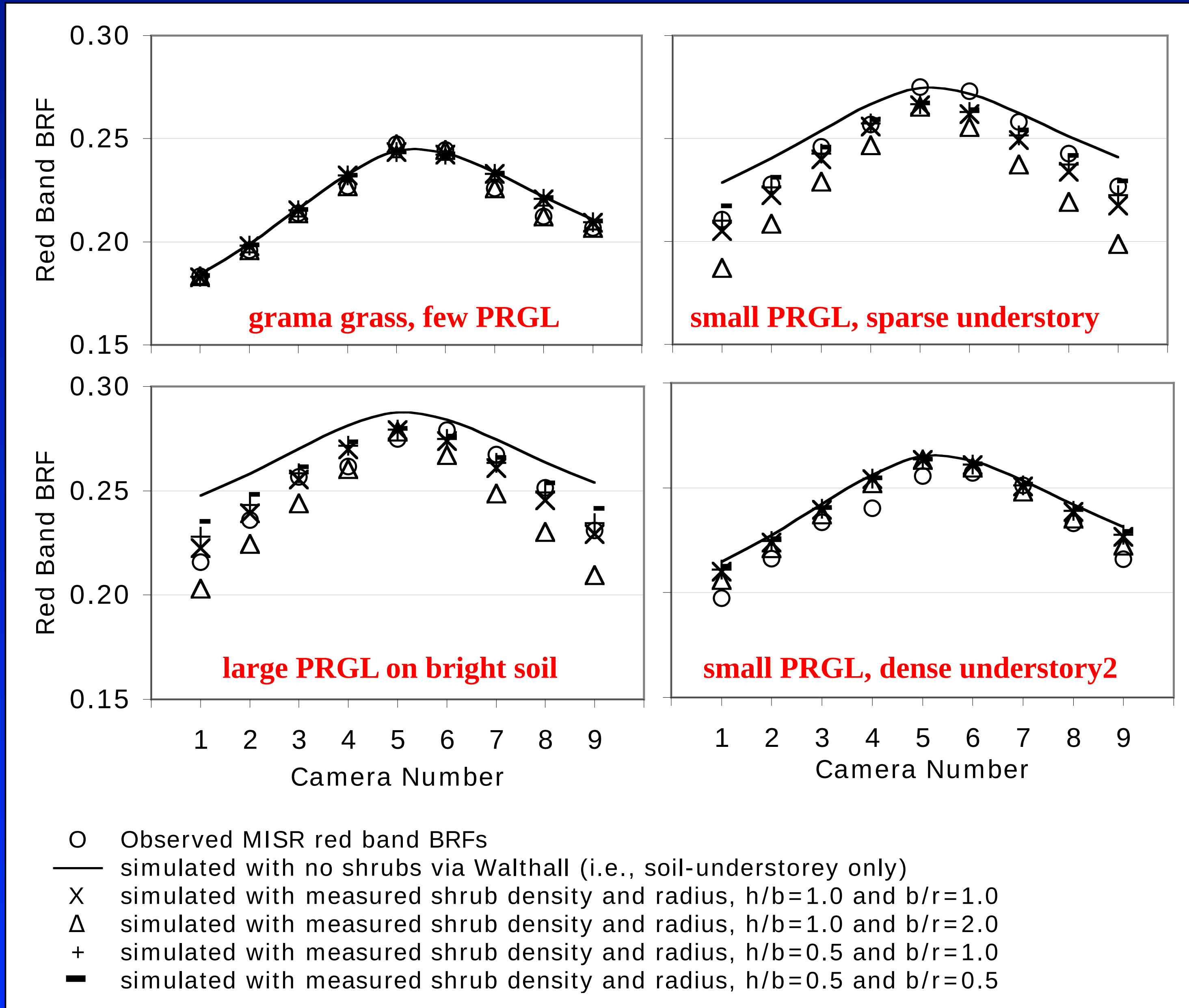


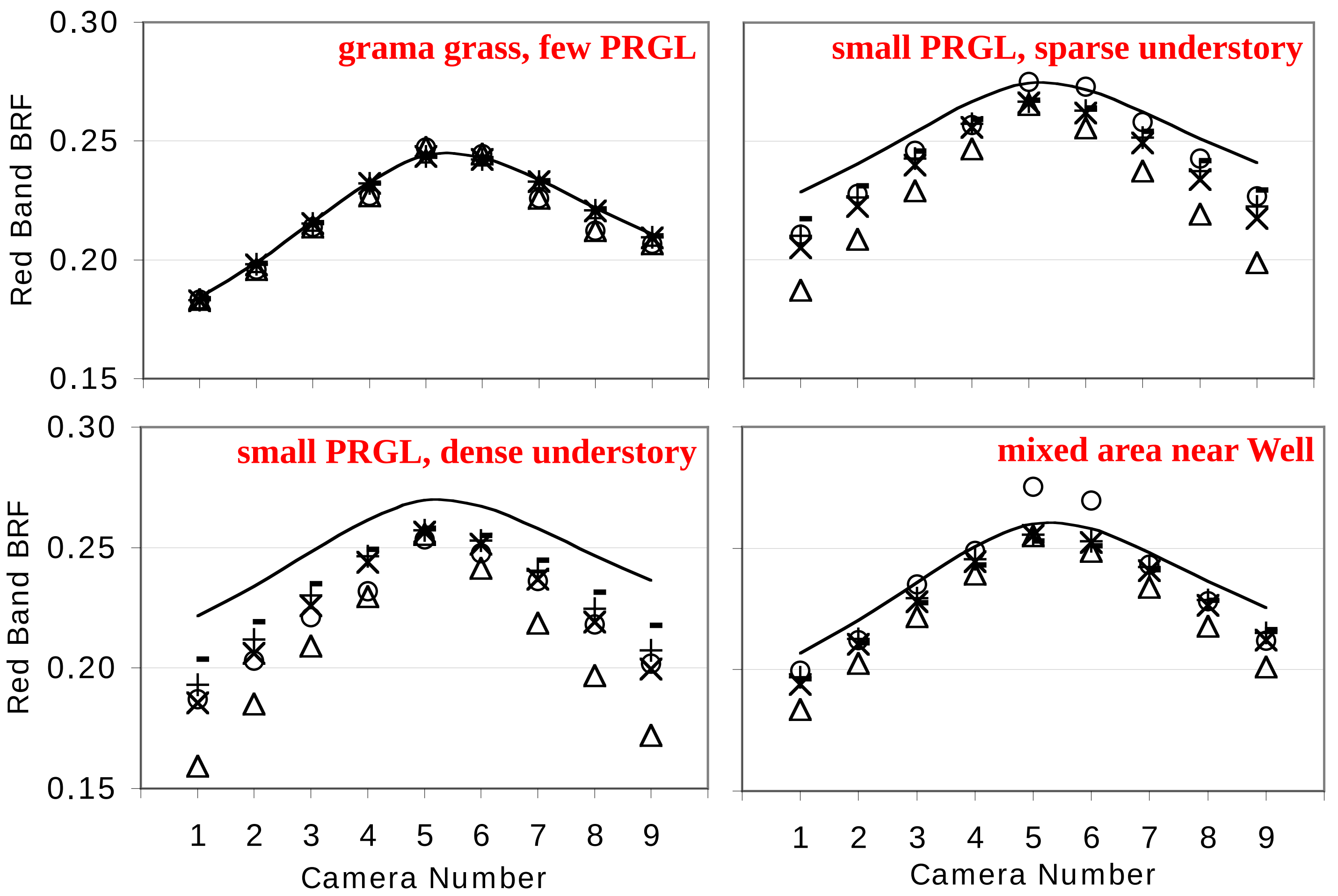
Modeled vs. Observed MISR Red BRFs

Using vol kernel weight as BG predictor



Modeled vs. Observed MISR Red BRFs

Using vol kernel weight as BG predictor



O Observed MISR red band BRFs
—— simulated with no shrubs via Walthall (i.e., soil-understorey only)
X simulated with measured shrub density and radius, h/b=1.0 and b/r=1.0
Δ simulated with measured shrub density and radius, h/b=1.0 and b/r=2.0
\+ simulated with measured shrub density and radius, h/b=0.5 and b/r=1.0
▬ simulated with measured shrub density and radius, h/b=0.5 and b/r=0.5

Are there alternatives? Yes!

