NASA Earth Observing System (EOS)

Quantifying Changes in Carbon Pools with Shrub Invasion of Desert Grasslands using Multi-Angular Data from EOS Terra and Aqua

— preliminary results —
Carbon Pools in Desert Grasslands from EOS

— project start July 2004 —

— people —

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Carbon Pools in Desert Grasslands from EOS

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Data sets were provided by NASA EOS/EOSDIS/LaRC; NSF (grants DEB-0080412 and DEB-94-11971 to the Jornada Basin and Sevilleta NWR LTERs, respectively); and the USDA, Agricultural Research Service, Jornada Experimental Range.
Goal: To improve estimates of above- and belowground C pools in desert grasslands by providing improved maps of:

- plant community type (Kremer & Running, 1993\(^1\))
- canopy structural parameters
- soil/shrub/grass fractional cover

Method: exploit unique information content of multiangle remotely-sensed data from MISR & MODIS on NASA EOS satellites.

\(^1\) See references on later slide.
why?

1. World-wide increase in woody plant abundance in grasslands since C19th, e.g. the SW US --> changes in C pools and cycling.

2. Our ability to model biogeochemical processes depends on knowledge of cover and community type (+ other parameters).

3. Moderate resolution Earth Observation is the only technology which provides a means to map changes in community type and structure over large areas.
study area

Sevilleta National Wildlife Refuge

Jornada Experimental Range
community types

The physical structure of plant communities is very different

Sacaton grasslands (SNWR)

Creosotebush shrublands (SNWR)
community types

The physical structure of plant communities is very different

Black grama grasslands (SNWR)

Pinyon pine stands (SNWR)
community types

The physical structure of plant communities is very different

Black grama grasslands (JER)

Honey mesquite dunes (JER)
community types

The physical structure of plant communities is very different

Black grama grasslands (SNWR)

Creosotebush shrublands (JER)
community types

The physical structure of plant communities is very different.

Tarbush Shrubland (JER)

Broom snakeweed (JER)
community types

The physical structure of communities is very different (also spectral differences)

Tobosa grasslands (JER)

Annuals (JER)
Work with the AVHRRs (AM+PM)...

Iso-Geo-Vol FCC: LiSparse-RossThin kernel weights from AVHRR VIS BAND ONLY. The unique information content of multi-angular imagery is important.

Kernel weights from BRDF model fitting using just the VISIBLE AVHRR channel
work with the AVHRRs...

Experiments in NM and Inner Mongolia grasslands\(^2\) show there is great potential for exploiting the angular signal to map plant communities, *cf.* Pinty *et al.* 2002\(^3\) & many others.
Remote Sensing Approaches

• **Kernel-driven and MPRV BRDF model inversions (both 3-parameter models)**

• **Geometric-optical models (GO) and derived models; e.g. GORT, SGM, FLAIR**

• **Empirical & derived measures: ANIX (anisotropy index); NDAX (surrogate for spectral variability of BRDF); Structural Scattering Index (Gao *et al.* 2003⁴); Clumping Index (Chen *et al.*, 2003⁵).**
Current Work with MISR & MODIS

**MISR Product:** Level 1B2 Terrain Data (MI1B2T) at 275 m: red for all cameras and all bands for the An camera.

**MODIS Product:** MOD09 (nadir & off-nadir surface reflectance estimates at 250 m).

**Bounding coordinates:**
-105.5 to -111.0 degrees W
  31.2 to 35.0 degrees N

**Dates:**
May 15 - June 15, 2002 (end of dry season).
Current Work with MISR & MODIS

HDF-EOS MODIS Observations
(MOD09 -- 250 m ISIN)

HDF-EOS MODIS Angles
(MODPTQKM -- 1,000 m ISIN)

HDF-EOS MODIS QC
(MODGST -- 1,000 m ISIN)

HDF-EOS MISR Observations
(MI1B2T, includes QC -- 275 m)

HDF-EOS MISR Angles
(GEOM -- 17,600 m)

HDF-EOS MISR Cloud Mask
(RCCM -- 1,100 m)

HDF-EOS MISR Aerosols
(17,600 m)

Screened surface bi-directional reflectance estimates accumulated over a 9-day period. Max. # observations possible for RED wavelength = 27 (9 x MODIS/Terra + 9 x MISR and eventually + 9 from MODIS/Aqua). …plus other MISR channels at nadir.

