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.

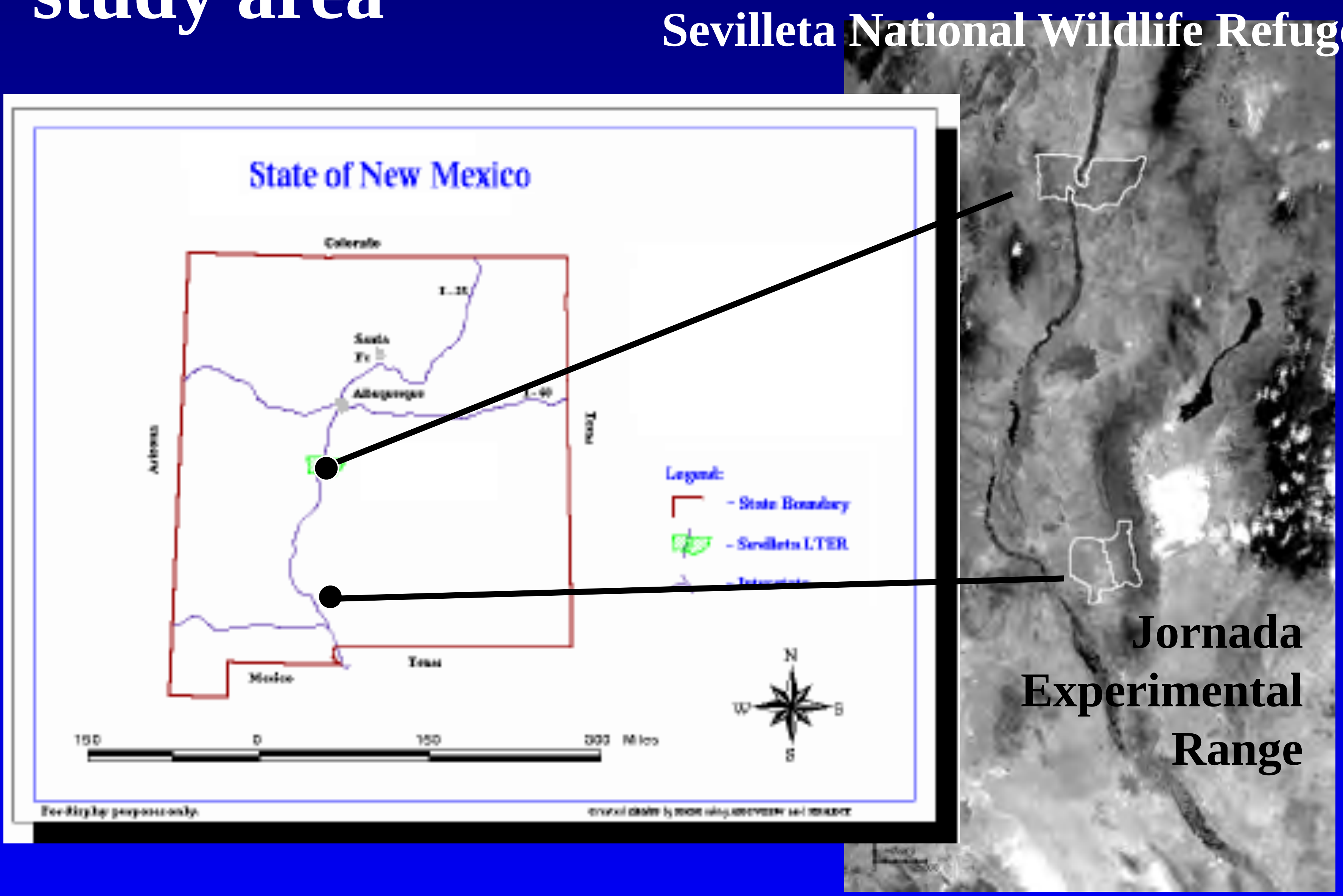
why?

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 <u>over large areas</u>.

study area


Sevilleta National Wildlife Refuge
State of New Mexico
Colorado
Santa Fe
Albuquerque
Arizona
Texas
Mexico
Legend:
- State Boundary
- Sevilleta LTER
N
W
E
S
150
0
150
300
Miles
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

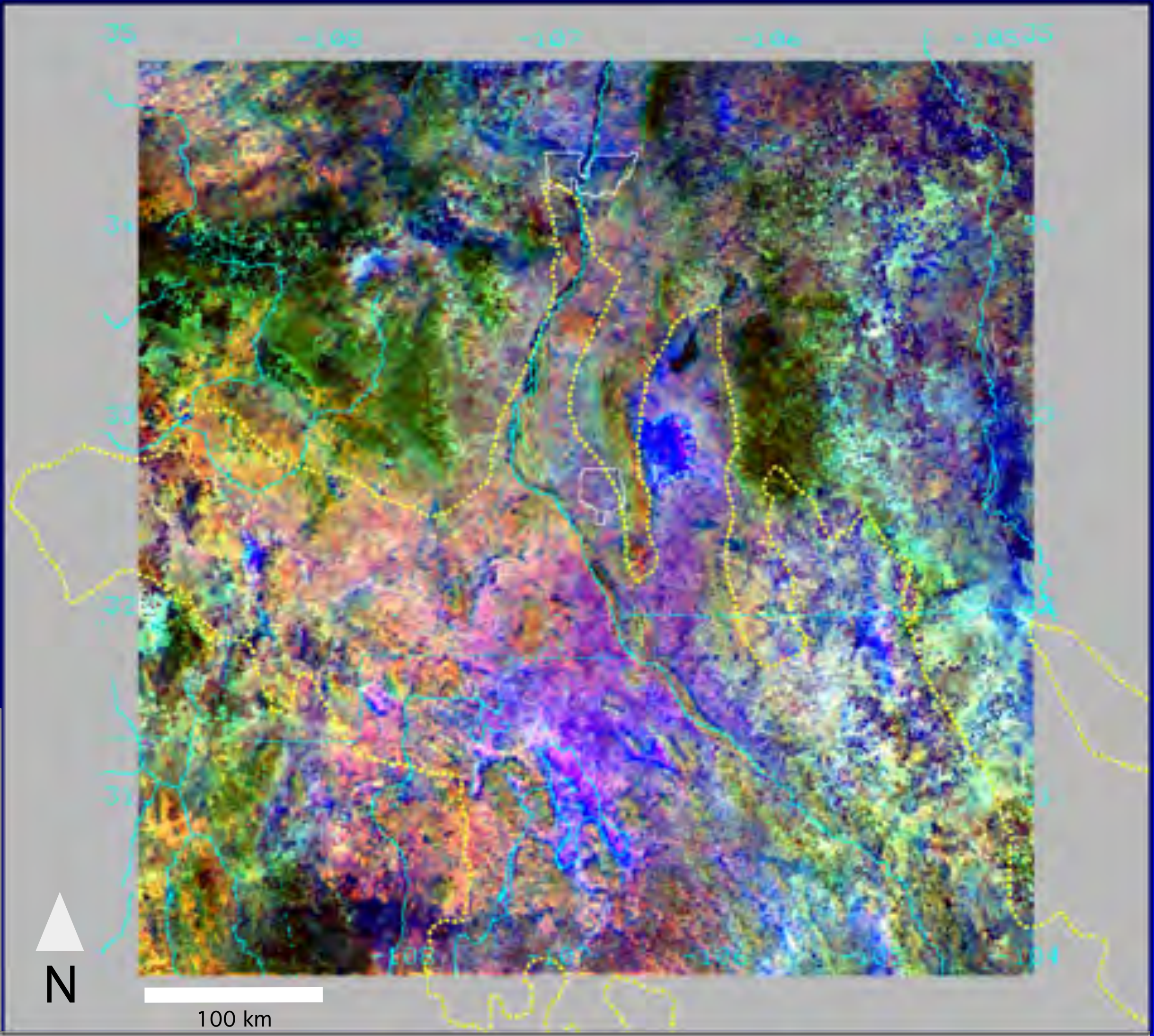
Tobosa grasslands (JER)

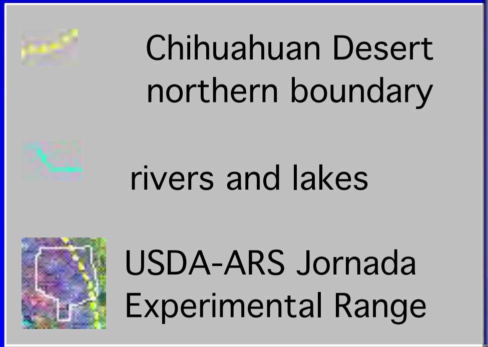
The physical structure of communities is very different (also spectral differences)

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.

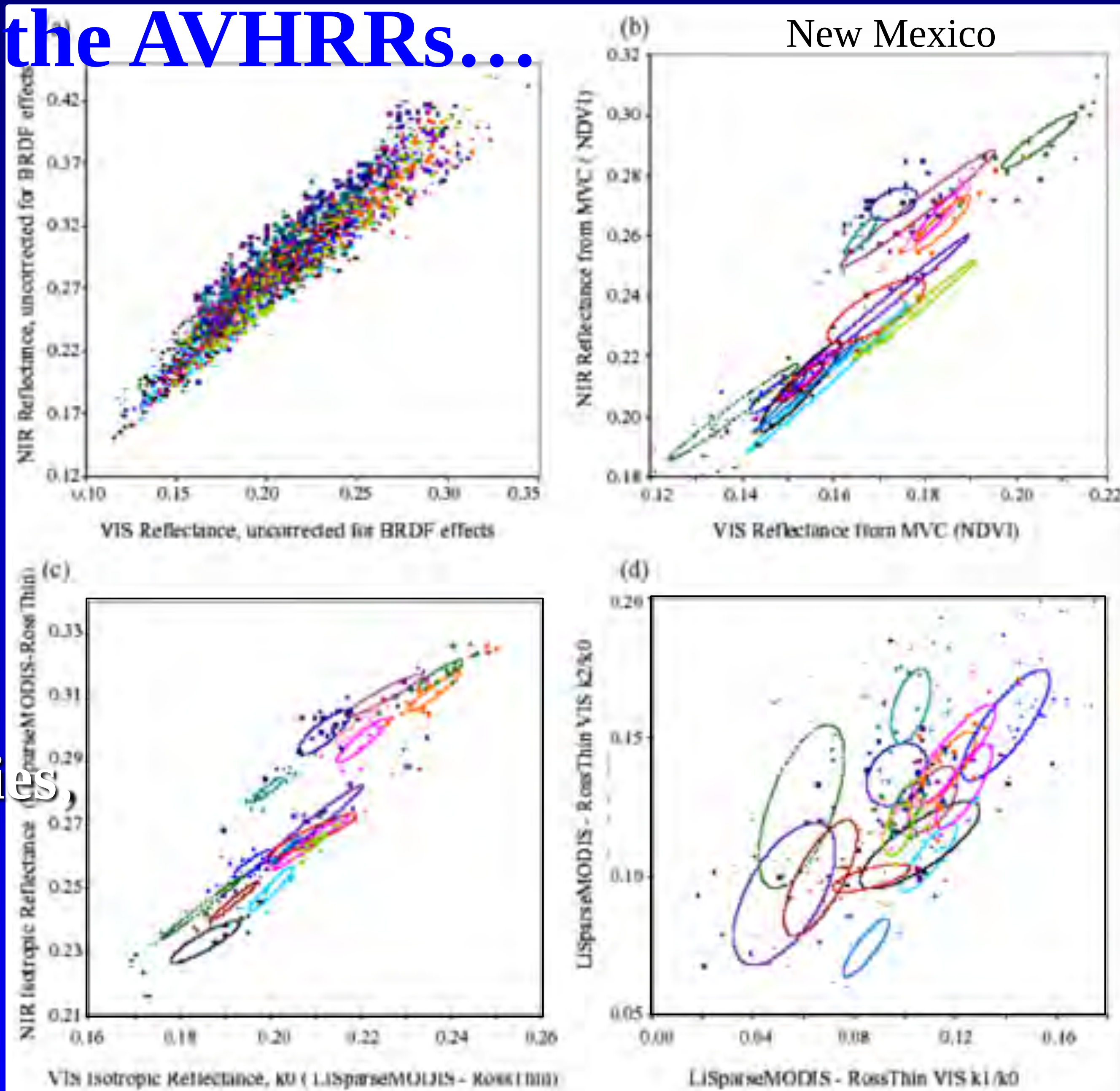




Kernel weights from BRDF model fitting using just the VISIBLE AVHRR channel

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*. 2003[4]); Clumping Index (Chen *et al*., 2003[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:

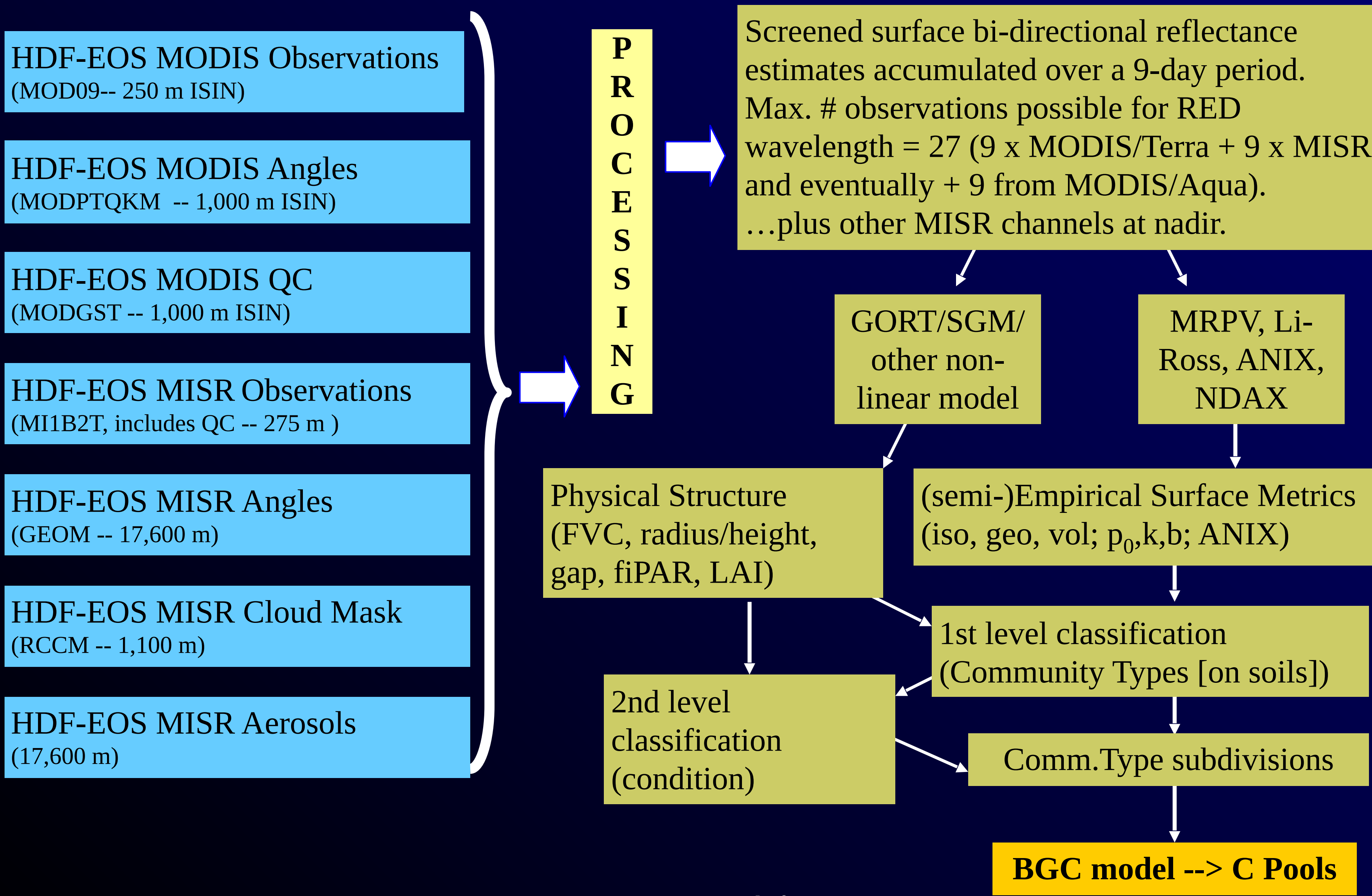
-105.5 to -111.0 degrees W

31.2 to 35.0 degrees N

Dates:

May 15 - June 15, 2002 (end of dry season).