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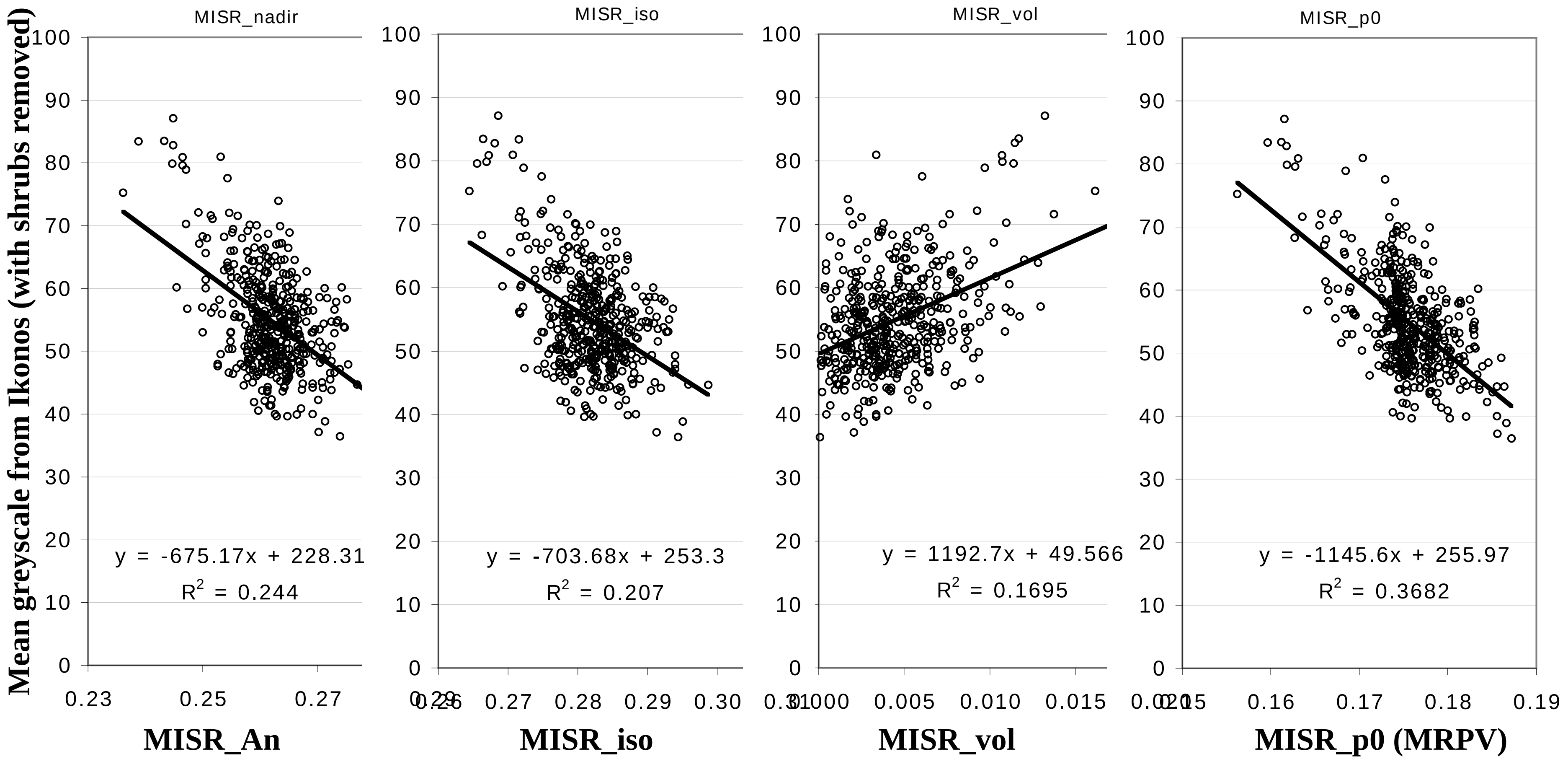

The MISR $\rho 0$ parameter (magnitude) retrieved via the MRPV BRDF model performs slightly better than the Li-Ross volume scattering parameter when tested against mean Ikonos pan values from which shrubs have been removed.

Modeled vs. Observed MISR

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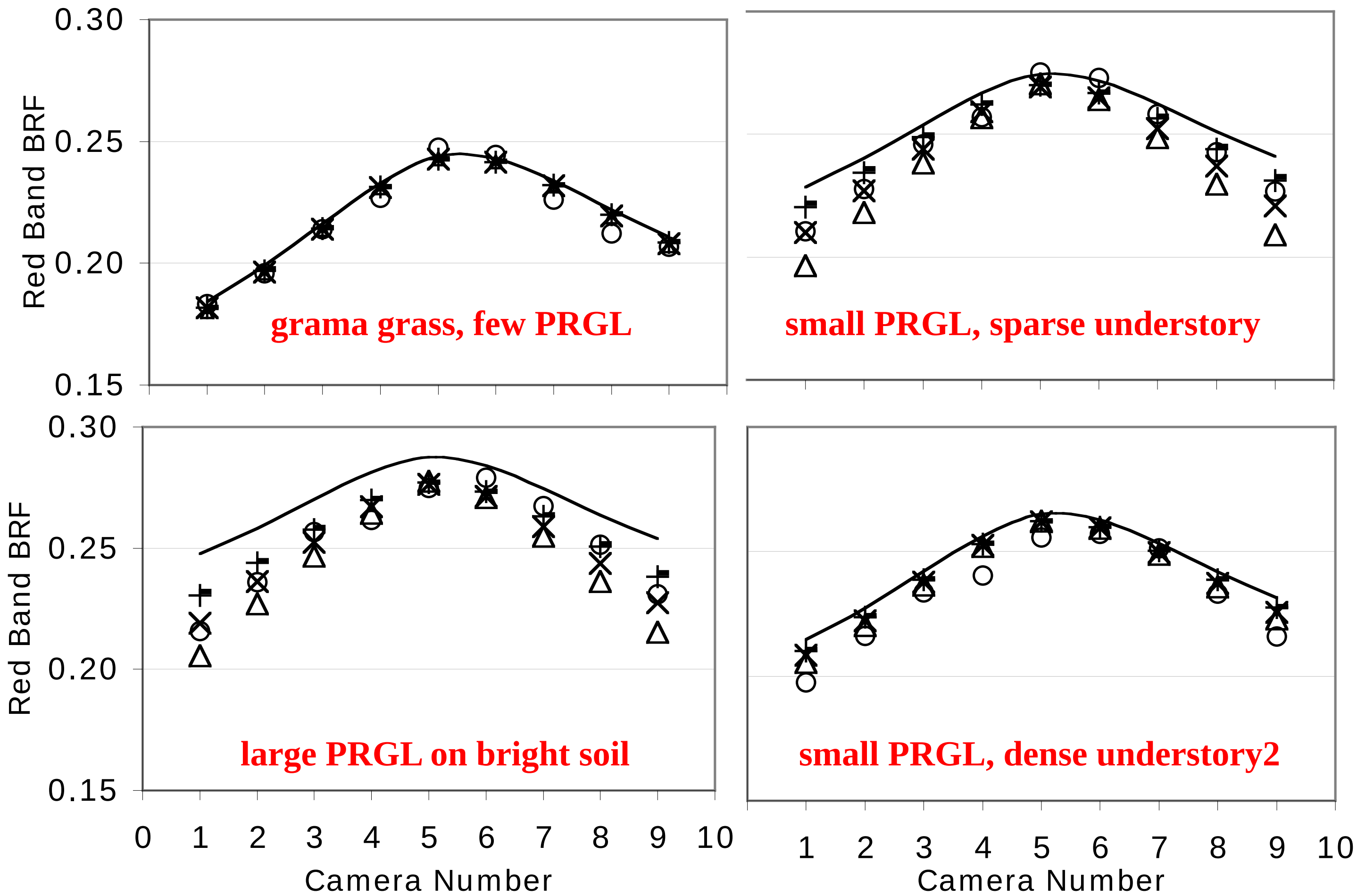
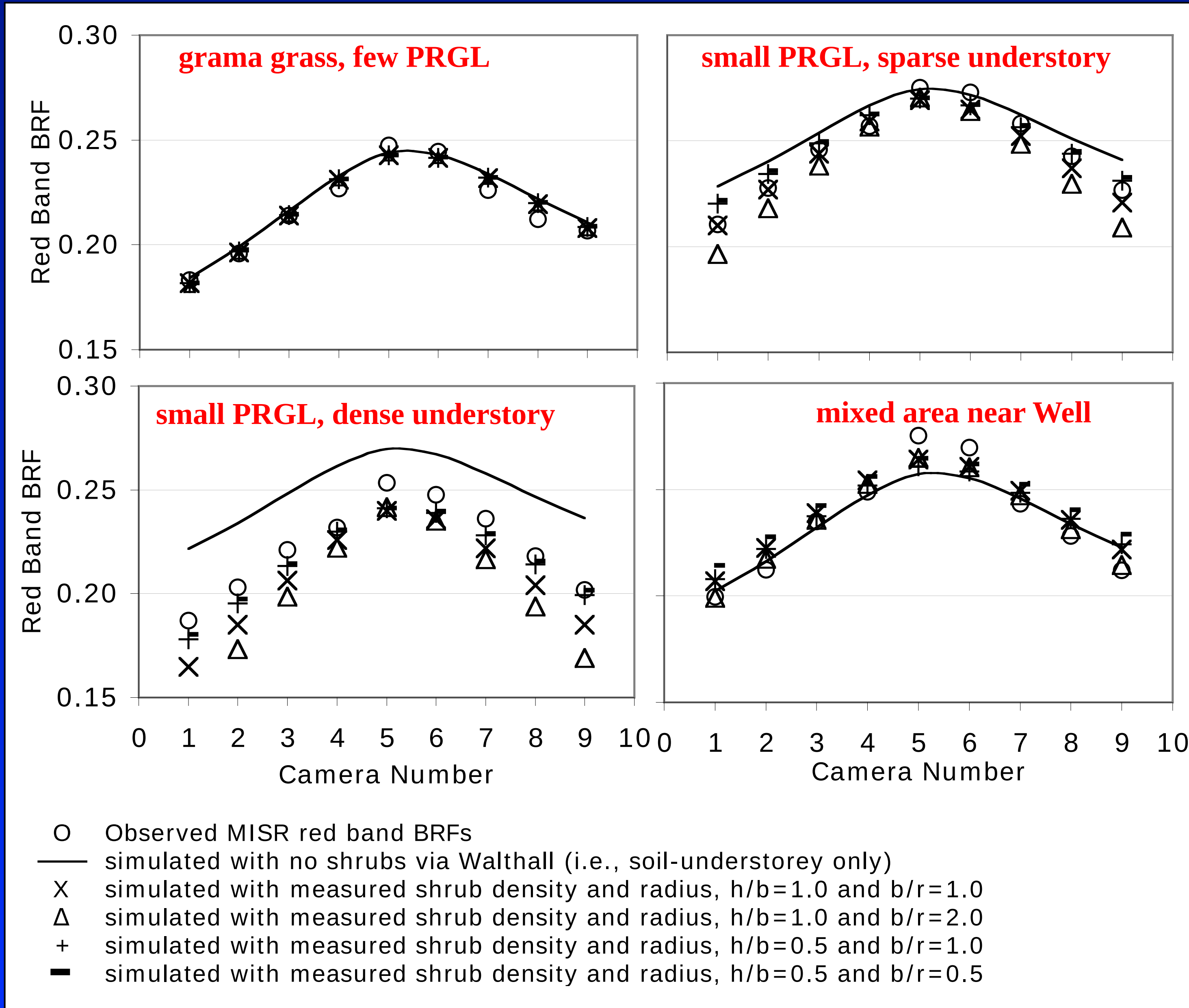
Using MRPV $\rho 0$ as BG predictor



