NASA Earth Observing System

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

— introduction and 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

Acknowledgment: This work is supported by NASA grant NNG04GK91G to EOS project EOS/03-0183-0465 under EOS/LCLUC, (program manager: Dr. Garik Gutman).

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.
overview

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 the unique information content of multi-angle remotely-sensed data from MISR and 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)

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 the 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
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.

New Mexico
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. 2003\textsuperscript{4}); Clumping Index (Chen et al., 2003\textsuperscript{5}).

* discussed today.
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**
  - M1B2T, 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)

**Processing**

- 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])

- **Comm.Type subdivisions**

- **BGC model --> C Pools**

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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 ==> TOC reflectance 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)

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
MISR & MODIS: “9x9” Data- complementarity

Angular sampling in June 2002 (9 days)

* MISR

Δ MODIS (Terra)

★ Sun

azimuth
MISR/MRPV $\rho_0$ and AOD (Orbit 013039)

* if MISR data are missing, the AOD defaults to ~0.2 (~16 km visibility)
LiSparse-RossThin model kernel weights

Weight of Determination:

MISR isotropic

MODIS isotropic

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LiSparse-RossThin model kernel weights

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MISR volume

MODIS volume

Weight of Determination --

0.28 - 1.00

0.47 - 1.17
LiSparse-RossThin model kernel weights

MISR+MODIS iso  
MISR+MODIS geo  
MISR+MODIS vol

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Our work with MODIS shows that we have some further work to do on cloud and cloud-shadow screening.

Note that the artefacts are only apparent in anisotropic kernel weight images.
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/MRPV parameters

$\rho_0$ (magnitude)

$b$ (fwd or back)

$k$ (bell or bowl)

MISR_MRPV $\rho_0$, $b$, $k$, 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).

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MISR/MRPV parameters

\( \rho_0 \) (magnitude)

\( b \) (fwd or back)

\( k \) (bell or bowl)

MISR_MRPV \( \rho_0 \), \( b \), \( k \)
Jornada Experimental Range

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Separability Analysis -- class pairs

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January 11, 2005
Separability Analysis -- class pairs

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Unit Average Separability: 1867.11

MISR iso, geo, vol

OTD<1000
Separability Analysis -- class pairs

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OTD < 1000
Separability Analysis -- class pairs

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Distance Measure: Transformed Divergence
Using Layers: 1, 2
Threshold: 1.0
Average Separability: 1.6371

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January 11, 2005
Separability Analysis -- class pairs

| Signature Name | 1   | 2   | 3   | 4   | 5   | 6   | 7   | 8   | 9   | 10  | 11  | 12  | 13  | 14  | 15  | 16  | 17  | 18  | 19  | 20  | 21  |
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Best Average Separability: 1624.2

MODIS MRPV

OTD < 1000

January 11, 2005
Separability Analysis -- class pairs

MODIS+MISR MRPV

OTD<1000
Separability Analysis -- class pairs

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<th>Column 12</th>
<th>Column 13</th>
<th>Column 14</th>
<th>Column 15</th>
<th>Column 16</th>
<th>Column 17</th>
<th>Column 18</th>
</tr>
</thead>
<tbody>
<tr>
<td>MISR MRPV$<em>{red}$+AN$</em>{RGBNIR}$</td>
<td>1973</td>
<td>OTD&lt;1000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## Separability Analysis -- class pairs

### MISR AN (R, G, B, NIR)

<table>
<thead>
<tr>
<th>Class</th>
<th>R</th>
<th>G</th>
<th>B</th>
<th>NIR</th>
<th>TD</th>
<th>OTD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1932</td>
<td>1932</td>
<td>1932</td>
<td>1932</td>
<td>1932</td>
<td>1932</td>
<td>1932</td>
</tr>
</tbody>
</table>