Current Work with MISR & MODIS



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 ==> 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-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

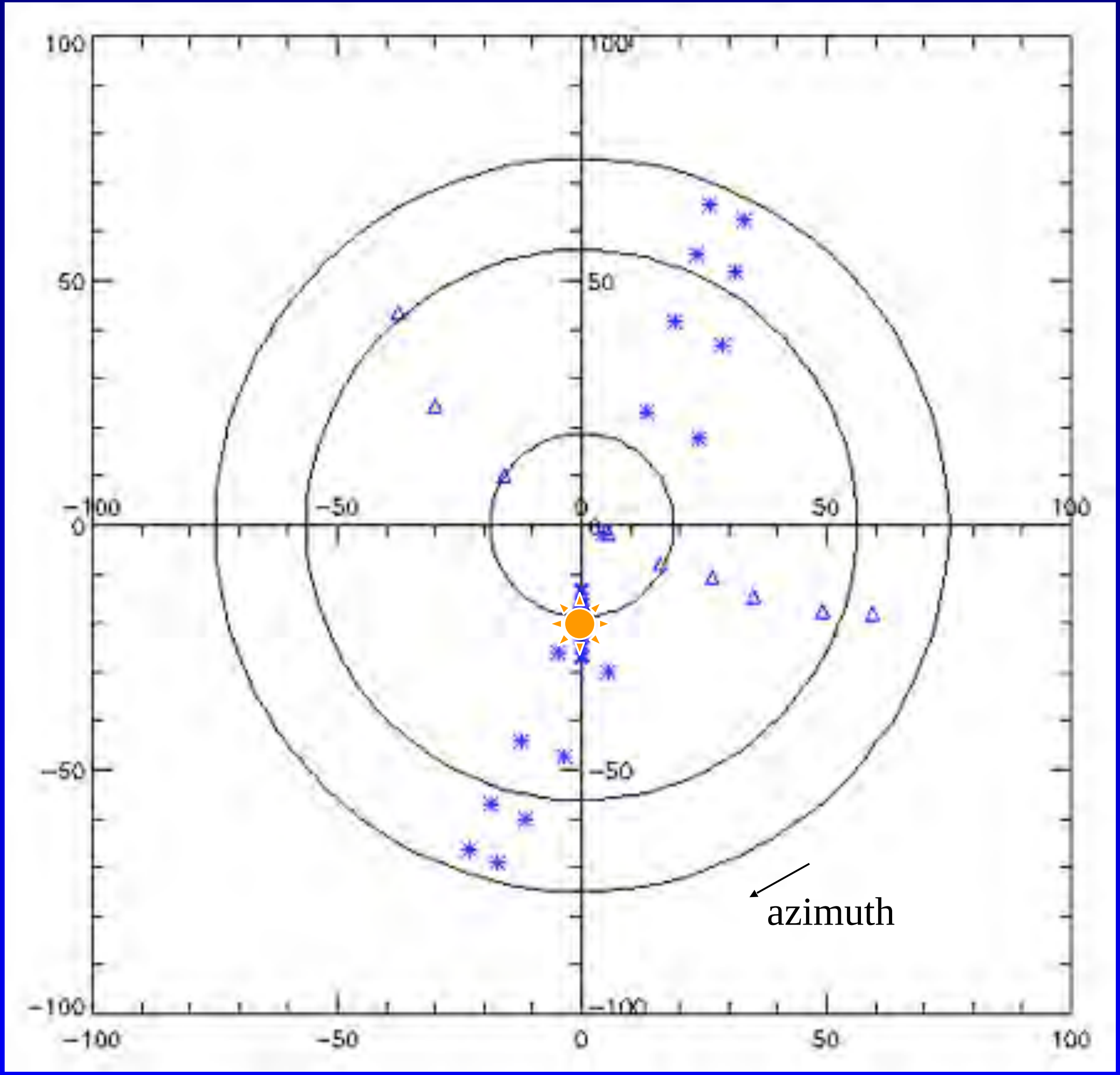
MISR & MODIS: "9x9" Data- complementarity

Angular sampling in June 2002 (9 days)

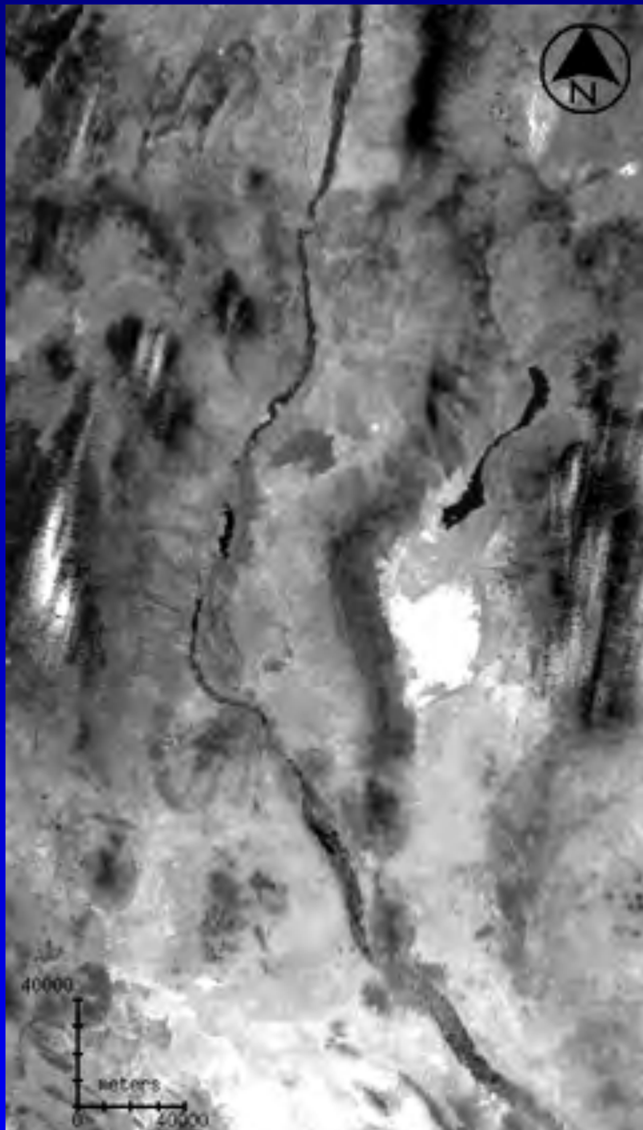
*** MISR**

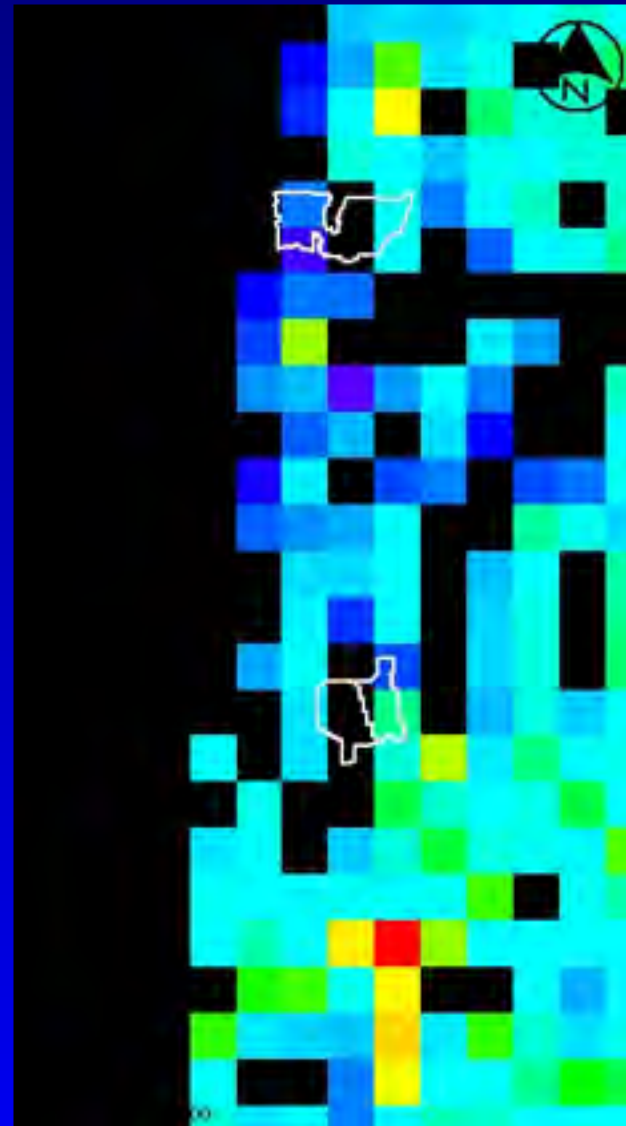
Δ MODIS (Terra)

Sun



MISR/MRPV ρ0 and AOD (Orbit 013039)



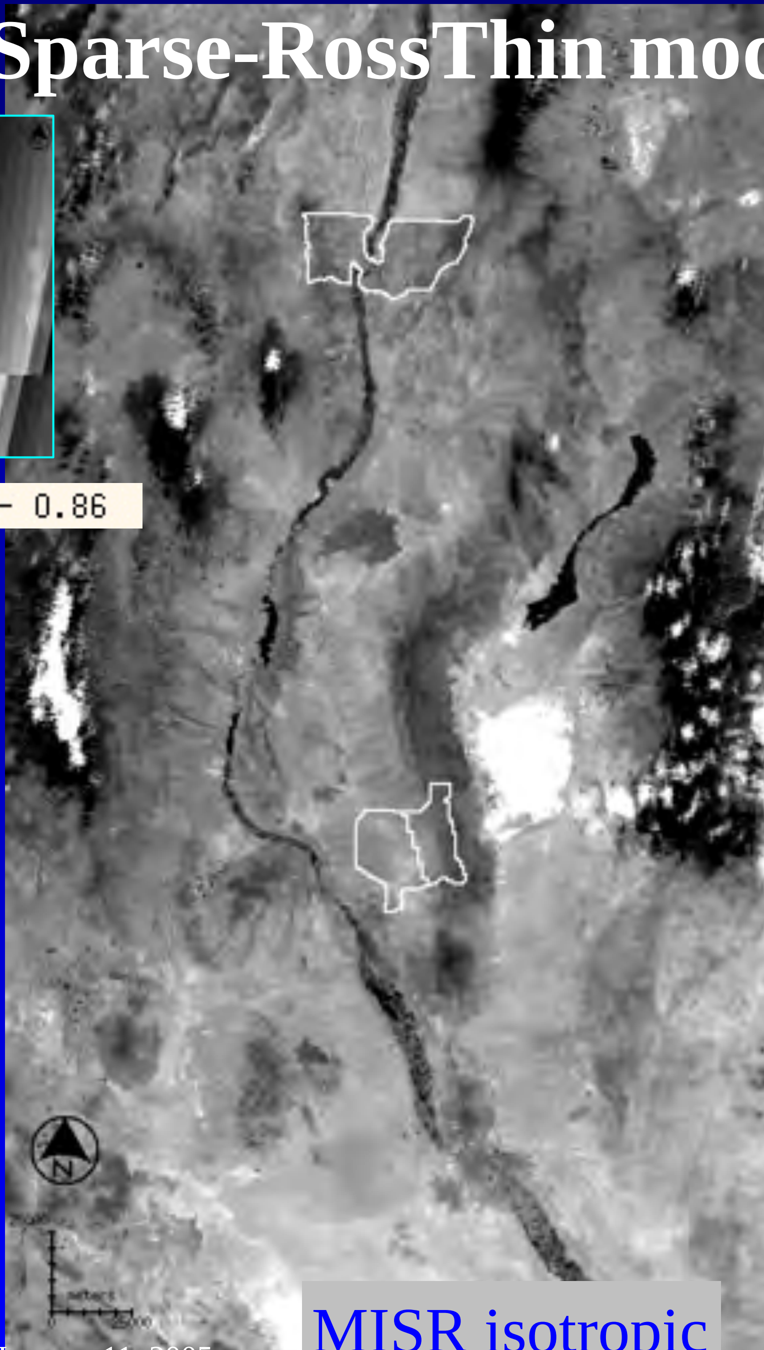


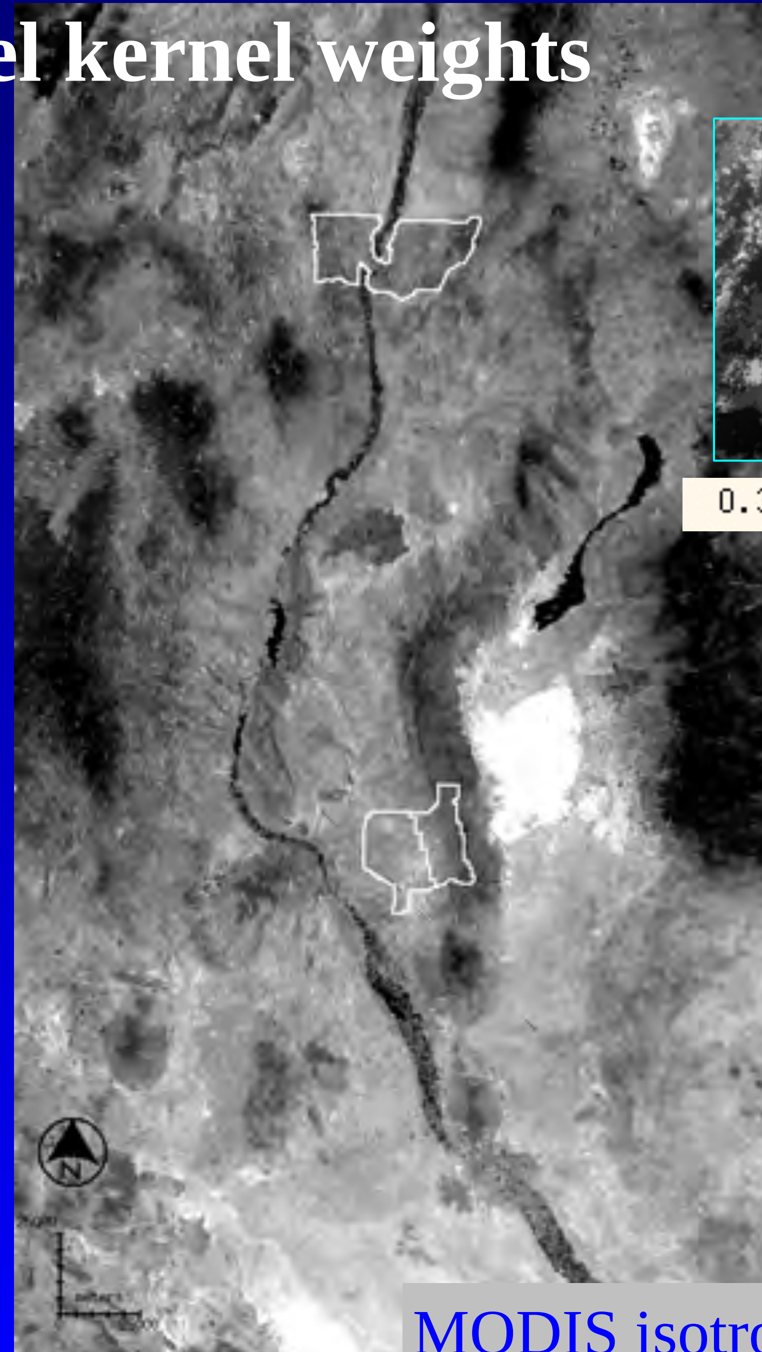
* if MISR data are missing, the AOD defaults to ~0.2 (~16 km visibility)

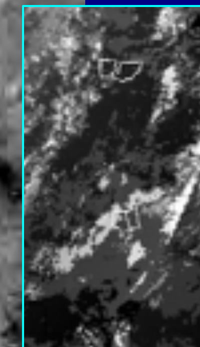
MISR MRPV rho0 image   MISR Aerosol Optical Depth @ 550nm (ROYGBIV = 0.251 to 0.001)