O Observed MISR red band BRFs
— simulated with no shrubs via Walthall (i.e., soil-understorey only)
X simulated with measured shrub density and radius, h/b=1.0 and b/r=1.0
Δ simulated with measured shrub density and radius, h/b=1.0 and b/r=2.0
+ simulated with measured shrub density and radius, h/b=0.5 and b/r=1.0
▬ simulated with measured shrub density and radius, h/b=0.5 and b/r=0.5

Modeled vs. Observed MISR

Using MRPV $\rho 0$ as BG predictor



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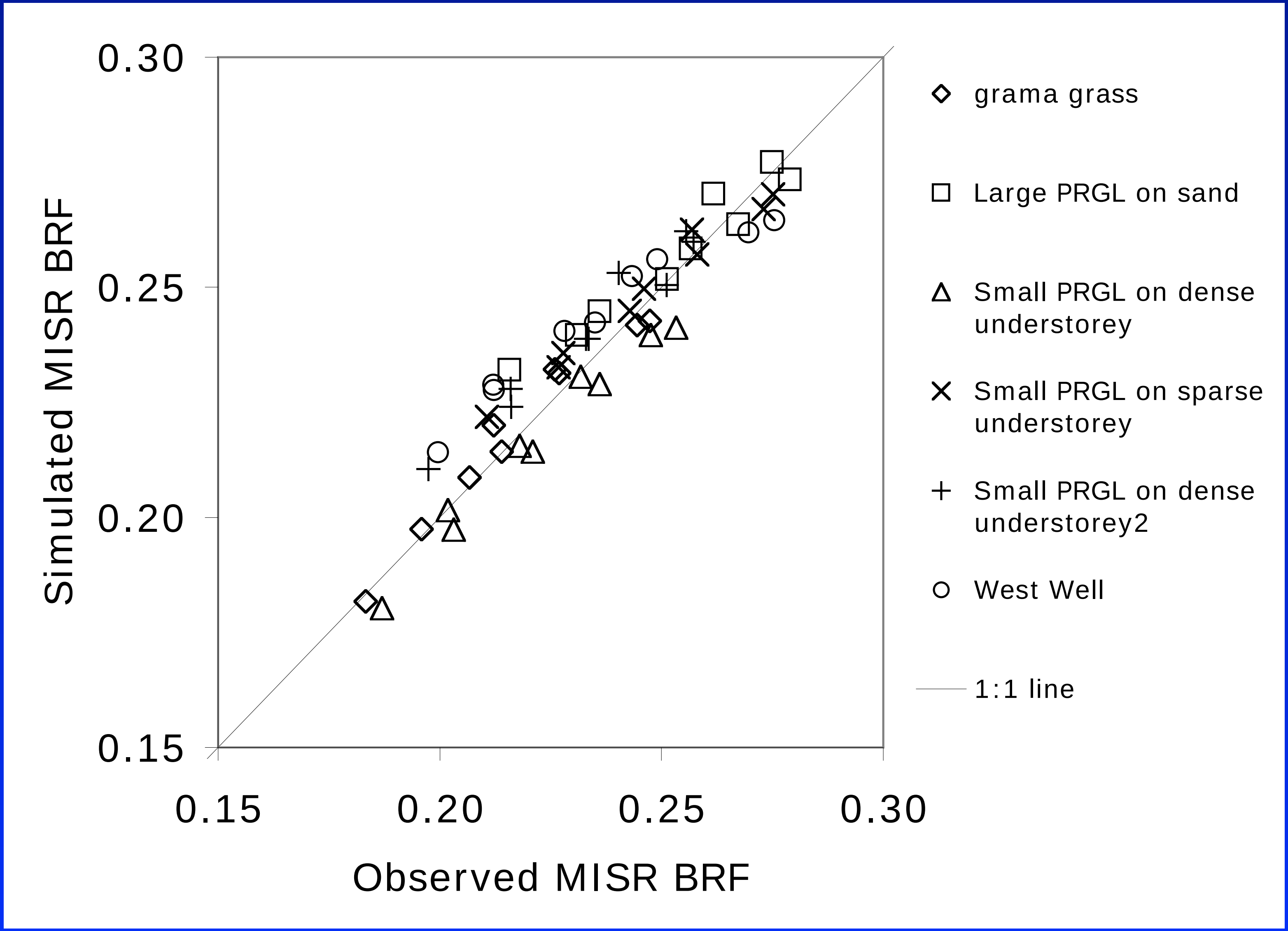
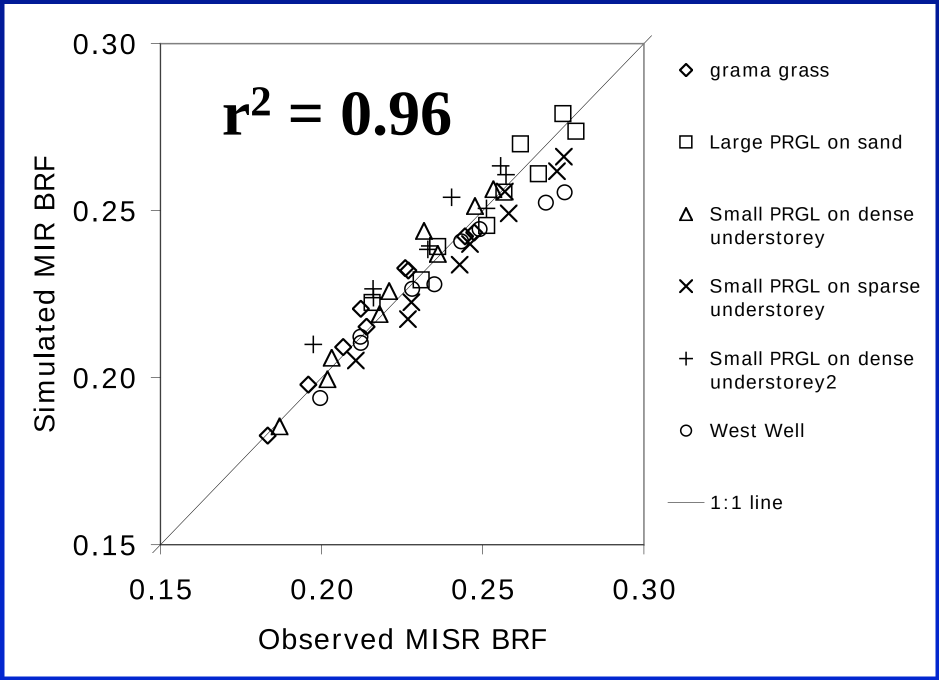
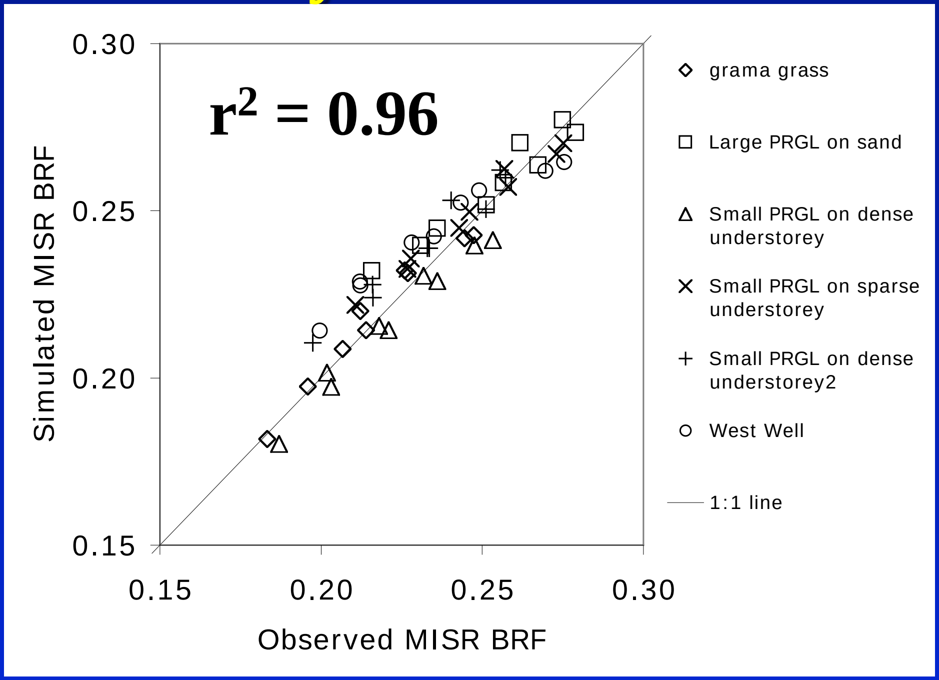
Modeled vs. Observed MISR Red BRFs ($\rho 0$)