GORT/SGM/ other non-linear model

MRPV, Li-Ross, ANIX, NDAX

Physical Structure
(FVC, radius/height, gap, fiPAR, LAI)

(semi-)Empirical Surface Metrics (iso, geo, vol; p₀,k,b; ANIX)

1st level classification
(Community Types [on soils])

2nd level classification
(condition)

Comm.Type subdivisions

BGC model --> C Pools
MISR & MODIS: “9x9” Processing

HDF-EOS MODIS Observations (MOD09-- 250 m ISIN)

HDF-EOS MODIS Angles (MODPTQKM -- 1,000 m ISIN)

HDF-EOS MODIS QC (MODGST -- 1,000 m ISIN)

HDF-EOS MISR Observations (MI1B2T, includes QC -- 275 m)

HDF-EOS MISR Cloud Mask (RCCM -- 1,100 m)

HDF-EOS MISR Aerosols (17,600 m)

HDF-EOS MISR Angles (GEOM -- 17,600 m)

HDF ==> TOA radiance, mask for cloud (IDL: SOM ==> UTM)

Estimate surface reflectance from TOA radiance (IDL/C/6S)

Merge the observations from the 9 cameras for one orbit (IDL)

Combine MISR and MODIS data for each 9-day period

HDF ==> TOA radiance for working region (ISIN ==> UTM w/MODIS Reprojection Tool)

Collate observations, angles, and screen by QC on an orbit (IDL)

Accumulate observations from multiple orbits (9 day cycles) (IDL)
MISR & MODIS: “9x9” Data

Angular sampling in June 2002 (9 days)

* MISR
Δ MODIS (Terra)
☀ Sun
MISR/MRPV $p_0$ and AOD (Orbit 013039)
LiSparse-RossThin model kernel weights

Weight of Determination --

MISR isotropic

MODIS isotropic

0.35 - 0.86

0.31 - 0.65
Weight of Determination -->

LiSparse-RossThin model kernel weights

MISR geometric
MODIS geometric

MODIS geometric
LiSparse-RossThin model kernel weights

Weight of Determination --

MISR volume

MODIS volume
LiSparse-RossThin model kernel weights

MISR+MODIS iso

MISR+MODIS geo

MISR+MODIS vol

December 8, 2004

C Pools from EOS MISR & MODIS
Community Type Mapping

Jornada and Sevilleta Vegetation Maps were used to collect “signatures” from these data:

1. An camera multi-spectral (blue, green, red, NIR)
2. MRPV BRDF model parameters*
3. LiSparse-RossThin BRDF model parameters*

* Adjusted against MISR, MODIS and MISR+MODIS BRF data sets.
Community Type Mapping

Jornada Vegetation Map (Jornada LTER)

In 1998 aerial photography and field data were combined to create a current vegetation map of species composition and dominant species, including major plant communities. Using 1996 aerial photos, up to four major dominant species were estimated for each vegetation type.
Community Type Mapping

Sevilleta NWR Vegetation Map (SNWR LTER)

The map includes 13 vegetation classes derived from an unsupervised classification of 12 Landsat TM images (NDVI transformed) collected in various seasons over a seven year period from 1987. A plant classification at the association level was developed from which the initial 32 images classes were combined into the final 13 classes.
MISR/MPRV parameters

MISR_MRPV p0, b, k
Sevilleta National Wildlife Refuge
MISR/MRPV parameters

MISR/MRPV b parameter: Sevilleta National Wildlife Refuge

Breaks (N.B. colors are not matched but distributions are similar).

December 8, 2004

C Pools from EOS MISR & MODIS
MISR/MRPV parameters

MISR_MRPV p0, b, k
Jornada Experimental Range
## Examples of Separability Analysis

**Distance Measure:** Transformed Divergence

Using Layers: 1 2 3

Taken 3 at a time

Best Average Separability: 1725.32

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<td>1924</td>
<td>1902</td>
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MODIS iso, geo, vol

**OTD<1000**
### Examples of Separability Analysis

**Distance Measure:** Transformed Divergence

**Using Layers:** 1 2 3

**Taken 3 of c-time**

**Best Average Separability:** 1867.11

**Combination:** 1 2 3

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### Examples of Separability Analysis

**Distance Measure:** Transformed Divergence  
**Using Layers:** 1 2 3  
**TD < 1000**

#### Signature Name

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Examples of Separability Analysis

Distance Measure: Transformed Divergence

Using Layers: 1 2 3
Taken 1 at a time
Best Average Separability: 1743.71
Combination: 1 2 3

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Examples of Separability Analysis