LiSparse-RossThin model kernel weights

Weight of Determination -->





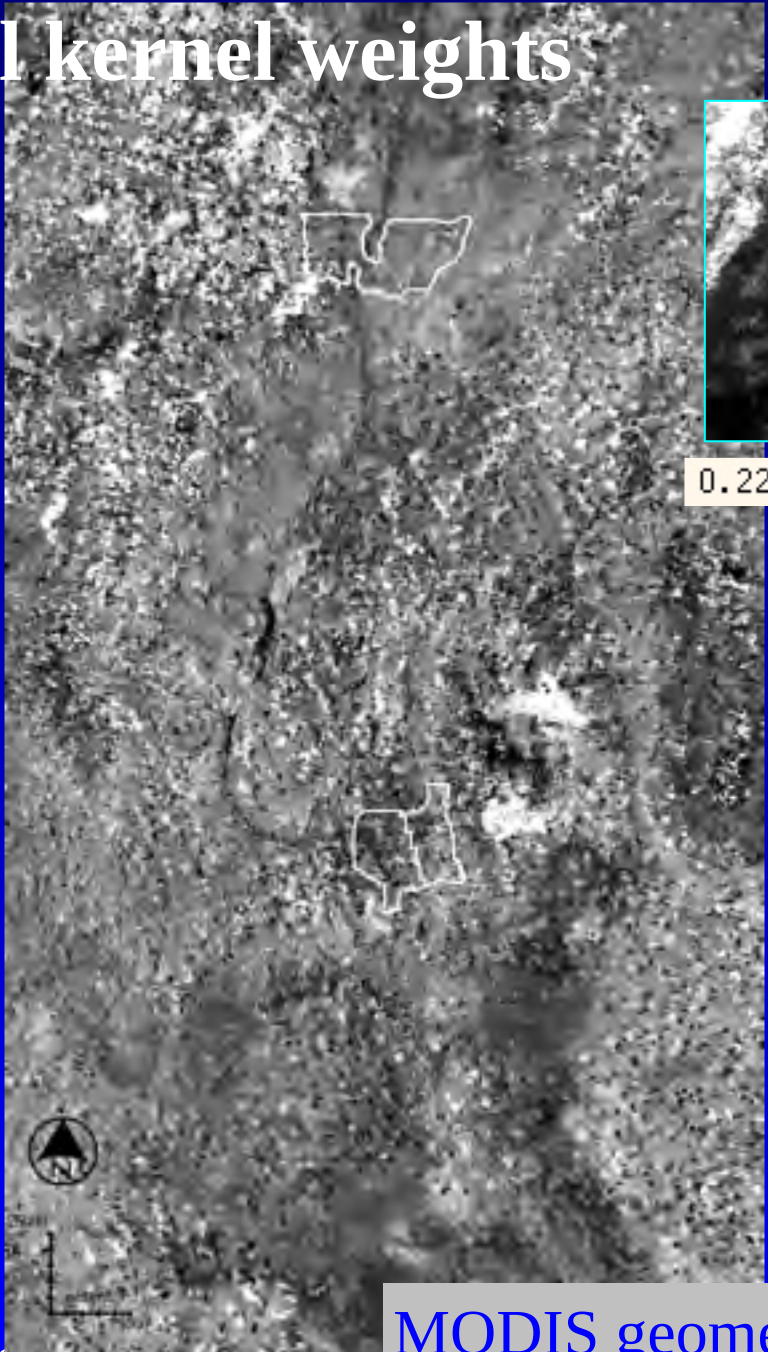


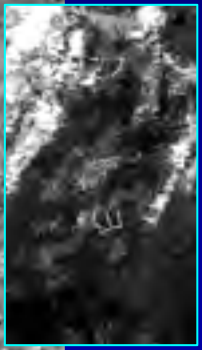
LiSparse-RossThin model kernel weights

0.45 - 0.86

Weight of Determination -->

MISR geometric





0.22 - 0.66

!

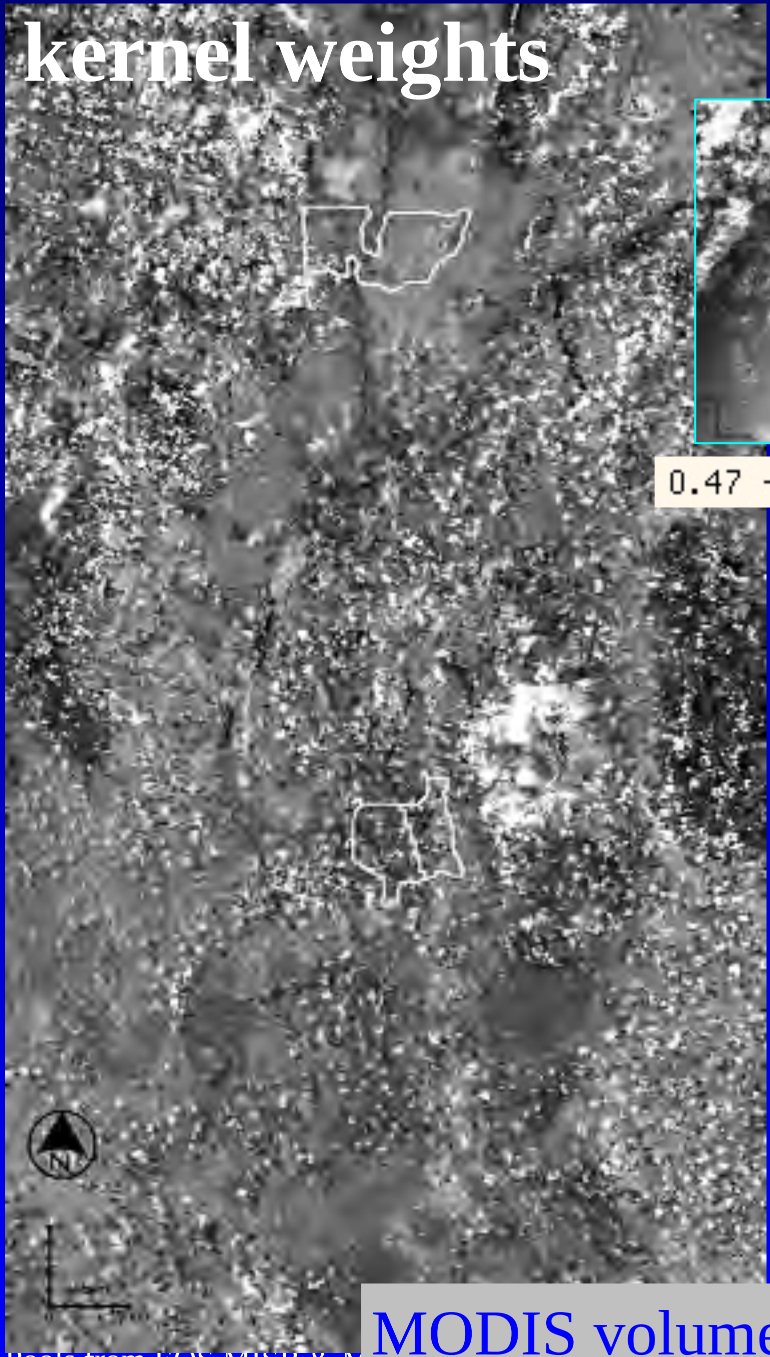
MODIS geometric

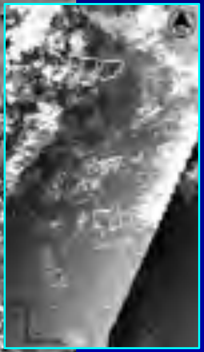
LiSparse-RossThin model kernel weights

0.28 - 1.00

Weight of Determination -->

MISR volume



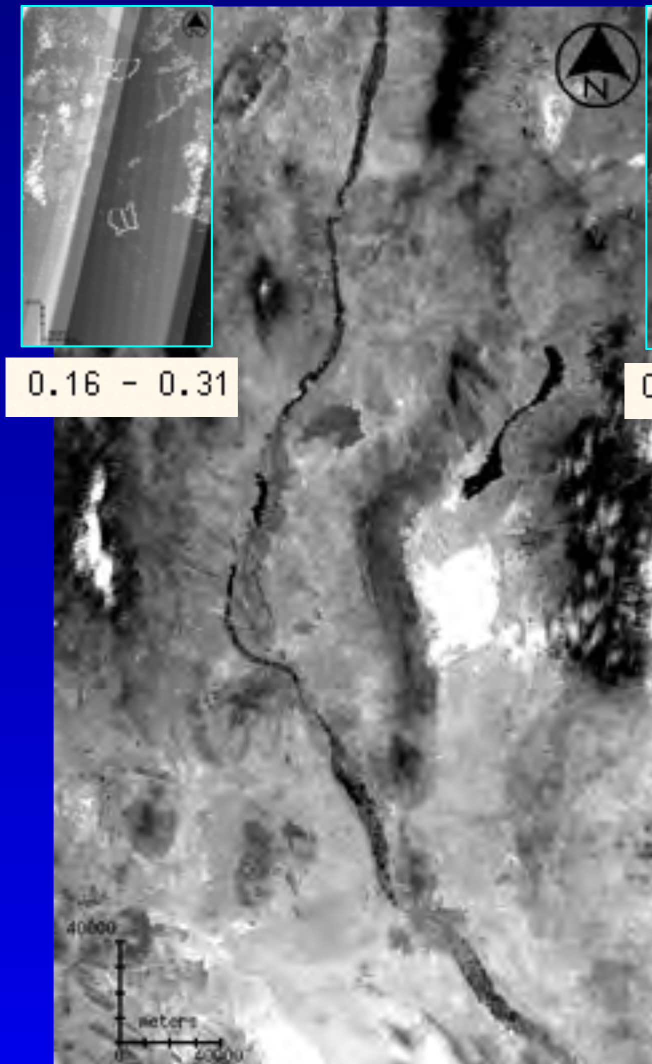


0.47 - 1.17

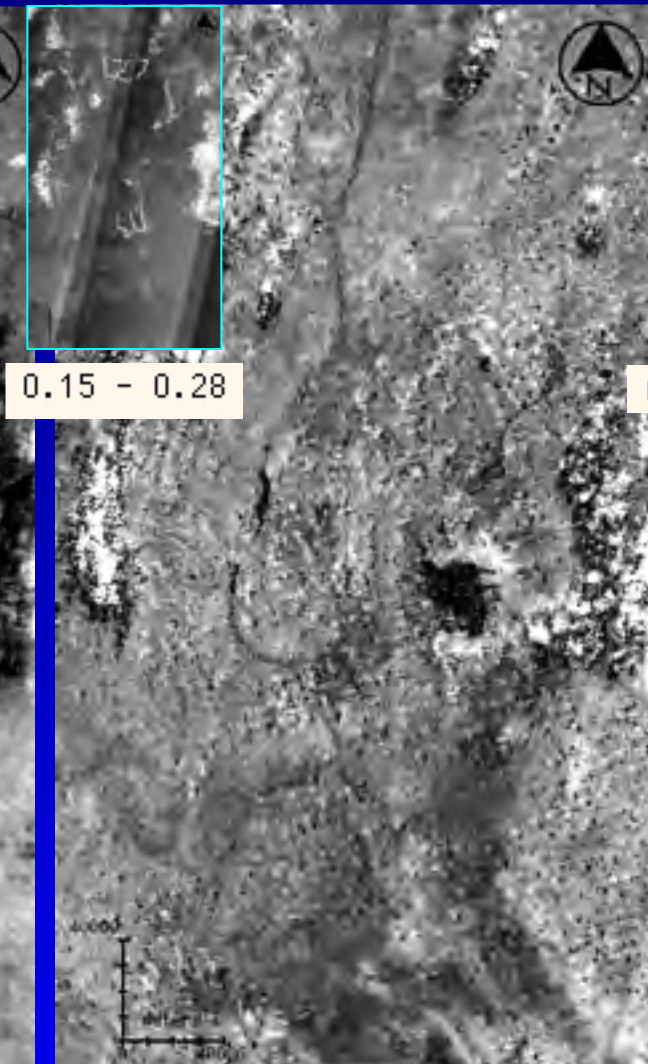
!

MODIS volume

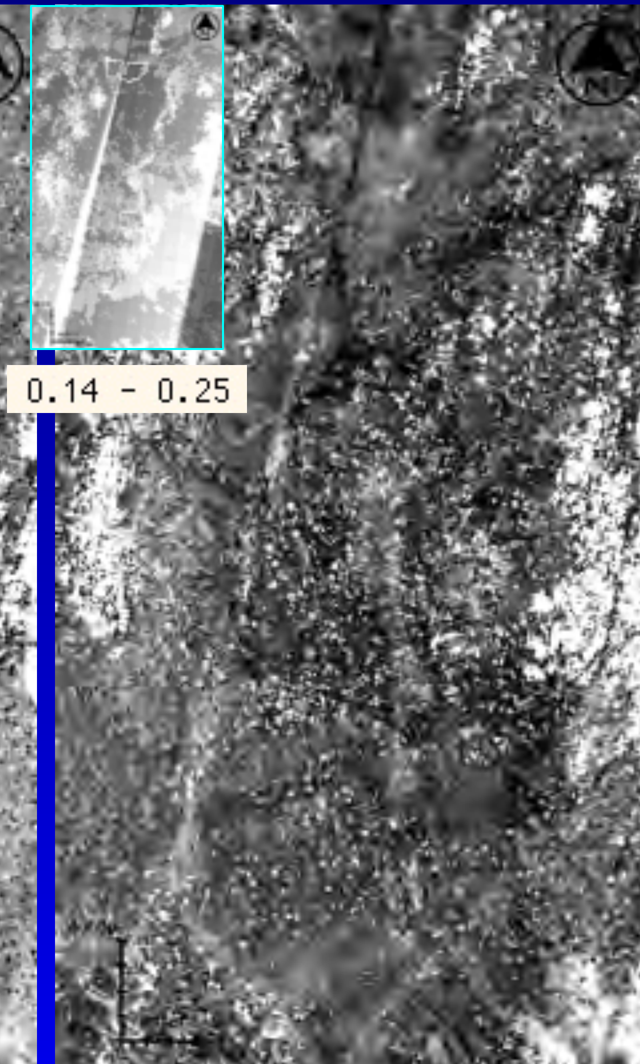
LiSparse-RossThin model kernel weights



MISR+MODIS iso



MISR+MODIS geo

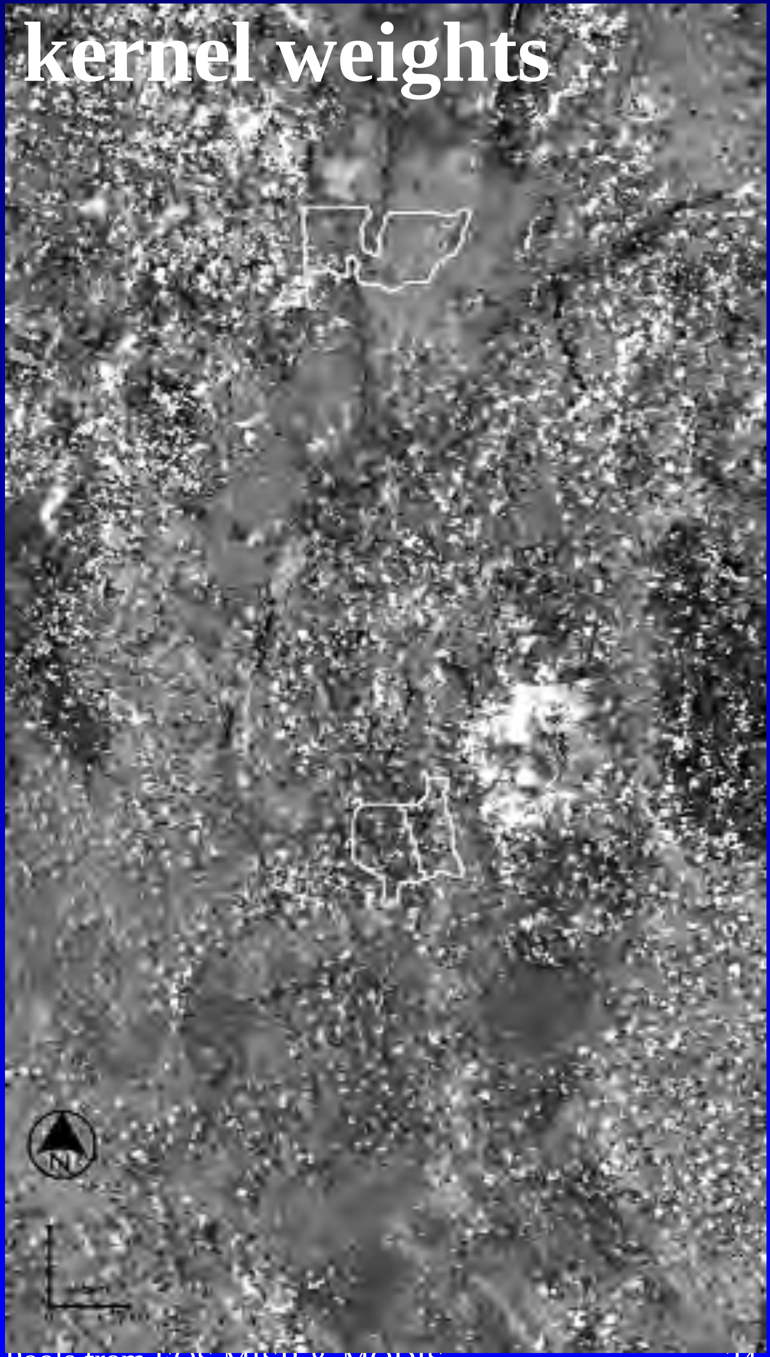


MISR+MODIS vol

LiSparse-RossThin model kernel weights

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)