Using MRPV $\rho 0$ as BG predictor



Modeled vs. Observed Accuracy is Similar





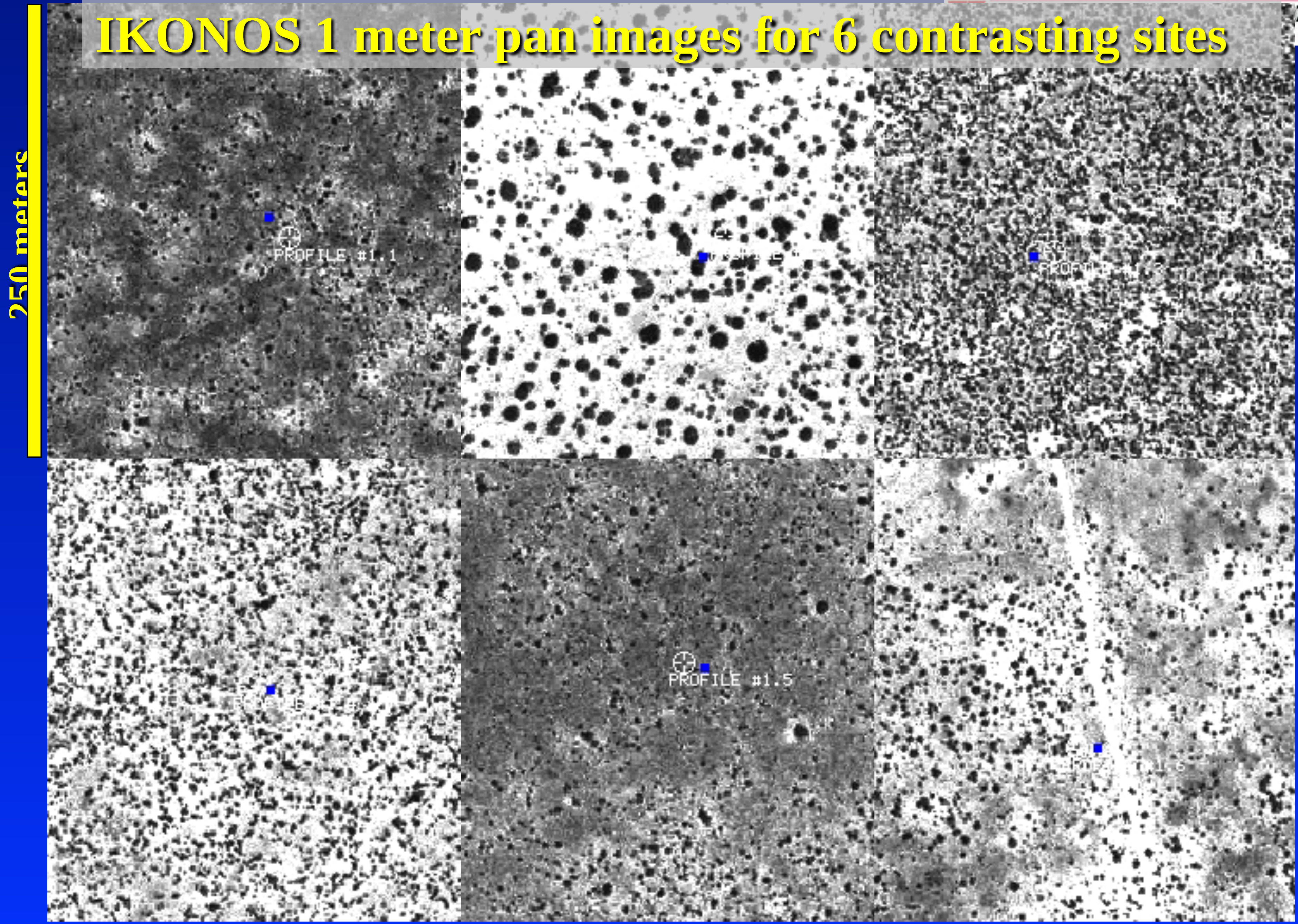
Soil-understory BRDF simulated with the Walthall model driven using <u>volume scattering magnitude</u> from a Li-Ross model, inverted with a MISR data set.

Soil-understory BRDF simulated with the Walthall model driven using <u>$\rho\Theta$ (diffuse brightness)</u> from the MRPV model, inverted with a MISR data set.

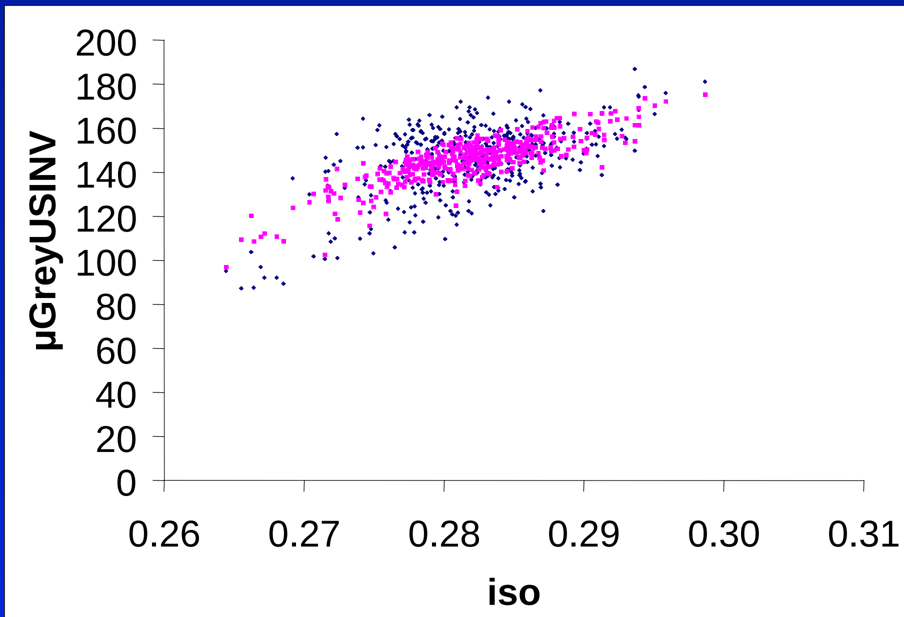
However neither was CORRECT!

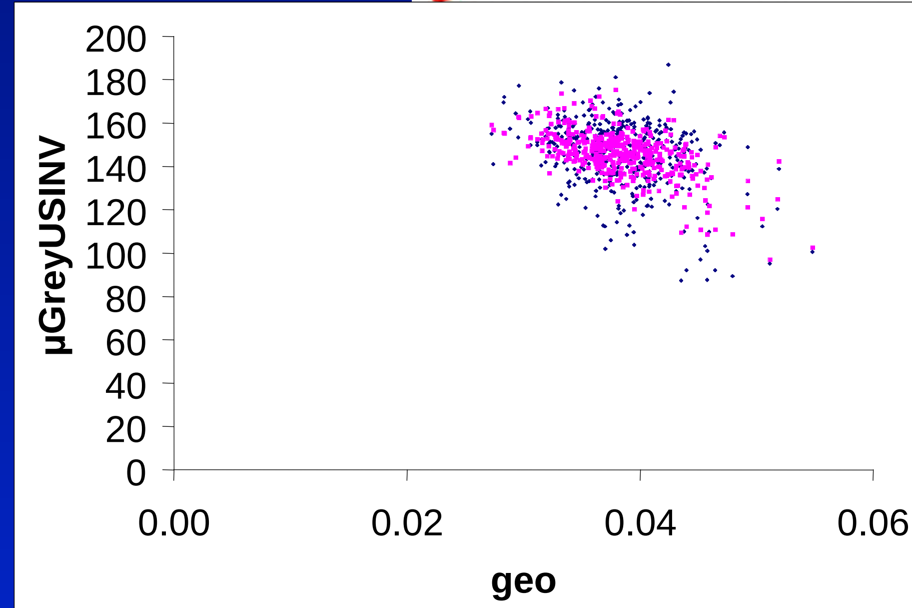
Checking the 'grama grass' site: there are mesquite shrubs! Implication: there is not enough information in a single metric to predict the understory reflectance magnitude and anisotropy with sufficient precision. …so now what?