Distance Measure: Transformed Divergence
Using Layers: 1 2 3
Taken 3 at a time
Best Average Separability: 1624.2
Combination: 1 2 3

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Examples of Separability Analysis

Distance Measure: Transformed Divergence
Using Layers: 1 2 3 4 5 6 7
Taken 7 at a time
Best Average Separability: 1973.94
Combination: 1 2 3 4 5 6 7

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MISR MRPV_{\text{red}}+AN_{\text{RGBNIR}} \quad OTD<1000
Bivariate Distribution PDFs

LiSparse-RossThin Anisotropic Kernel Weights (MISR)
Bivariate Distribution PDFs

MISR An Camera Red and NIR BRFs

- jer_blackgrama
- jer_burrograss
- jer_transition
- jer_sporobolis
- jer_tobosa
- jer_othershrubs
- jer_tarbush
- jer_creosote
- jer_mesquite_dunes
- sev_creosote_W
- sev_creosote_E
- sev_blueNhaired
- sev_4wingNdalea
- sev_blackNgalleta
- sev_blackgrama
- sev_barren
- sev_grasscreomix
- sev_blackNblue
- sev_GalletaNIndian
Bivariate Distribution PDFs

LiSparse-RossThin Anisotropic Kernel Weights (MODIS)
Bivariate Distribution PDFs

LiSparse-RossThin Anisotropic Kernel Weights (MISR+MODIS)
Bivariate Distribution PDFs

LiSparse-RossThin Anisotropic Kernel Weights (MISR)

---
jer_blackgrama
jer_burrograss
jer_transition
jer_sporobolis
jer_tobosa
jer_othershrubs
jer_tarbush
jer_creosote
jer_mesquite_dunes
sev_creosote_W
sev_creosote_E
sev_blueNhairy
sev_4wingNdalea
sev_blackNgalleta
sev_blackgrama
sev_barren
sev_grasscreomix
sev_blackNblue
sev_GalletaNlndian
Bivariate Distribution of MRPV k and b

MRPV k and b Parameters (MISR)

- jer_blackgrama
- jer_burrograss
- jer_transition
- jer_sporobolus
- jer_tobosa
- jer_othershrubs
- jer_tarbush
- jer_creosote
- jer_mesquite_dunes
- sev_cresosote_W
- sev_cresosote_E
- sev_blueNhairy
- sev_4wingNdalea
- sev_blackNgalleta
- sev_blackgrama
- sev_grasscreomix
- sev_blackNblue
- sev_GalletaNIndian
CLASSIFICATION TESTS

We have just started to look at classifications:
- maximum likelihood
- no prior probabilities
- angular and spectral data
maps: JER

Contingency: MISR An-spectral
maps: JER

Contingency: MRPV (MISR red band)
maps: JER

Contingency: MRPV_MISR_red band + An_all_bands
maps: JER

Contingency: MISR
(isogeovol, red band)
maps: JER

Contingency: MODIS
(isogeolvol, red band)
CONCLUSIONS

Multi-angular “signatures” from BRDF modeling show great potential. The angular sampling of MISR will add consistency to the mix ...but (much) more work is needed; we have only just started.
Plans for Work in Immediate Future:

- Check the consistency of the input data: 1. Calibration 2. Surface BRF retrieval 3. Screening for cloud and cloud shadow. Our (averaged) 275m Red BRFs are > 1100m for all cameras, while our green, blue and NIR 275m BRFs for the An camera are < 1100m ones.
- Extend temporal sampling (end of wet season)
- Classification 1. Find comprehensive set of classes 2. incorporate soil information 3. hard/soft/ANNs?
- Seek solutions to the background modeling problem for GO modeling.
Questions?
References


Also...
We have been investigating the potential for using a model based on geometric-optics (GO) to retrieve information on shrub cover, density, size and shape. Principles:
How does a GO model respond to very heterogeneous canopies?  
-- are GO principles violated in this case?  
-- do GO models operate on mean parameter values?
Can GO models work for very heterogeneous canopies which have a highly variable and bright understorey?
Can GO models work for very heterogeneous canopies which have a highly variable and bright understorey, on different soils?
GO models have been demonstrated as useful tools for forested environments but are more challenging in arid environments: here, the magnitude and anisotropy of the remotely-sensed signal is dominated by the "background" comprised of varying proportions of exposed soil, grasses, litter and forbs.

How to obtain the background BRDF in order to isolate the effects of the larger canopy elements? We are investigating ways…
Summary of Activities: Milestones & Preliminary Results (Chopping/Su)
MISR Camera Registration -- Visual Comparison