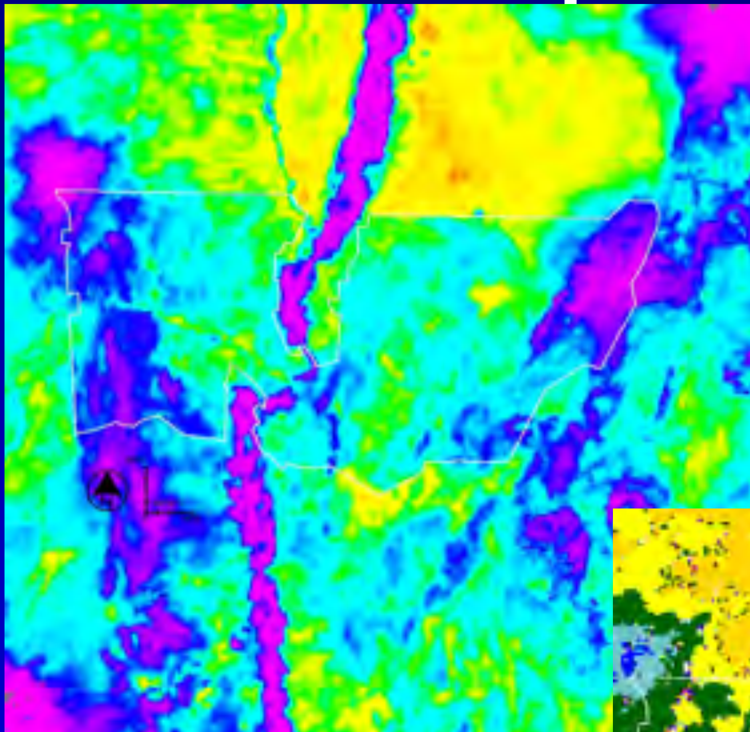
In 1998 aerial photography and field data were combined to create a current vegetation map of species composition and dominant species, including major plant communities. Using 1996 aerial photos, up to four major dominant species were estimated for each vegetation type.

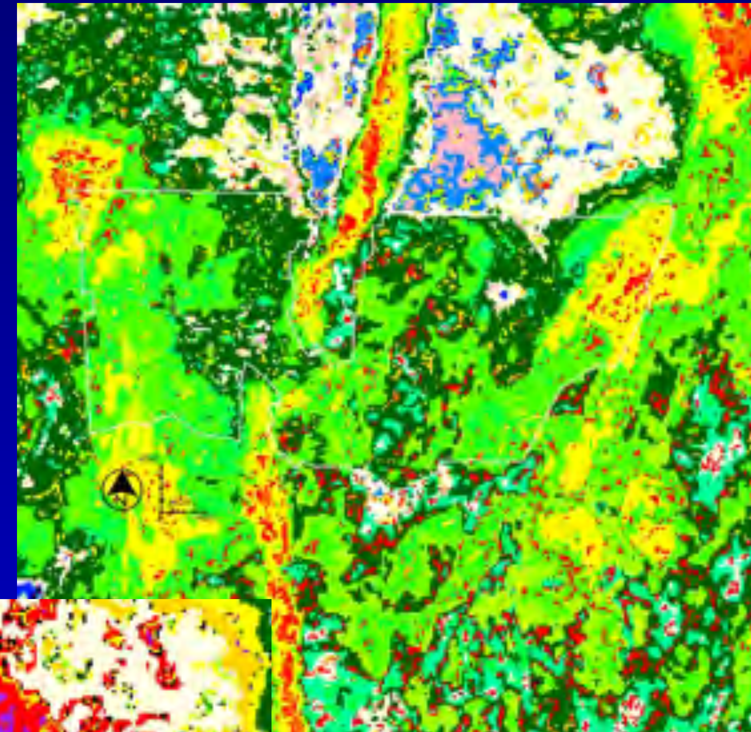
Community Type Mapping

Sevilleta NWR Vegetation Map (SNWR LTER)

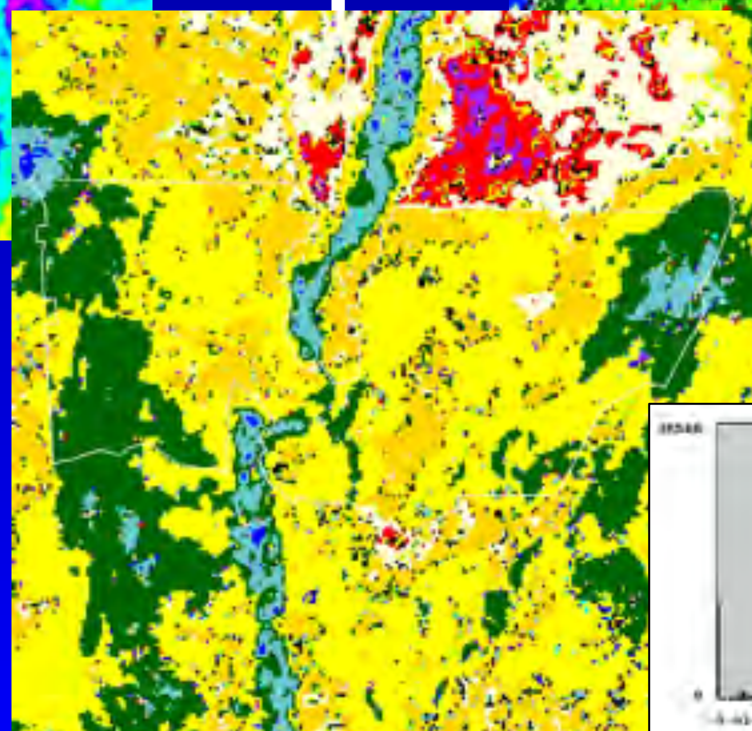
The map includes 13 vegetation classes derived from an unsupervised classification of 12 Landsat TM images (NDVI transformed) collected in various seasons over a seven year period from 1987. A plant classification at the association level was developed from which the initial 32 images classes were combined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

MISR/MRPV parameters



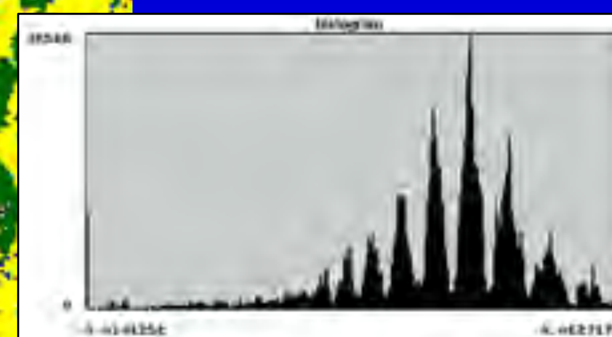


b
(fwd or back)



k
(bell or bowl)

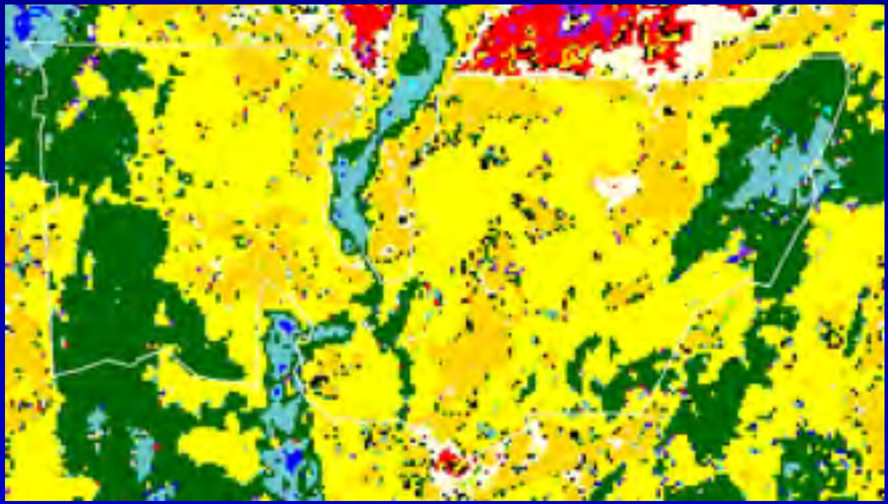
ρ0
(magnitude)

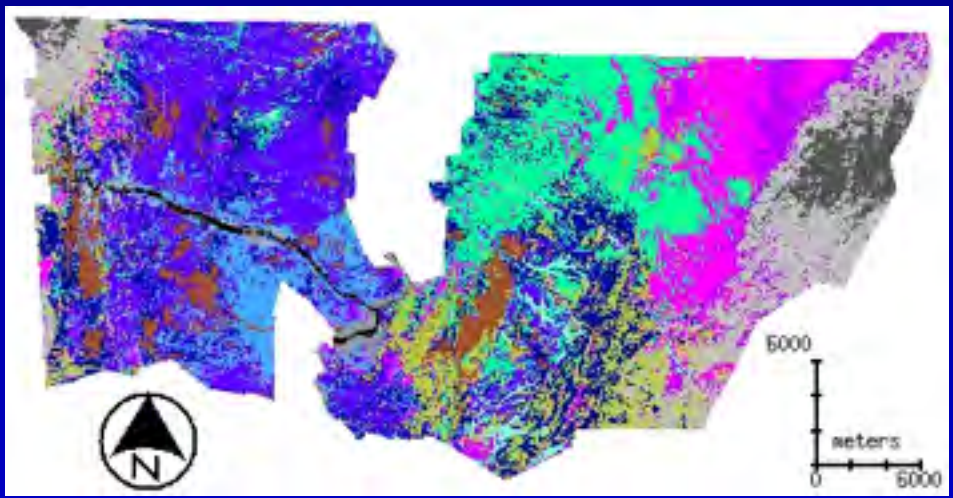


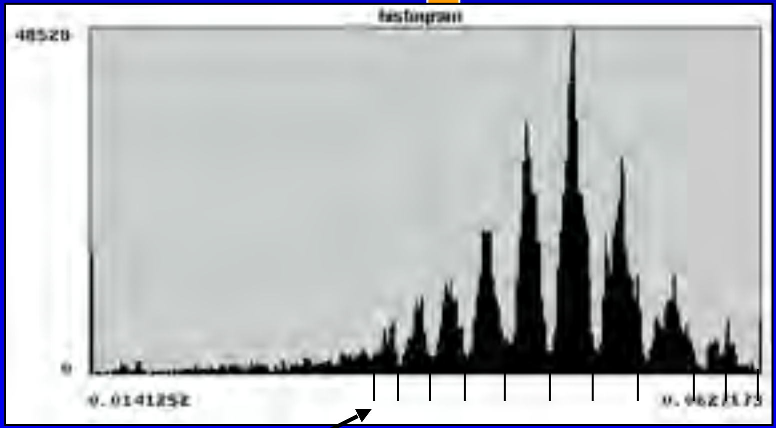
MISR_MRPV ρ0, *b*, *k*, Sevilleta National Wildlife Refuge

MISR/MRPV parameters

MISR/MRPV b parameter: Sevilleta National Wildlife Refuge

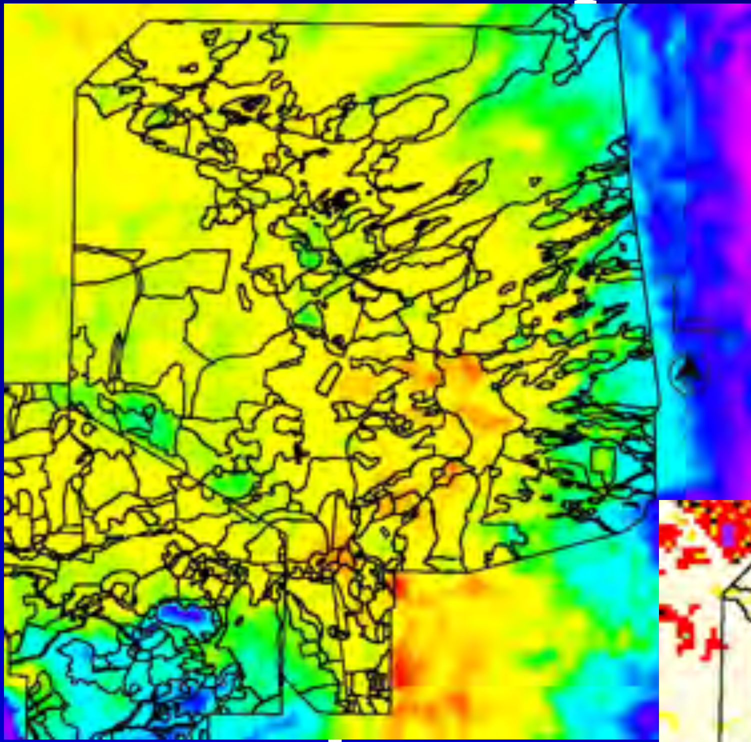


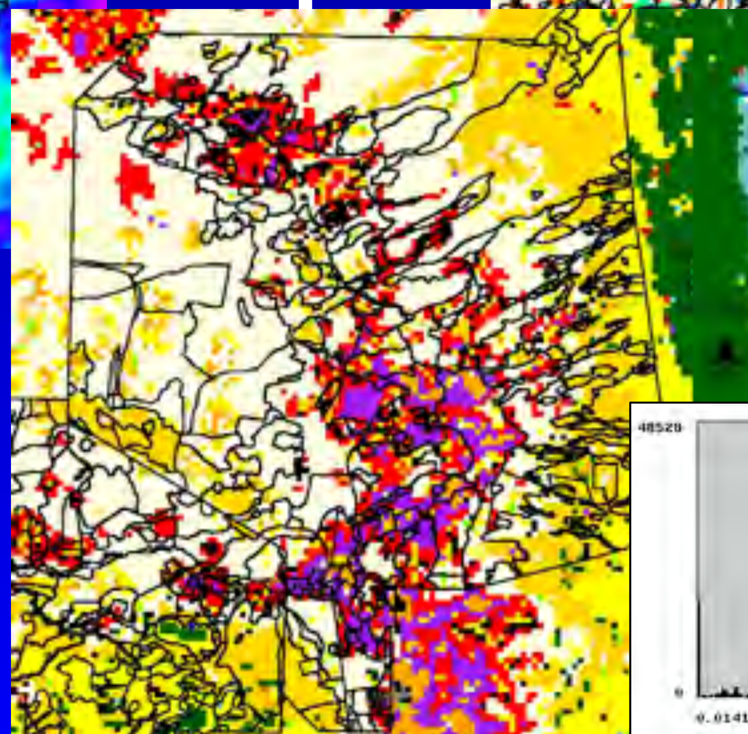


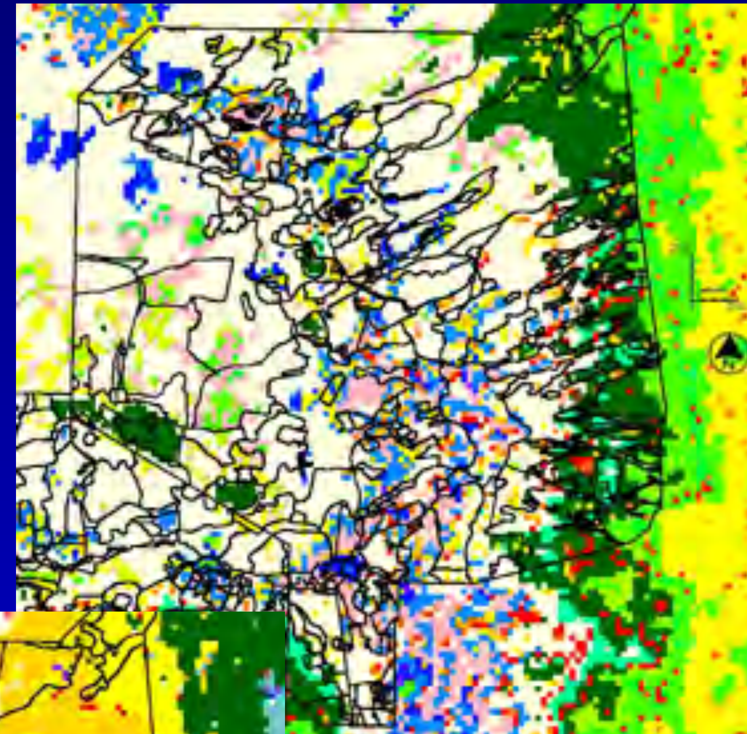


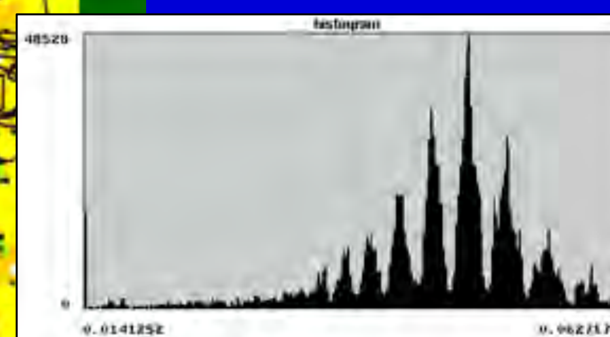
Breaks (N.B. colors are not matched but distributions are similar).