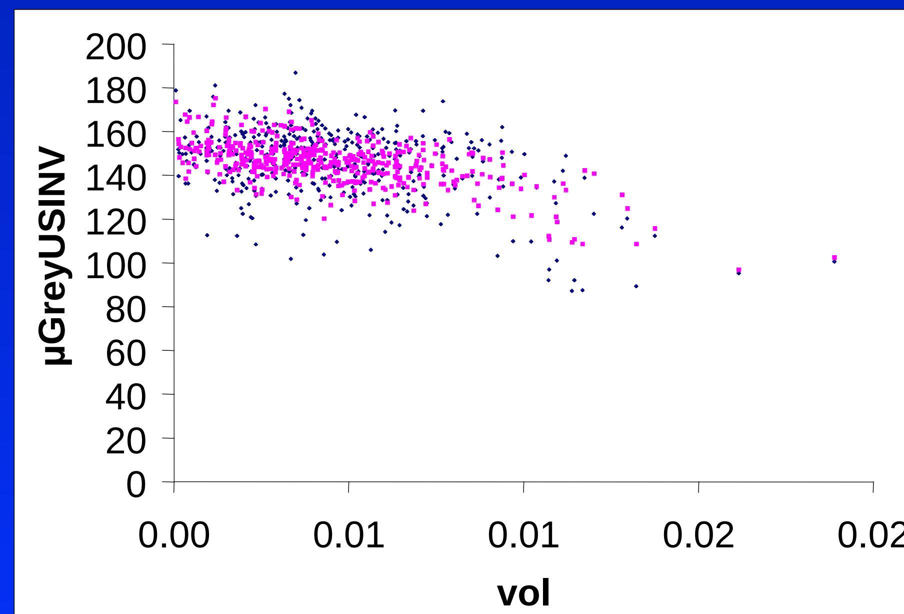
IKONOS 1 meter pan images for 6 contrasting sites



Test *iso, geo, vol* --> understory density

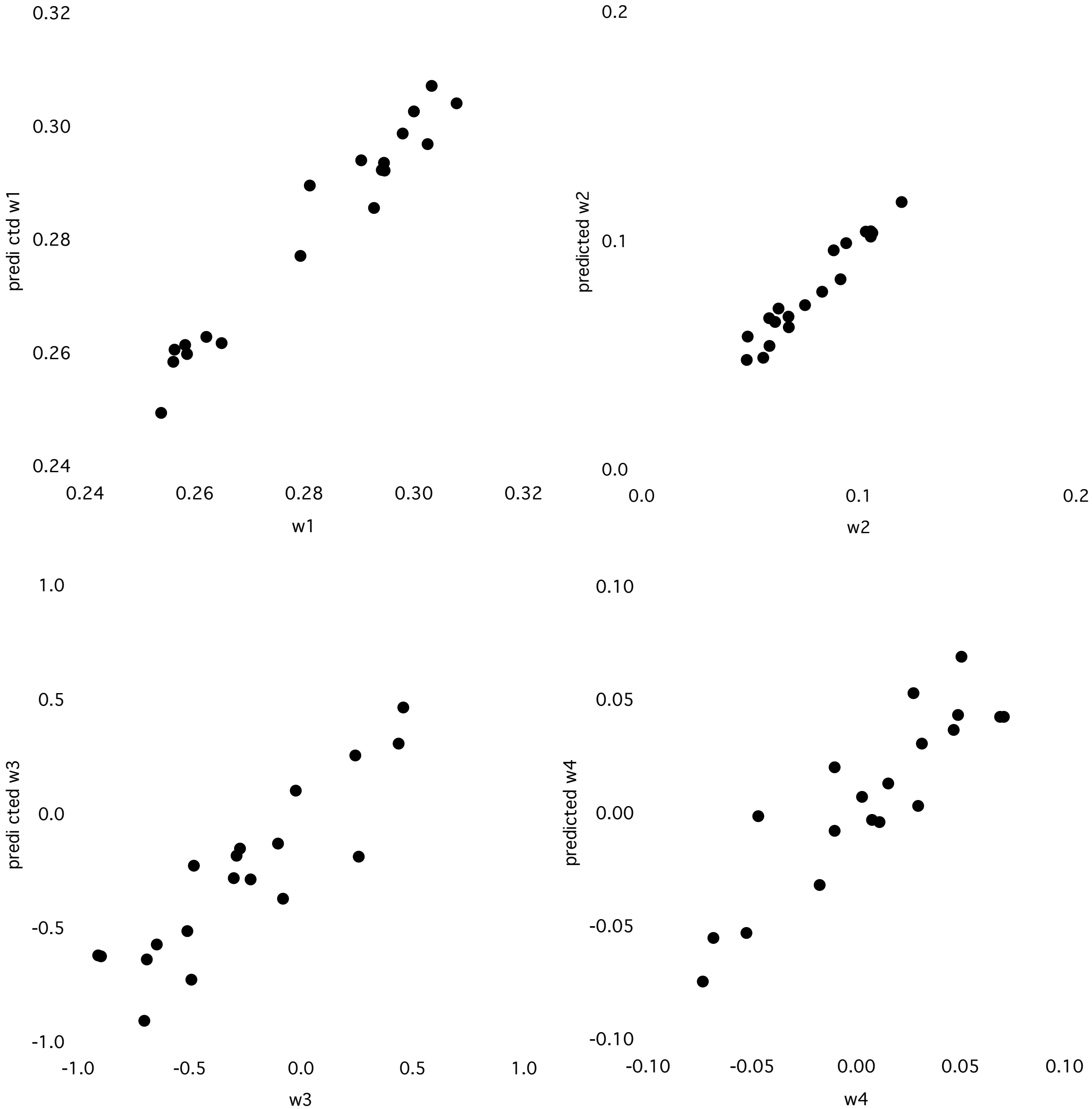






µGreyUSINV = mean IKONOS greyscale for Understory for each mapped 250 m area, excluding shrub polygons.

iso, geo, vol, AnB, AnG, AnNIR --> understory BRDF



	p-value			
	w1	w2	w3	w4
Intercept	0.4	0.0	0.3	0.3
iso_misr	0.3	0.5	1.0	0.9
geo_misr	0.5	0.2	0.7	0.8
vol_misr	0.5	0.4	0.1	0.1
blue	0.5	0.6	0.6	0.5
green	0.2	0.3	0.9	0.9
NIR	0.2	0.4	0.9	1.0

	coefficients			
	w1	w2	w3	w4
Intercept	0.07	0.28	-4.37	0.52
iso_misr	-1.31	1.06	-3.24	-0.55
geo_misr	0.50	1.26	12.56	-0.93
vol_misr	-0.49	-1.01	-67.40	6.85
blue	-1.40	1.43	56.28	-5.83
green	2.02	-2.31	-11.02	0.87
NIR	1.09	-0.92	5.58	-0.03

Bold = two most noteworthy values for each parameter
Red = match between coefficient magnitude and *p*.
Clearly, the volume scattering weight is important in estimating bg BRDF shape.

This is much better:

MISR modeled using Li-Ross model kernel weights *iso*, *geo*, *vol* plus *An* camera blue, green and NIR

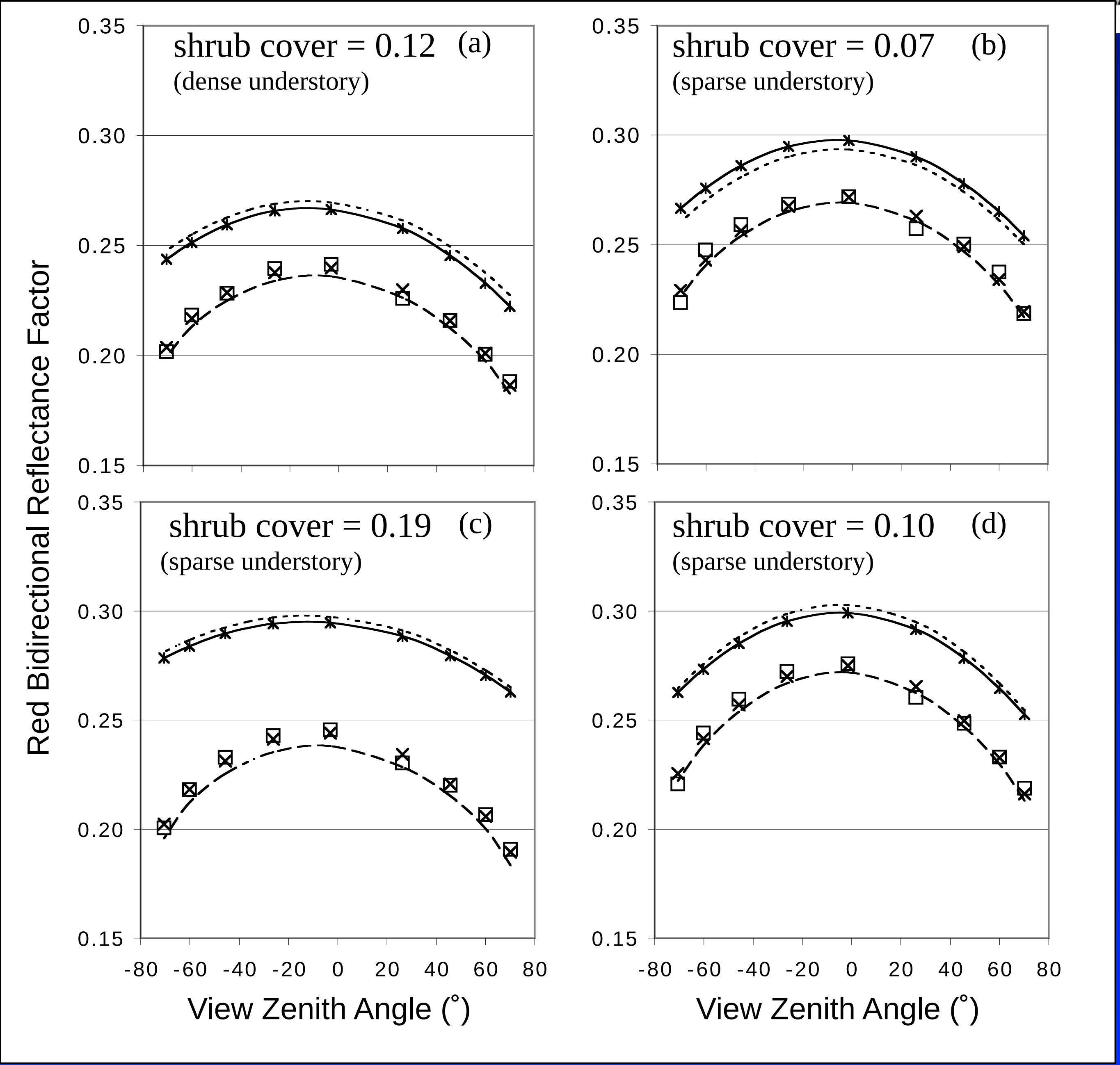
□ MISR

× Model (SGM)