**First Average Separability:** 1932

**Total Distance:** <1000
### Separability Analysis Summary (RED BAND ONLY)

<table>
<thead>
<tr>
<th>Data Set</th>
<th>Mean TD*</th>
<th># TD&lt;1000</th>
</tr>
</thead>
<tbody>
<tr>
<td>MISR MRPV&lt;sub&gt;red&lt;/sub&gt; + AN&lt;sub&gt;RGBNIR&lt;/sub&gt;</td>
<td>1973</td>
<td>0</td>
</tr>
<tr>
<td>MISR AN (R, G, B, NIR)</td>
<td>1932</td>
<td>1</td>
</tr>
<tr>
<td>MISR iso, geo, vol</td>
<td>1867</td>
<td>7</td>
</tr>
<tr>
<td>MISR+MODIS iso, geo, vol</td>
<td>1839</td>
<td>8</td>
</tr>
<tr>
<td>MISR MRPV</td>
<td>1744</td>
<td>13</td>
</tr>
<tr>
<td>MODIS iso, geo, vol</td>
<td>1723</td>
<td>13</td>
</tr>
<tr>
<td>MODIS+MISR MRPV</td>
<td>1653</td>
<td>17</td>
</tr>
<tr>
<td>MODIS MRPV</td>
<td>1624</td>
<td>29</td>
</tr>
</tbody>
</table>

* *transformed divergence*

January 11, 2005
Bivariate Distribution PDFs

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

MISR An Camera Red and NIR BRFs
Bivariate Distribution PDFs

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

LiSparse-RossThin Anisotropic Kernel Weights (MISR+MODIS)

[Graph showing bivariate distribution PDFs for various species.]
Bivariate Distribution PDFs

LiSparse-RossThin Anisotropic Kernel Weights (MISR)
Bivariate Distribution of MRPV k and b
Contingency tests

The separability and PDF results are confirmed in contingency tests (classifications of the training sites)

--maximum likelihood

--no prior probabilities

--angular signatures via red bands only

--spectral data (MISR R, G, B, NIR)
Contingency tests

Contingency: MISR An-spectral

Other colors represent classes belonging to the Sevilleta

January 11, 2005
Contingency tests

Contingency: MRPV_MISR_red band + An_all_bands

Other colors represent classes belonging to the Sevilleta
Contingency tests

Contingency: MRPV (MISR red band)

Other colors represent classes belonging to the Sevilleta
Contingency tests

Contingency: MISR (iso-geo-vol, red band)

Other colors represent classes belonging to the Sevilleta
Contingency tests

Contingency: MODIS (iso-geo-vol, red band)

Other colors represent classes belonging to the Sevilleta
CONCLUSIONS

• Multiangle data from MISR and MODIS show potential for improving community type mapping.

• The improvements obtained here are not as important as expected: this may be related to the lack of variation in the solar zenith angle.

• We will review Li-Ross and MRPV approaches while also investigating other methods which may be less sensitive to the angular sampling (e.g., GO modeling) and multiangle metrics (SSI, CI, ANIX).
Plans for Work in Immediate Future

- Incorporate NIR band data and model parameters.
- Investigate different combinations of MISR views.
- Improve screening for cloud and cloud shadow.
- Extend temporal sampling to the end of the wet season -- we expect this to produce better results.
- Check signature distributions for normality and modify the set of classes accordingly.
Plans for Work in Medium Term

- Investigate other multiangle metrics (SSI, ANIX…)

- Investigate other classification schemes (SVMs).

- Incorporate soil information.

- Investigate other modeling methods (GO models; this requires e.g., that we address the background problem for GO modeling in desert grasslands).
Questions?
References


GO modeling in Desert Grasslands
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?

Note: MODIS/MISR fields of view are appropriate.
Can GO models work for very heterogeneous canopies which have highly variable and bright understoreys, on different soils?
Conclusions to date: 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. We are investigating ways of obtaining the background BRDF in order to isolate the effects of the larger canopy elements, e.g., to estimate shrub abundance.