MISR/MRPV parameters









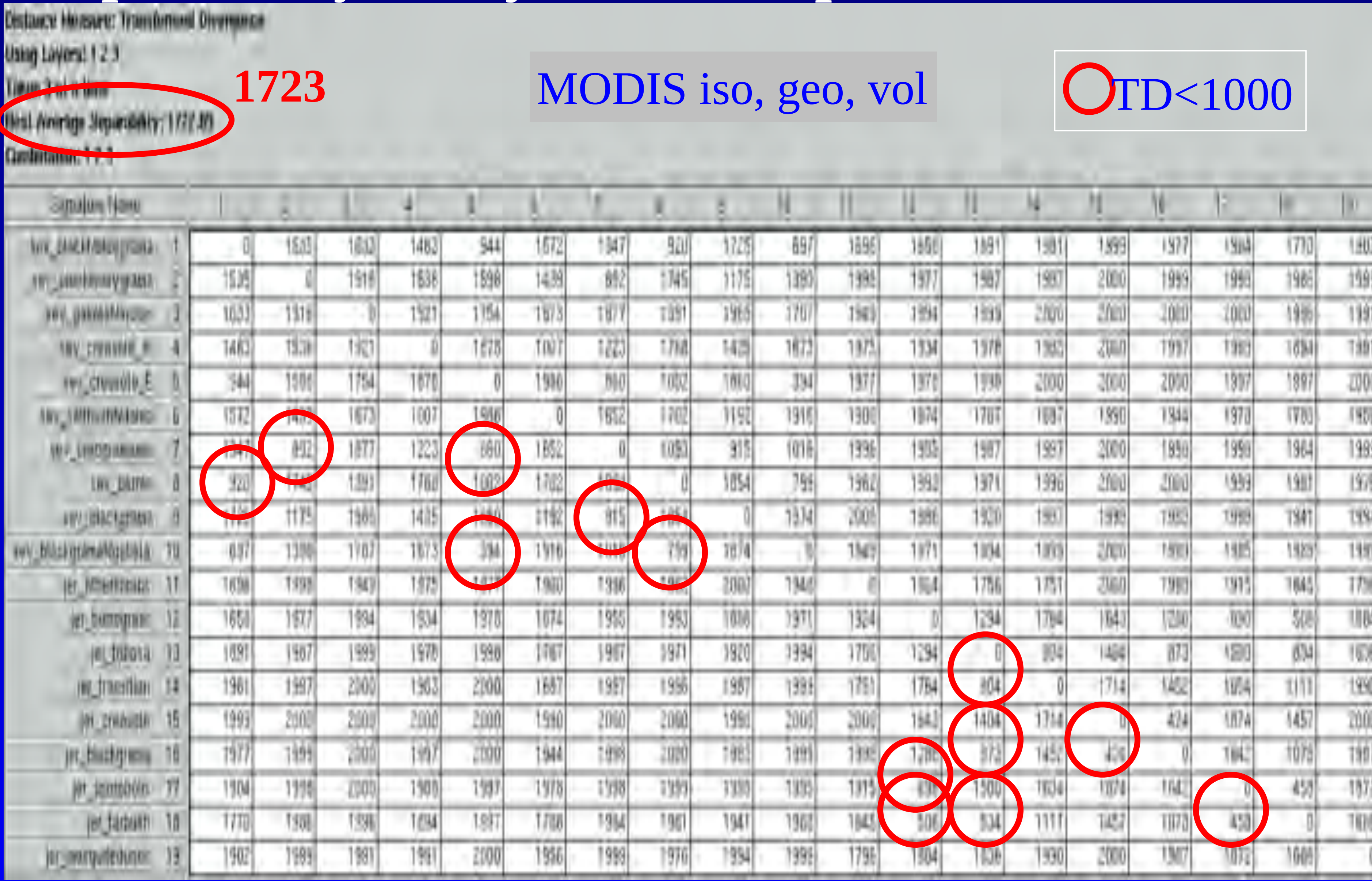
$\rho 0$
(magnitude)

b
(fwd or back)

k
(bell or bowl)

MISR_MRPV ρ0, b, k
Jornada Experimental Range

Separability Analysis -- class pairs



Distance Measure: Transformed Divergence
Using Layers: 1 2 3
Taken: 3 at a time
Best Average Separability: 1722.89
Combination: 1 2 3

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jer_tobosa	13	1891	1987	1999	1976	1998	1767	1987	1971	1920	1994	1756	1294	0	804	1404	873	1500	534	1636
jer_transition	14	1981	1997	2000	1963	2000	1687	1997	1996	1987	1999	1751	1794	804	0	1714	1452	1674	1111	1930
jer_creosote	15	1999	2000	2000	2000	2000	1990	2000	2000	1998	2000	2000	1643	1404	1714	0	424	1874	1457	2000
jer_blackgrama	16	1977	1999	2000	1997	2000	1944	1998	2000	1983	1999	1990	1280	873	1452	424	0	1642	1075	1907
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Separability Analysis -- class pairs

Distance Measure: Transformed Divergence
Using Layers: 1 2 3
Taken 3 at a time
Best Average Separability: 1867.11
Combination: 1 2 3

1867

MISR iso, geo, vol

○ TD<1000

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Separability Analysis -- class pairs

Distance Measure: Transformed Divergence
Using Layers: 1 2 3
Taken 3 at a time
Best Average Separability: 1839.1
Combinations: 1 2 3

1839

MISR+MODIS iso, geo, vol

○ TD<1000

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[illegible]	5	1609	1900	1594	1340	0	1694	1270	1660	1913	1403	2000	1995	2000	2000	2000	2000	2000	2000	2000
[illegible]	6	1277	1632	1531	1695	1694	0	1932	1949	1911	1918	1978	1939	1682	1985	1997	1985	1984	1960	1973
[illegible]	7	1903	1893	1929	1142	1270	1932	0	1194	940	1790	2000	2000	2000	2000	2000	2000	2000	2000	2000
[illegible]	8	1902	1996	1604	1933	1660	1949	1194	0	1847	1666	2000	1999	2000	2000	2000	2000	2000	2000	2000
[illegible]	9	1911	1834	1990	1703	1913	1911	940	1847	0	1984	2000	1999	2000	2000	2000	2000	2000	2000	2000
[illegible]	10	847	1677	1719	1974	1403	1918	1790	1666	1984	0	1998	1996	1993	2000	2000	1999	1999	1999	2000
[illegible]	11	[illegible]	2000	2000	2000	2000	1978	2000	2000	2000	1998	0	1900	1421	1968	2000	1991	1962	1914	1895
[illegible]	12	1901	1997	1999	2000	1995	1939	2000	1999	1999	1996	1980	0	1645	2000	1866	1602	1656	1612	1963
[illegible]	13	1760	1994	2000	2000	2000	1682	2000	2000	2000	1993	1421	1645	[illegible]	885	1505	624	1746	847	1288
[illegible]	14	1995	2000	2000	2000	2000	1985	2000	2000	2000	2000	1968	2000	885	0	1390	1311	2000	1742	1288
[illegible]	15	1997	2000	2000	2000	2000	1997	2000	2000	2000	2000	2000	1866	[illegible]	[illegible]	0	469	1973	713	1977
[illegible]	16	1945	1999	2000	2000	2000	1985	2000	2000	2000	1999	1991	1603	624	1311	469	0	1906	401	1797
[illegible]	17	1909	2000	2000	2000	2000	1984	2000	2000	2000	1999	1962	1656	[illegible]	2000	[illegible]	[illegible]	0	1667	1790
[illegible]	18	1951	2000	2000	2000	2000	1960	2000	2000	2000	1999	1914	1612	847	1742	713	401	1667	0	1753
[illegible]	19	1994	2000	2000	2000	2000	1973	2000	2000	2000	2000	1895	1963	[illegible]	1288	[illegible]	[illegible]	1790	1753	0

Separability Analysis -- class pairs

Distance Measure: Transformed Divergence
Using Layers: 1 2 3
Taking 3 at a time
Best Average Separability: 1743.71
Combination: 1 2 3

1744

MISR MRPV

TD<1000

Signature Name		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
[illegible]	1	0	1975	1729	1829	1709	1403	1957	1930	1897	593	1897	1597	839	1914	1901	1664	1665	1734	1667
[illegible]	2	1975	0	1831	1986	2000	1261	1998	1652	1729	1980	2000	2000	2000	2000	2000	2000	2000	2000	2000
[illegible]	3	1729	1831	0	869	1999	457	1734	1539	1883	1288	2000	2000	1994	2000	2000	2000	2000	2000	2000
[illegible]	4	1829	1986	869	0	2000	1008	1850	1541	1980	1587	2000	2000	1998	2000	2000	2000	2000	2000	2000
[illegible]	5	1750	2000	1999	2000	0	2000	1976	1991	2000	1009	2000	2000	1974	1998	2000	2000	2000	2000	2000
[illegible]	6	1403	1261	457	1008	2000	0	1850	1417	1927	1475	2000	2000	1970	1999	2000	2000	2000	2000	1994
[illegible]	7	1957	1996	1734	1850	1976	1850	0	1600	1714	1179	2000	2000	2000	2000	2000	2000	2000	2000	2000
[illegible]	8	1930	1652	1539	1541	1991	1417	1600	0	1880	1549	2000	2000	2000	2000	2000	2000	2000	2000	2000
[illegible]	9	1897	1729	1983	1980	2000	1927	1714	1880	0	1919	2000	2000	2000	2000	2000	2000	2000	2000	2000
[illegible]	10	593	1980	1286	1587	1009	1475	1179	1549	1919	0	1998	1002	1978	1979	1984	1940	1980	1921	1986
[illegible]	11	[illegible]	2000	2000	2000	2000	2000	2000	2000	2000	1998	0	1998	1478	1029	2000	1992	1984	1975	294
[illegible]	12	[illegible]	2000	2000	2000	2000	2000	2000	2000	2000	1002	1998	0	1407	1969	726	303	1203	351	1677
[illegible]	13	839	2000	1994	1998	1974	1970	2000	2000	2000	1578	1478	1407	0	501	1813	1310	1653	1384	1160
[illegible]	14	1914	2000	2000	2000	1998	1999	2000	2000	2000	1978	1029	[illegible]	501	0	1997	1981	1980	1960	1220
[illegible]	15	1901	2000	2000	2000	2000	2000	2000	2000	2000	1984	2000	726	1813	1997	0	281	272	584	1911
[illegible]	16	1660	2000	2000	2000	2000	2000	2000	2000	2000	1940	1992	[illegible]	1310	1981	281	0	328	230	1620
[illegible]	17	1665	2000	2000	2000	2000	2000	2000	2000	2000	1980	1984	[illegible]	1653	1980	[illegible]	328	0	865	1585
[illegible]	18	1734	2000	2000	2000	2000	2000	2000	2000	2000	1921	1975	351	1384	1960	584	[illegible]	865	0	1753
[illegible]	19	1667	2000	2000	2000	2000	1994	2000	2000	2000	1986	294	[illegible]	1160	1220	[illegible]	1620	1585	1753	0

Separability Analysis -- class pairs

Distance Measure: Transformed Divergence

Using Layers: 1 2 3

Taken: 3 at a time

Best Average Separability: 1624.2

Combination: 1 2 3

1624

MODIS MRPV

TD<1000

Signature Name	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
[illegible] 1	0	1270	2000	219	1997	202	342	690	1009	303	1142	2000	1906	2000	1030	1700	1939	1709	2000
[illegible] 2	1270	0	2000	1239	1983	948	471	1087	761	1291	1962	2000	1905	2000	1997	1904	1999	1981	2000
[illegible] 3	2000	2000	0	2000	2000	2000	2000	2000	2000	2000	2000	1940	2000	1650	2000	2000	2000	2000	1597
[illegible] 4	219	1239	2000	0	1983	150	472	427	1096	230	1345	2000	1903	2000	1093	1739	1926	1703	2000
[illegible] 5	[illegible]	1983	2000	1983	0	1859	1934	1993	1999	2000	1242	2000	1571	2000	2000	1999	1992	1917	2000
[illegible] 6	[illegible]	948	2000	[illegible]	1859	0	297	294	907	194	1746	2000	1929	2000	1600	1037	1900	1793	2000
[illegible] 7	[illegible]	[illegible]	2000	[illegible]	1934	[illegible]	[illegible]	445	429	429	1945	2000	1999	2000	1943	1070	1992	1922	2000
[illegible] 8	[illegible]	[illegible]	2000	[illegible]	1993	[illegible]	[illegible]	0	1016	240	1747	2000	1997	2000	1997	1926	1997	1964	2000
[illegible] 9	[illegible]	761	2000	[illegible]	1999	[illegible]	[illegible]	[illegible]	0	1153	1962	2000	1909	2000	1972	1914	1997	1945	2000
[illegible] 10	303	[illegible]	2000	230	2000	104	429	240	1153	0	1078	2000	2000	2000	1902	1953	1934	1951	2000
[illegible] 11	1142	1962	2000	[illegible]	1242	[illegible]	[illegible]	[illegible]	[illegible]	1078	0	2000	1171	2000	1981	1906	1795	1327	2000
[illegible] 12	2000	2000	1940	2000	2000	2000	2000	2000	2000	2000	2000	0	2000	830	2000	2000	2000	2000	1007
[illegible] 13	1905	1905	2000	1903	1571	1929	1999	1997	1909	2000	1171	[illegible]	0	2000	1706	1200	1010	634	2000
[illegible] 14	2000	2000	1650	2000	2000	2000	2000	2000	2000	2000	2000	830	2000	0	2000	2000	2000	2000	100
[illegible] 15	1030	1997	2000	1093	2000	1600	1943	1997	1972	1902	1981	[illegible]	1706	2000	0	329	341	920	2000
[illegible] 16	1700	1904	2000	1739	1999	1037	1070	1926	1914	1953	1906	2000	1200	2000	[illegible]	0	204	546	2000
[illegible] 17	1939	1999	2000	1926	1992	1900	1992	1997	1997	1934	1795	2000	1010	2000	[illegible]	[illegible]	0	199	2000
[illegible] 18	1709	1981	2000	1703	1917	1793	1922	1964	1945	1951	1327	2000	634	[illegible]	[illegible]	[illegible]	199	0	2000
[illegible] 19	2000	2000	1597	2000	2000	2000	2000	2000	2000	2000	2000	1007	[illegible]	100	[illegible]	[illegible]	[illegible]	2000	0

Separability Analysis -- class pairs

Distance Measure: Transformed Divergence
Using Layers: 1 2 3
Taken 3 at a time:
Best Average Separability: 1652.66
Combination: 1 2 3