······ optimal B’ Gnd

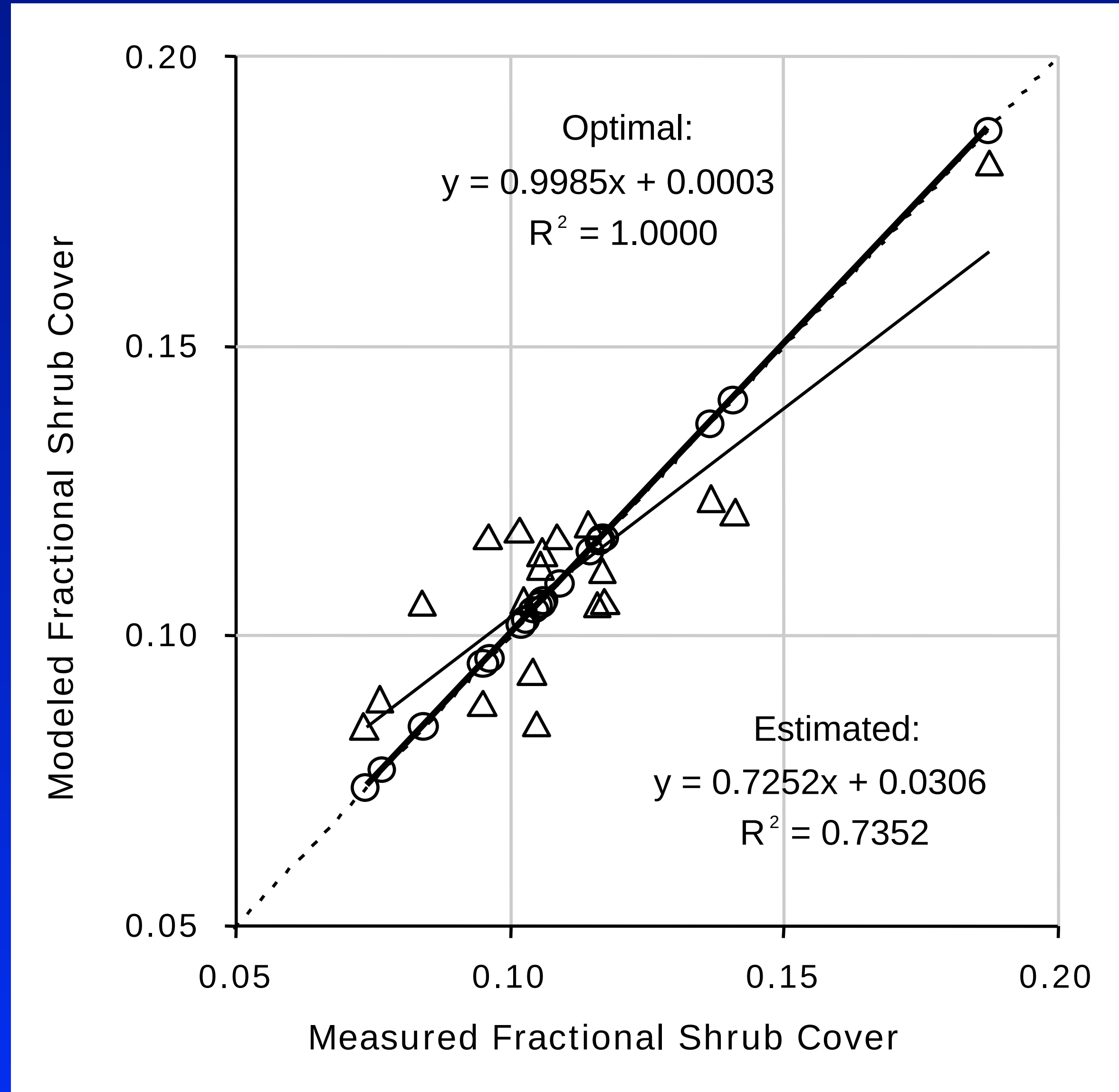
---*--- estimated B’ Gnd

- - - $G.k_G$



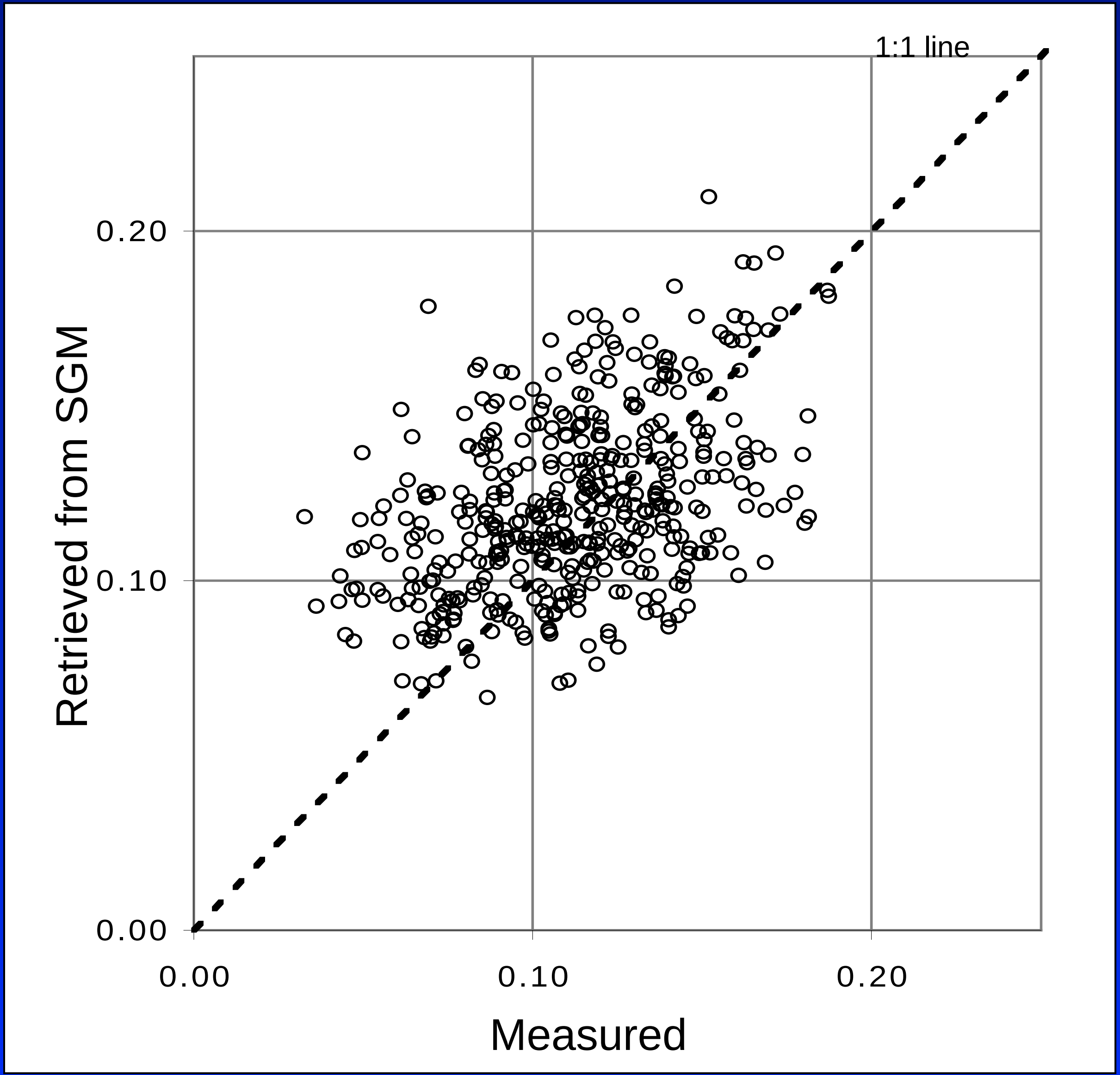
Much better:

Impact of using *estimated* (Δ) over *optimal* (O) background BRDFs for 19 cases covering a wide range of shrub cover/size and understory configurations.