1653

MODIS+MISR MRPV

○ TD<1000

Signature Name		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
[illegible]	1	0	1570	999	1420	1404	566	1688	1228	1795	1756	1812	1738	1688	1977	1763	1585	1902	1570	1354
[illegible]	2	1570	0	1566	1597	1732	1261	1259	1202	1180	1714	1976	1953	1950	2000	1993	1987	1995	1994	1996
[illegible]	3	999	1566	0	1026	1905	522	1947	1121	1915	1976	1992	1999	1995	2000	2000	1999	2000	1999	1987
[illegible]	4	1420	1597	1026	0	290	1436	605	1557	1798	1076	1785	1866	1577	1903	1972	1041	1953	1937	1970
[illegible]	5	1404	1732	1905	290	0	1741	798	1628	1888	722	1456	1803	916	1741	1805	1414	1743	1878	1876
[illegible]	6	506	1261	522	1436	1741	0	1746	400	1691	1925	1853	1869	1964	2000	1987	1972	1307	1943	1506
[illegible]	7	1688	1259	1947	605	798	1746	0	1753	1967	839	1629	1947	1787	1998	1995	1742	1985	1976	1992
[illegible]	8	1230	1202	1121	1557	1628	400	1753	0	1215	1957	1989	1995	1992	2000	1999	1996	2000	1993	1995
[illegible]	9	1786	1180	1915	1798	1888	1691	1967	1215	0	1928	1997	1931	1996	2000	1997	1992	2002	1994	2000
[illegible]	10	1700	1714	1976	1076	722	1925	839	1957	1928	0	1966	1967	1516	1932	1993	1056	1865	1996	1963
[illegible]	11	1612	1975	1992	1789	1456	1923	1629	1989	1997	1966	0	1592	1034	1703	1447	933	1291	1573	1404
[illegible]	12	1738	1993	1999	1866	1803	1969	1947	1995	1991	1997	1592	0	1025	1909	425	1234	1291	241	1797
[illegible]	13	1686	1985	1995	1577	916	1964	1787	1992	1996	1516	1034	1025	0	327	1737	1081	1272	1042	1491
[illegible]	14	1977	2000	2000	1903	1741	2000	1996	2000	2000	1932	1703	1909	327	0	1961	1003	1712	1990	1040
[illegible]	15	1763	1993	2000	1972	1805	1992	1996	1999	1997	1993	1447	425	1737	1961	0	700	796	373	1429
[illegible]	16	1709	1987	1999	1041	1414	1972	1742	1998	1982	1056	933	1234	1051	1802	700	0	634	1314	1362
[illegible]	17	1900	1993	2000	1953	1749	1997	1985	2000	2000	1985	1291	1291	1272	1712	796	634	0	1074	1096
[illegible]	18	1570	1984	1898	1937	1876	1949	1976	1993	1994	1996	1573	241	1042	1990	373	1314	1374	0	1333
[illegible]	19	1354	1996	1987	1976	1876	1906	1992	1993	2000	1983	1404	1797	1491	1843	1429	1362	1996	1333	0

Separability Analysis -- class pairs

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

1973

MISR MRPV$_{red}$+AN$_{RGBNIR}$

TD<1000

Signature Name		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
[illegible]	1	0	1994	2000	2000	2000	2000	2000	2000	2000	1606	2000	2000	1999	2000	2000	2000	2000	1998	2000
[illegible]	2	1994	0	2000	2000	2000	2000	2000	2000	2000	1993	2000	2000	2000	2000	2000	2000	2000	2000	2000
[illegible]	3	2000	2000	0	2000	2000	1970	2000	2000	1999	1946	2000	2000	2000	2000	2000	2000	2000	2000	2000
[illegible]	4	2000	2000	2000	0	2000	2000	1990	2000	1994	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
[illegible]	5	2000	2000	2000	2000	0	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
[illegible]	6	2000	2000	1970	2000	2000	0	1970	1986	1976	1995	2000	2000	1999	2000	2000	2000	2000	2000	2000
[illegible]	7	2000	2000	2000	1990	2000	1970	0	2000	1997	1998	2000	1999	2000	2000	2000	2000	2000	2000	2000
[illegible]	8	2000	2000	2000	2000	2000	1986	2000	0	1994	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
[illegible]	9	2000	2000	1999	1994	2000	1976	1997	1994	0	1999	2000	2000	2000	2000	2000	2000	2000	2000	2000
[illegible]	10	1606	1993	1946	2000	2000	1995	1998	2000	1999	0	2000	2000	2000	2000	2000	2000	2000	2000	2000
[illegible]	11	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	0	2000	2000	1898	2000	2000	2000	2000	1547
[illegible]	12	2000	2000	2000	2000	2000	2000	1999	2000	2000	2000	2000	0	1749	2000	1166	2000	1959	1537	2000
[illegible]	13	1999	2000	2000	2000	2000	1999	2000	2000	2000	2000	2000	1749	0	2000	1054	1999	1964	1943	2000
[illegible]	14	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	1898	2000	2000	0	2000	2000	2000	2000	1783
[illegible]	15	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	1166	1054	2000	0	1995	1710	1482	2000
[illegible]	16	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	1999	2000	1995	0	1917	1877	1999
[illegible]	17	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	1959	1964	2000	1710	1917	0	1827	1999
[illegible]	18	1998	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	1537	1943	2000	1482	1877	1827	0	2000
[illegible]	19	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	1547	2000	2000	1783	2000	1999	1999	2000	0

Separability Analysis -- class pairs

Distance Measure: Transformed Divergence
Using Layers: 1 2 3 4
Taken 4 at a time
Best Average Separability: 1931.7
Combination: 1 2 3 4

1932

MISR AN (R, G, B, NIR)

TD<1000

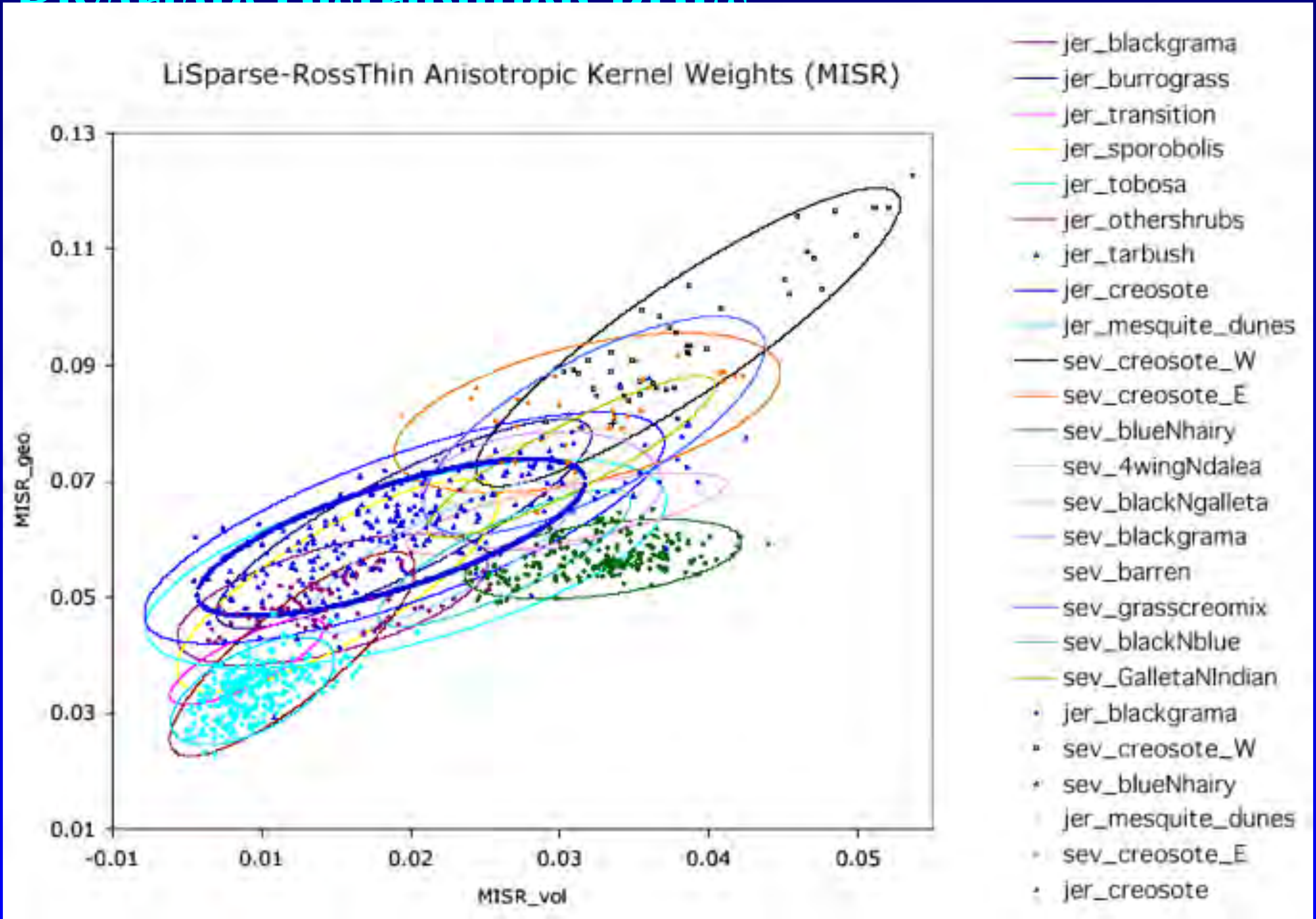
Signature Name	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
[illegible] 1	0	1844	2000	1944	2000	2000	1977	2000	2000	1825	2000	1999	1999	2000	1998	2000	1998	1980	2000
[illegible] 2	1844	0	1999	1999	2000	1999	1976	2000	1989	1861	2000	2000	2000	2000	2000	2000	2000	2000	2000
[illegible] 3	2000	1998	0	1941	2000	1800	1998	2000	1994	1810	2000	2000	2000	2000	2000	2000	2000	2000	2000
[illegible] 4	1944	1999	1941	0	1971	1707	1844	1891	1943	1904	2000	1502	1514	2000	1946	1971	1993	1077	2000
[illegible] 5	2000	2000	2000	1971	0	1985	1975	2000	2000	2000	2000	1980	1997	2000	1999	2000	2000	2000	2000
[illegible] 6	2000	1999	1800	1707	1985	0	1636	1952	1885	1974	2000	1974	1886	2000	1999	2000	2000	1999	2000
[illegible] 7	1977	1976	1998	1844	1975	1636	0	1936	1843	1965	1999	1814	1432	2000	1949	1987	1997	1938	2000
[illegible] 8	2000	2000	2000	1991	2000	1952	1936	0	1901	2000	2000	2000	1989	2000	2000	2000	2000	2000	2000
[illegible] 9	2000	1989	1994	1943	2000	1885	1843	1901	0	1998	2000	1994	1983	2000	2000	2000	2000	2000	2000
[illegible] 10	1825	1861	1810	1904	2000	1974	1965	2000	1995	0	2000	2000	1999	2000	2000	2000	2000	1999	2000
[illegible] 11	2000	2000	2000	2000	2000	2000	1999	2000	2000	2000	0	2000	1998	1709	1998	1978	1994	1998	1229
[illegible] 12	1999	2000	2000	1502	1998	1974	1814	2000	1994	2000	2000	0	1850	2000	889	1985	1929	1408	2000
[illegible] 13	1999	2000	2000	1514	1997	1886	1432	1989	1983	1999	1998	1850	0	2000	1700	1998	1940	1838	2000
[illegible] 14	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	1709	2000	2000	0	2000	2000	2000	2000	1411
[illegible] 15	1999	2000	2000	1946	1999	1999	1949	2000	2000	2000	1998	889	1700	2000	0	1963	1610	1248	1999
[illegible] 16	2000	2000	2000	1971	2000	2000	1987	2000	2000	2000	1978	1985	1998	2000	1963	0	1785	1612	1994
[illegible] 17	1998	2000	2000	1993	2000	2000	1997	2000	2000	2000	1994	1929	1940	2000	1610	1785	0	1741	1996
[illegible] 18	1980	2000	2000	1077	2000	1999	1938	2000	2000	1999	1998	1408	1838	2000	1248	1612	1741	0	2000
[illegible] 19	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	1229	2000	2000	1411	1999	1994	1996	2000	0

Separability Analysis Summary (RED BAND ONLY)

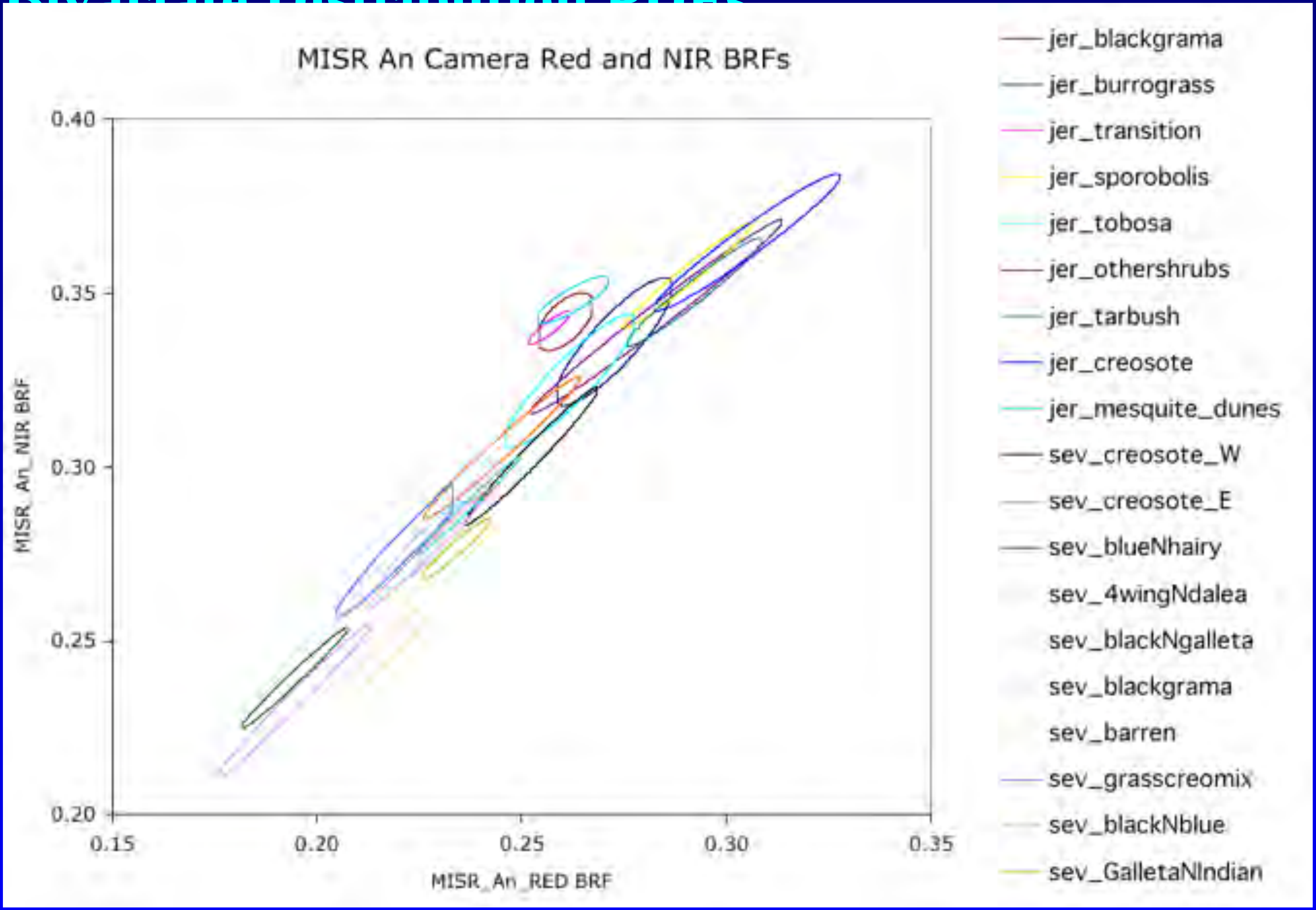
Data Set	Mean TD*	# TD<1000
MISR $MRPV_{red}+AN_{RGBNIR}$	1973	0
MISR AN (R, G, B, NIR)	1932	1
MISR iso, geo, vol	1867	7
MISR+MODIS iso, geo, vol	1839	8
MISR MRPV	1744	13
MODIS iso, geo, vol	1723	13
MODIS+MISR MRPV	1653	17
MODIS MRPV	1624	29

* transformed divergence

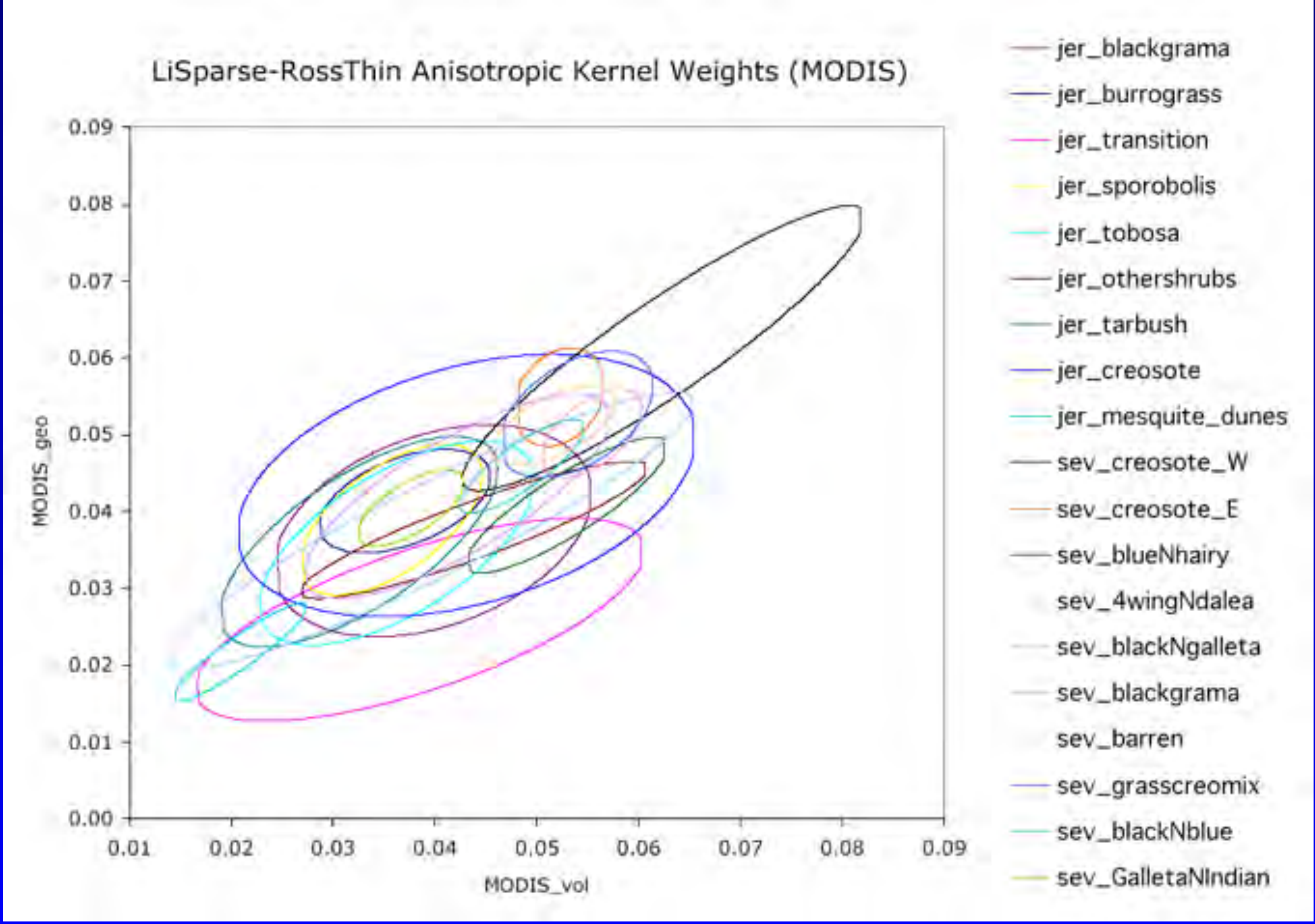
Bivariate Distribution PDFs



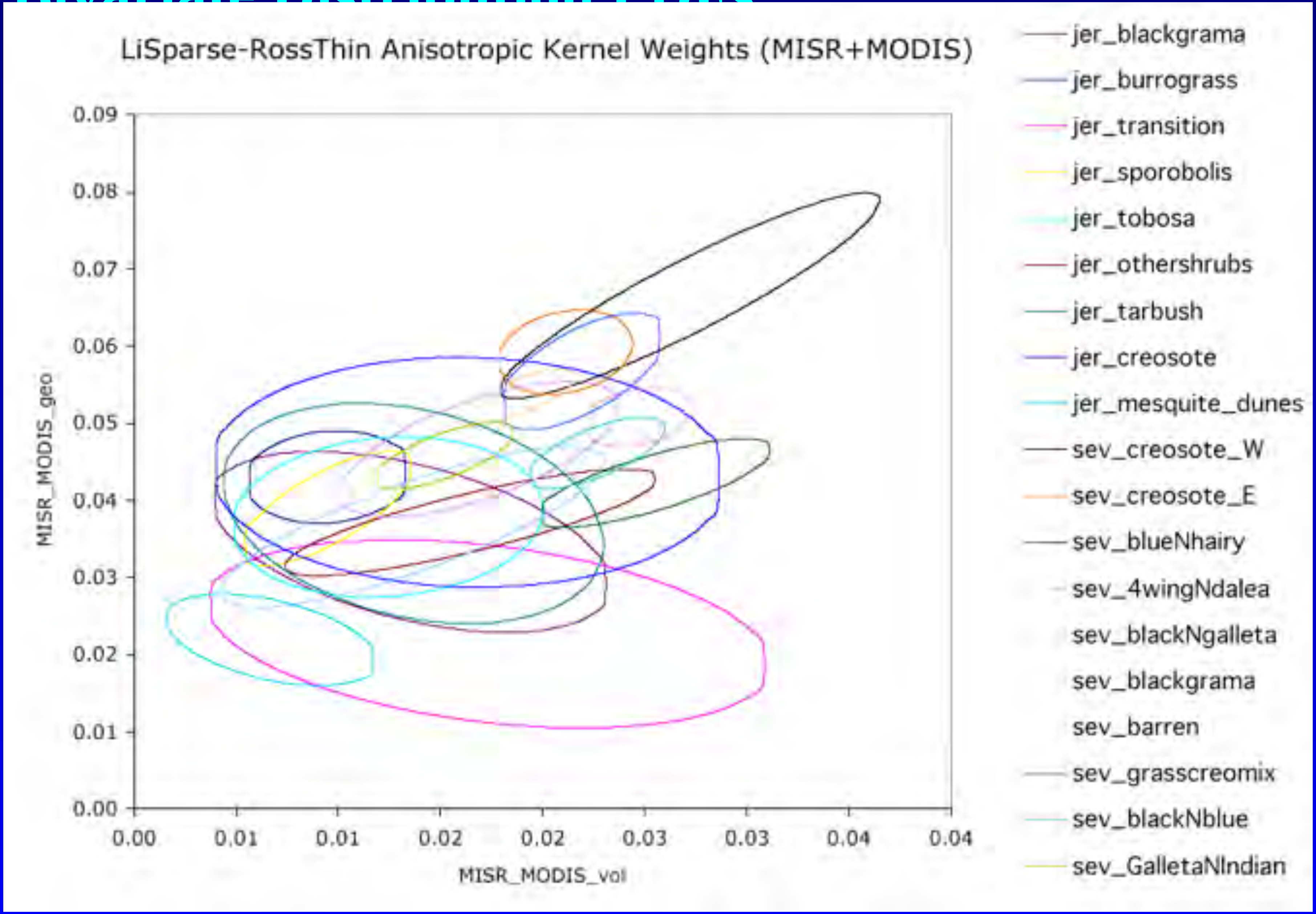
Bivariate Distribution PDFs



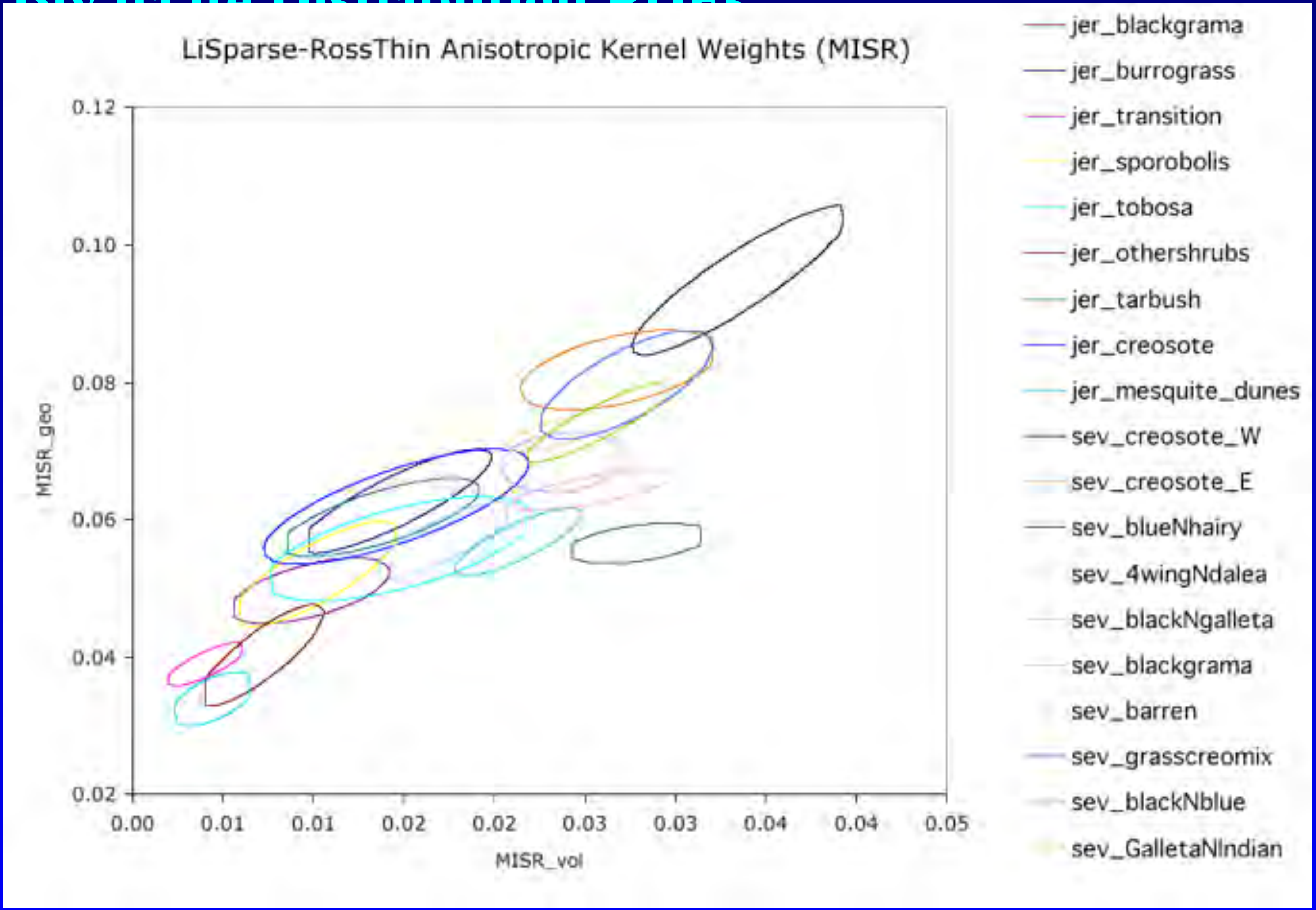
Bivariate Distribution PDFs



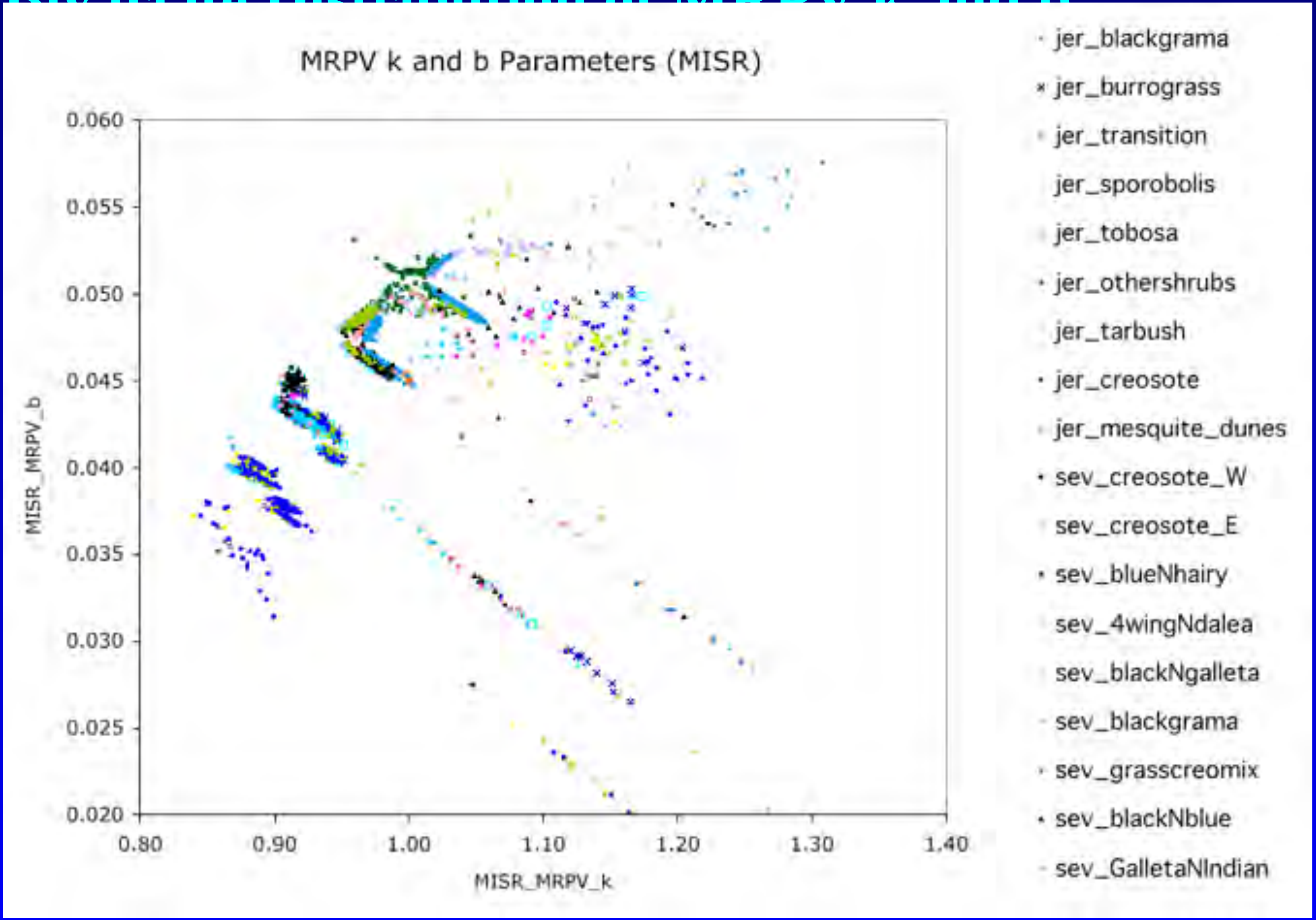
Bivariate Distribution PDFs



Bivariate Distribution PDFs



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

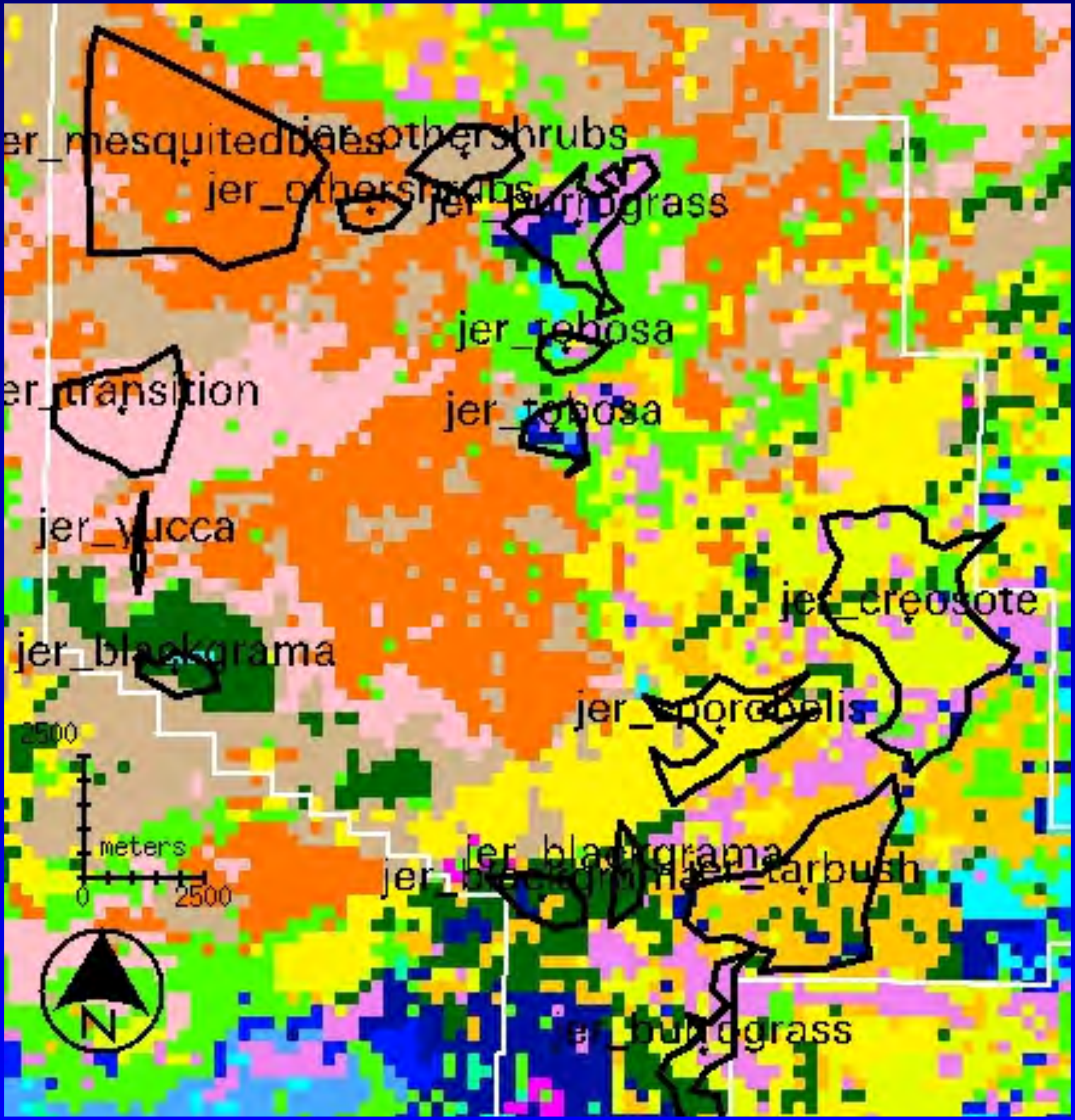
--spectral data (MISR R, G, B, NIR)