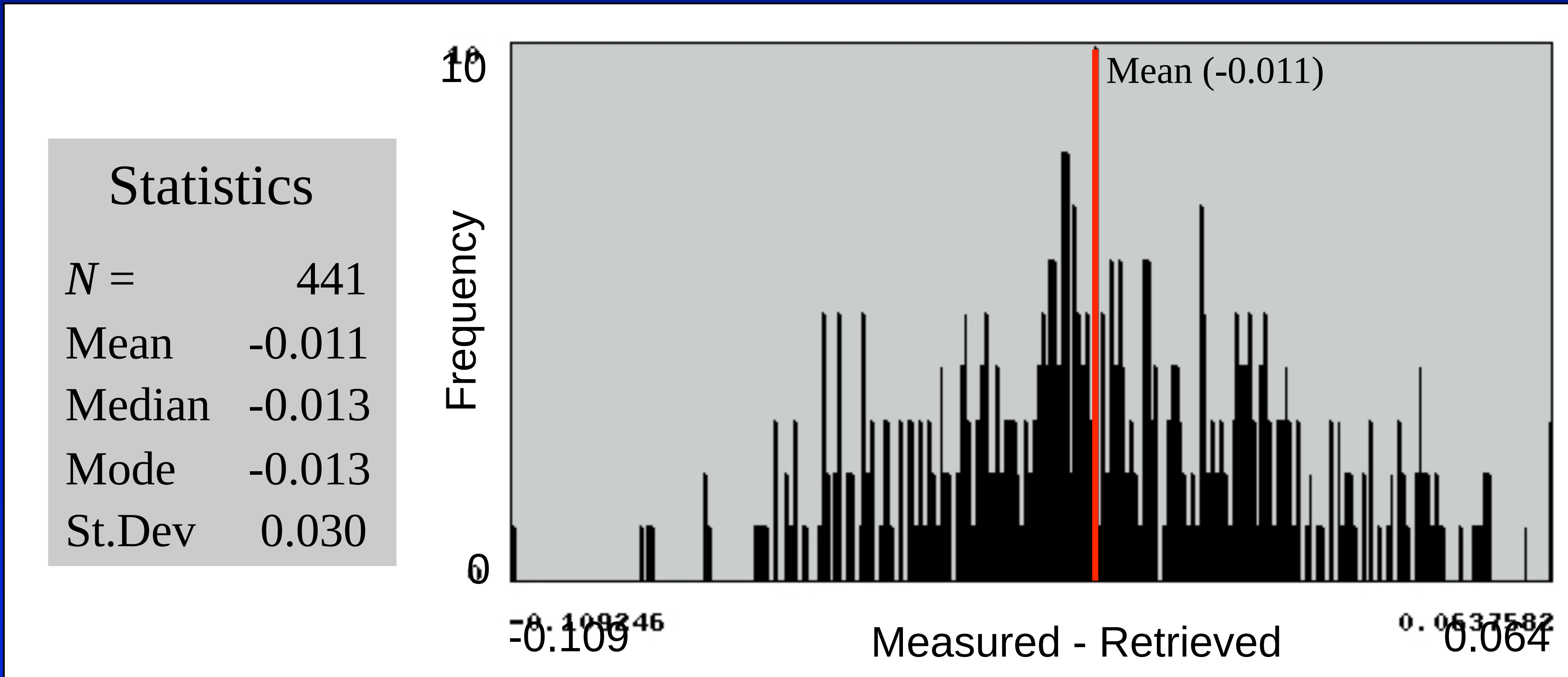
Much better: A rather weak relationship but low absolute error

Retrieved *vs* measured fractional shrub cover for a 21 x 21 x 250 m area in Chihuahuan Desert grassland.



***N* = 441 *RMSE* = 0.03 R^2 = 0.19**

Error Distribution ~ normal:

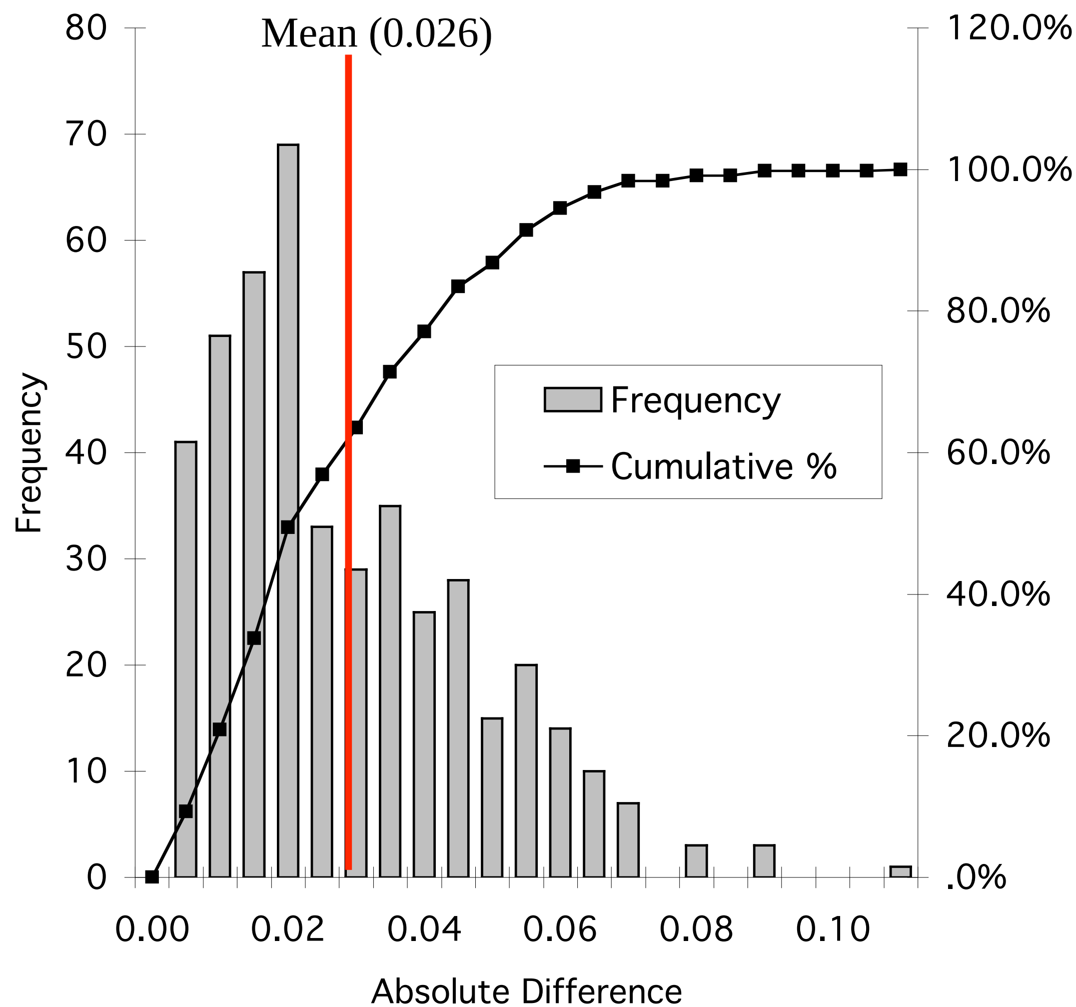


Difference in retrieved *vs* measured fractional shrub cover for a 21 x 21 x 250 m area in Chihuahuan Desert grassland.

Error Distribution: Absolute Difference

Statistics	
N =	441
Mean	0.026
Median	0.020
Mode	0.012
St.Dev	0.019

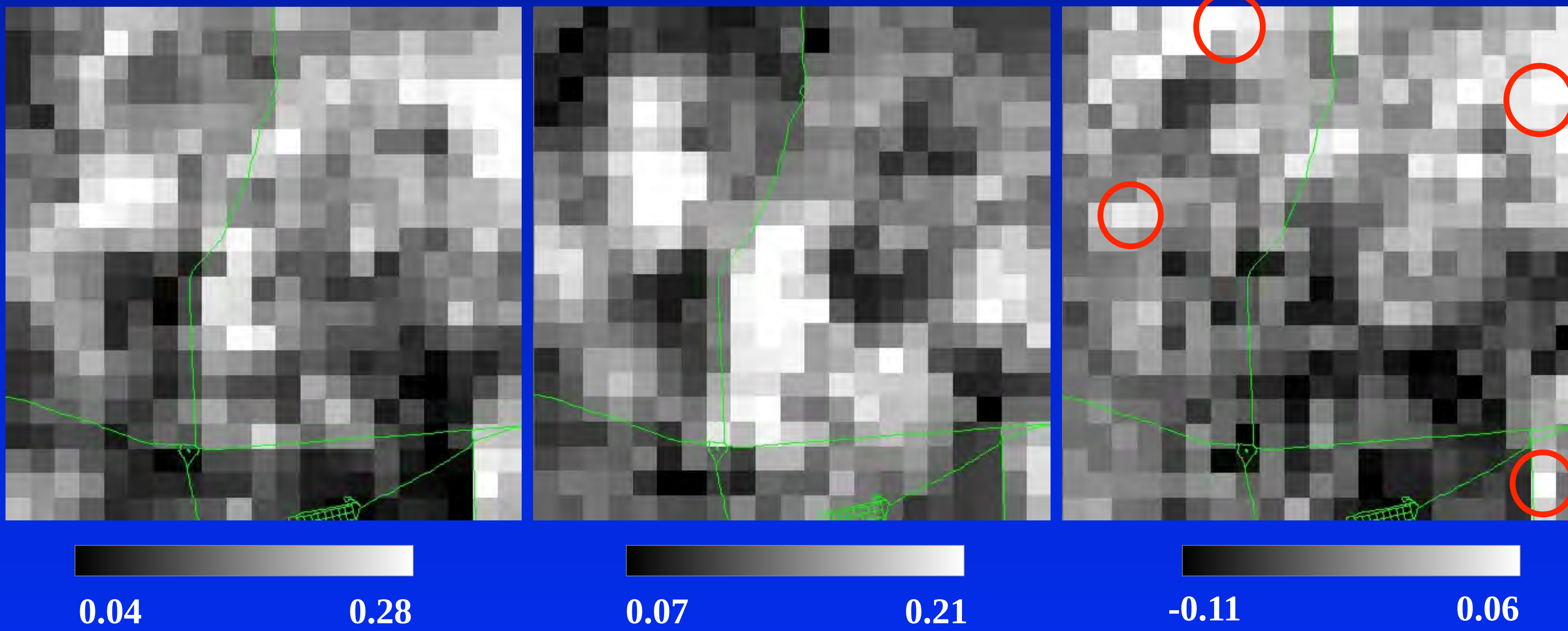
Absolute Difference in retrieved *vs* measured fractional shrub cover for a 21 x 21 x 250 m area in Chihuahuan Desert grassland



What about the spatial match?

Fractional Shrub Cover for a 21 x 21 x 250 m area

Measured | Retrieved | Meas-Ret



The green lines are roads and fences, for orientation

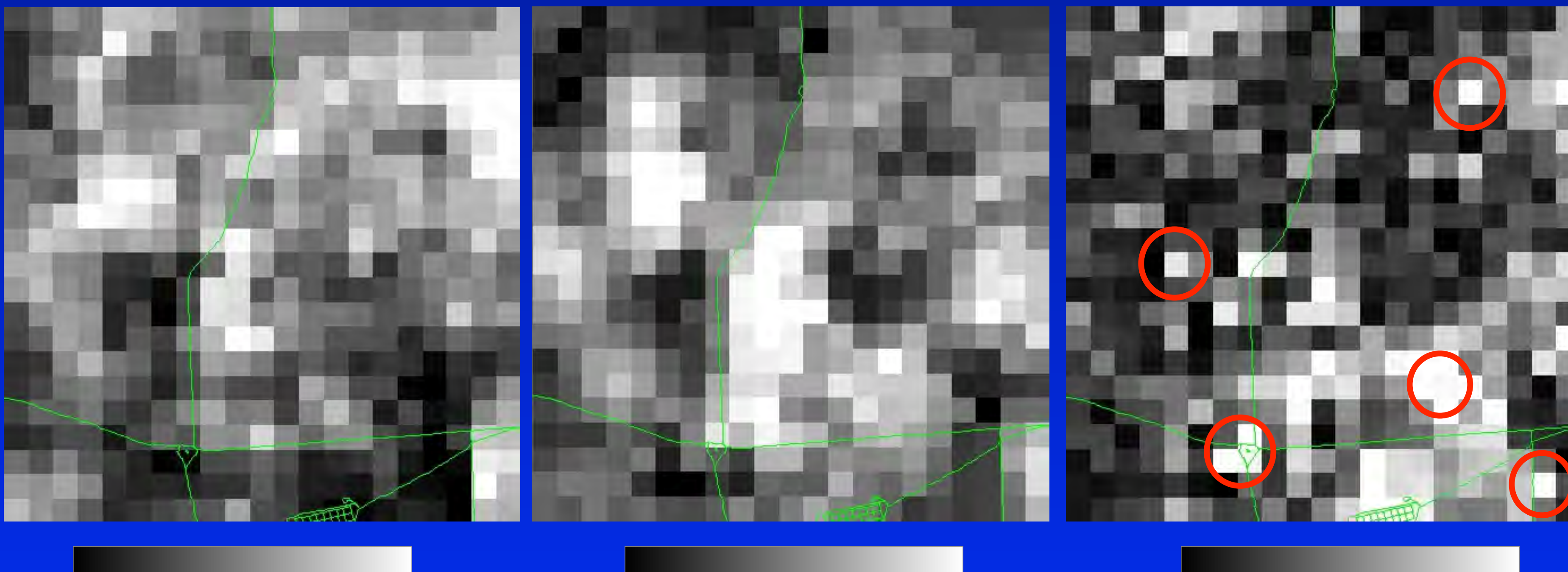
N

1.5 km

What about the spatial match?

Fractional Shrub Cover for a 21 x 21 x 250 m area

Measured | Retrieved | Abs(Meas-Ret)



0.04 0.28 | 0.07 0.21 | 0.00 0.07

The green lines are roads and fences, for orientation

N

1.5 km

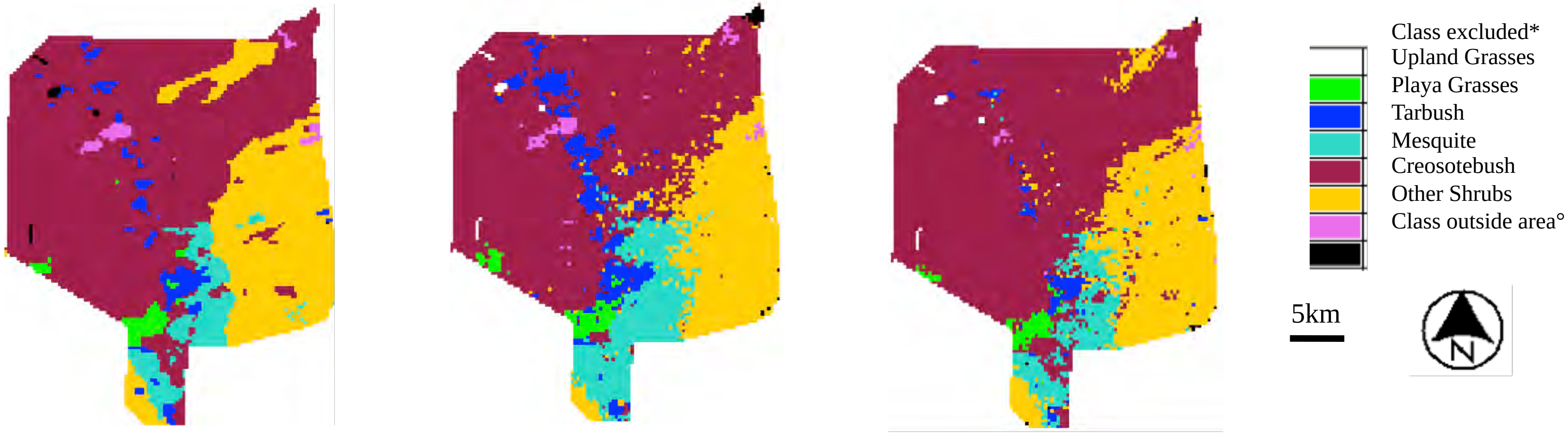
Conclusions

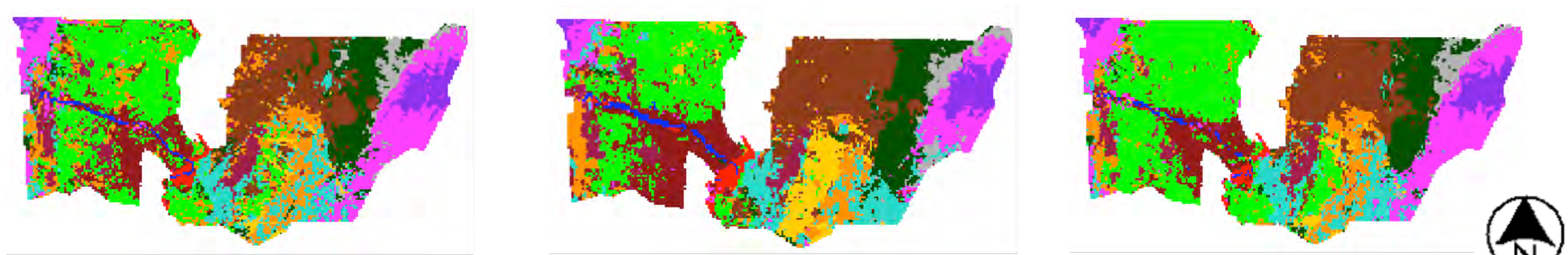
- **GO models can be used for the estimation of shrub cover in desert grasslands.**
- **The accurate understory BRDFs required for application of GO models in desert environments can be obtained by multiple regression on the *iso*, *geo*, and *vol* kernel weights from a Li-Ross model adjusted against MISR data + spectral BRFs**
- **MISR's stable angular sampling is useful in obtaining stable retrievals of the *vol* kernel weight that is needed to obtain the BG BRDF.**

Questions?

Community Type Mapping with MISR and SVM

Vegetation Map | Max. Like. | SVM





Using multi-angle data raises the classification accuracy from 45.4% for nadir observations to 60.9%, and with surface anisotropy patterns derived from MRPV and RossThick-LiSparse-Reciprocal BRDF models an overall accuracy of 67.5% can be obtained when maximum likelihood algorithms are used. Using the non-parametric SVM algorithms we can raise the classification accuracy to 76.7%.