Contingency tests

Contingency: MISR An -spectral

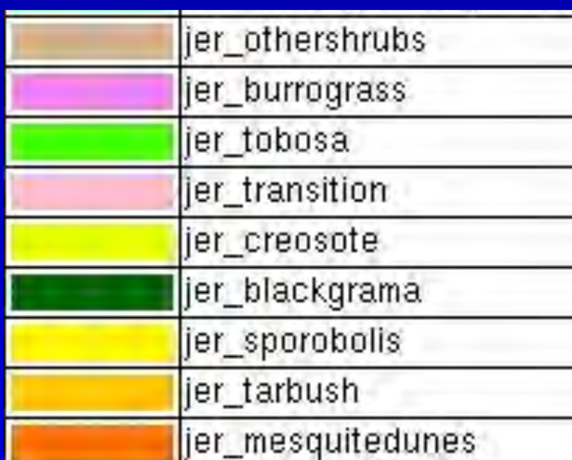
	jer_othershrubs
	jer_burrograss
	jer_tobosa
	jer_transition
	jer_creosote
	jer_blackgrama
	jer_sporobolis
	jer_tarbush
	jer_mesquitedunes

Other colors represent classes belonging to the Sevilleta

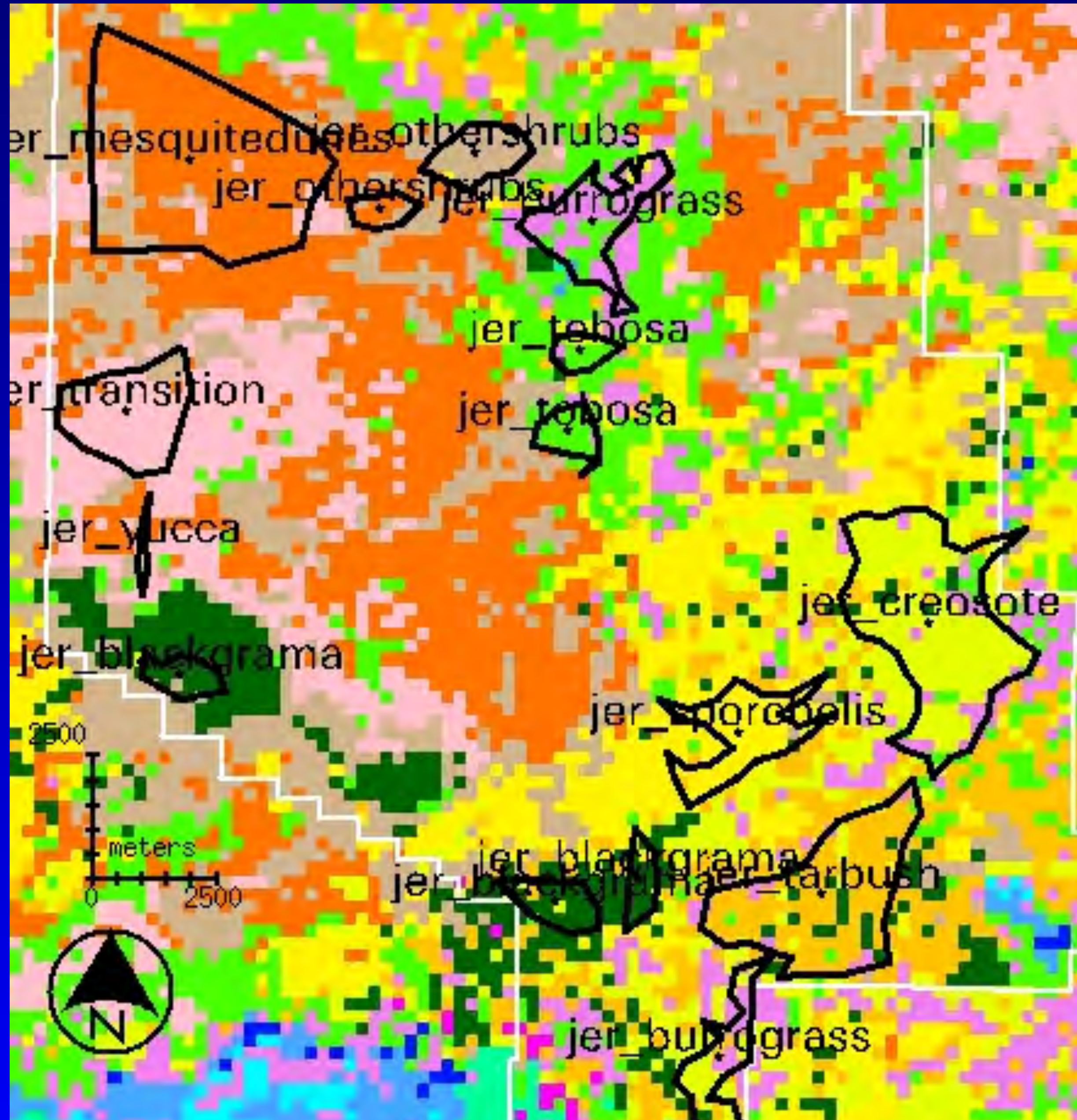


Contingency tests

Contingency: MRPV_MISR_red band + An_all_bands

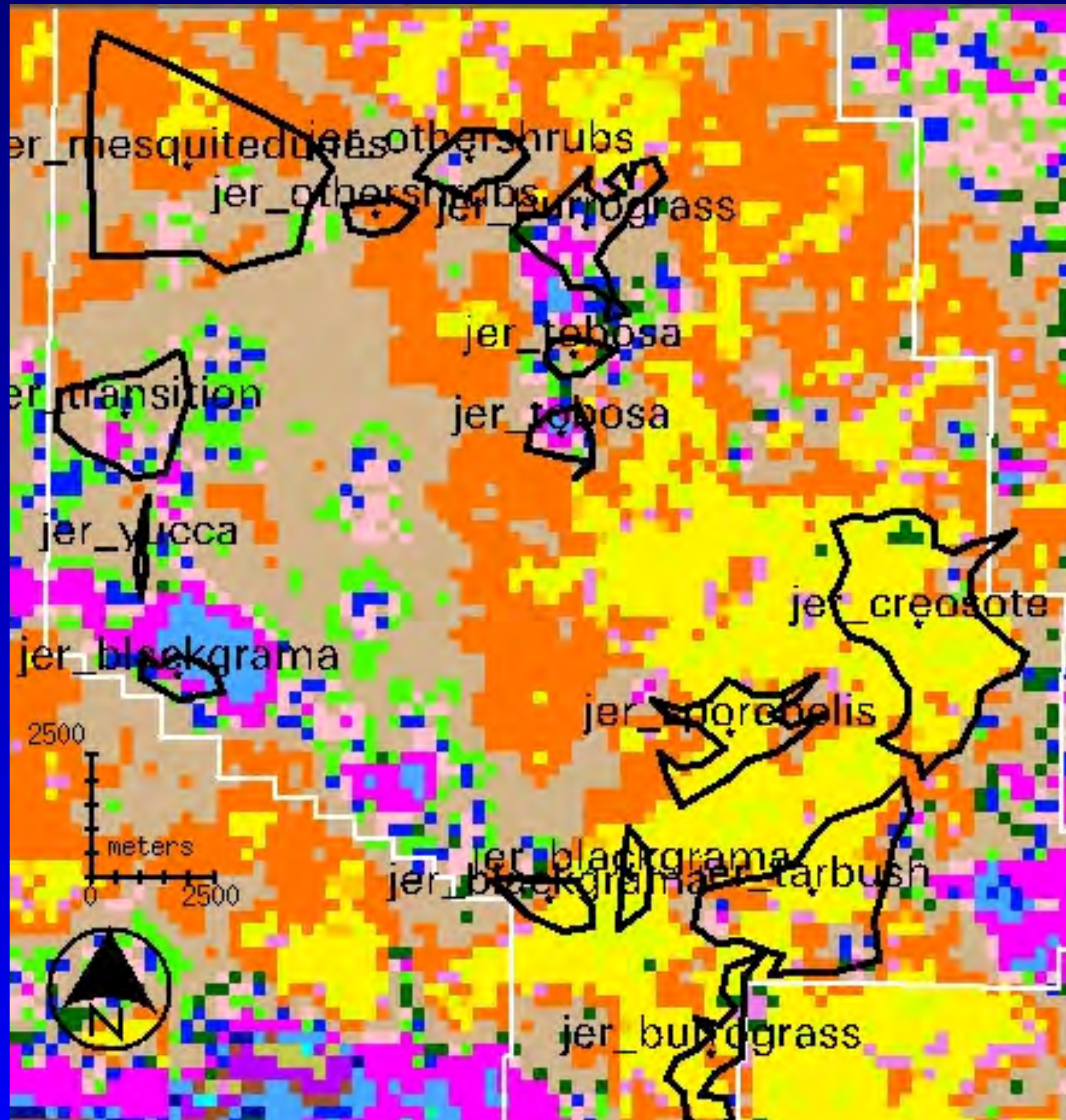


Other colors represent classes belonging to the Sevilleta



Contingency tests

Contingency: MRPV (MISR red band)



jer_othershrubs
jer_burrograss
jer_tobosa
jer_transition
jer_creosote
jer_blackgrama
jer_sporobolis
jer_tarbush
jer_mesquitedunes

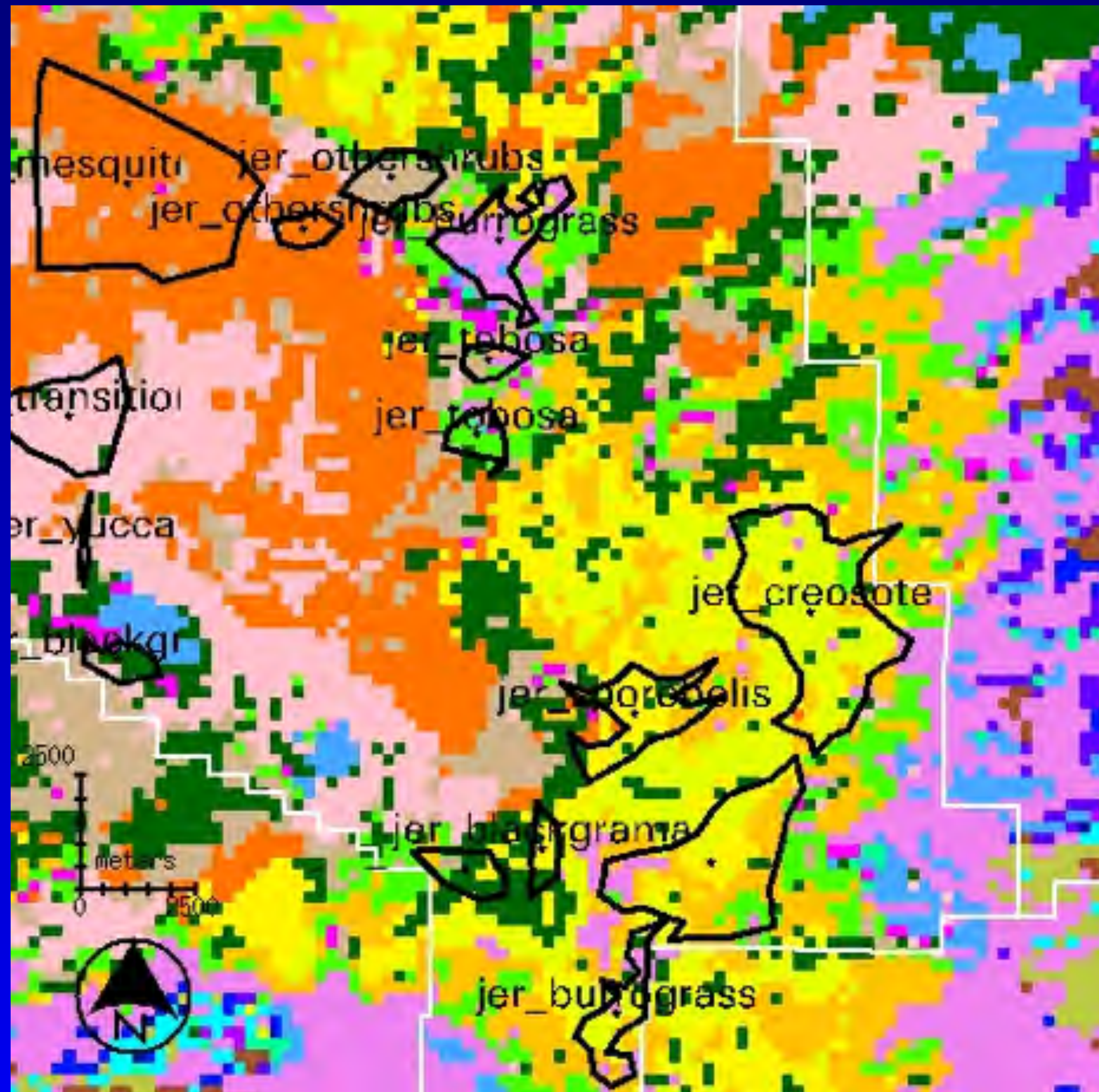
Other colors represent classes belonging to the Sevilleta

Contingency tests

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

	jer_othershrubs
	jer_burrograss
	jer_tobosa
	jer_transition
	jer_creosote
	jer_blackgrama
	jer_sporobolis
	jer_tarbush
	jer_mesquitedunes

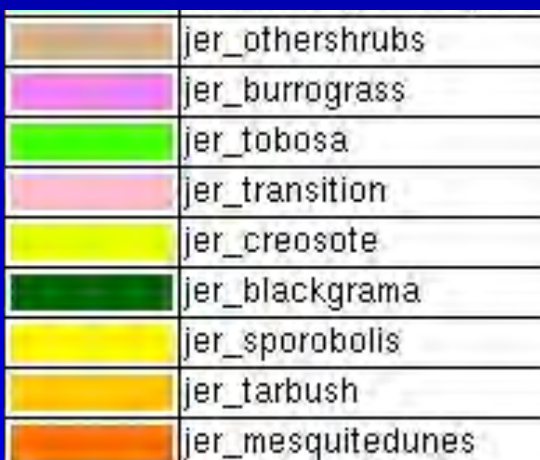
Other colors represent classes belonging to the Sevilleta



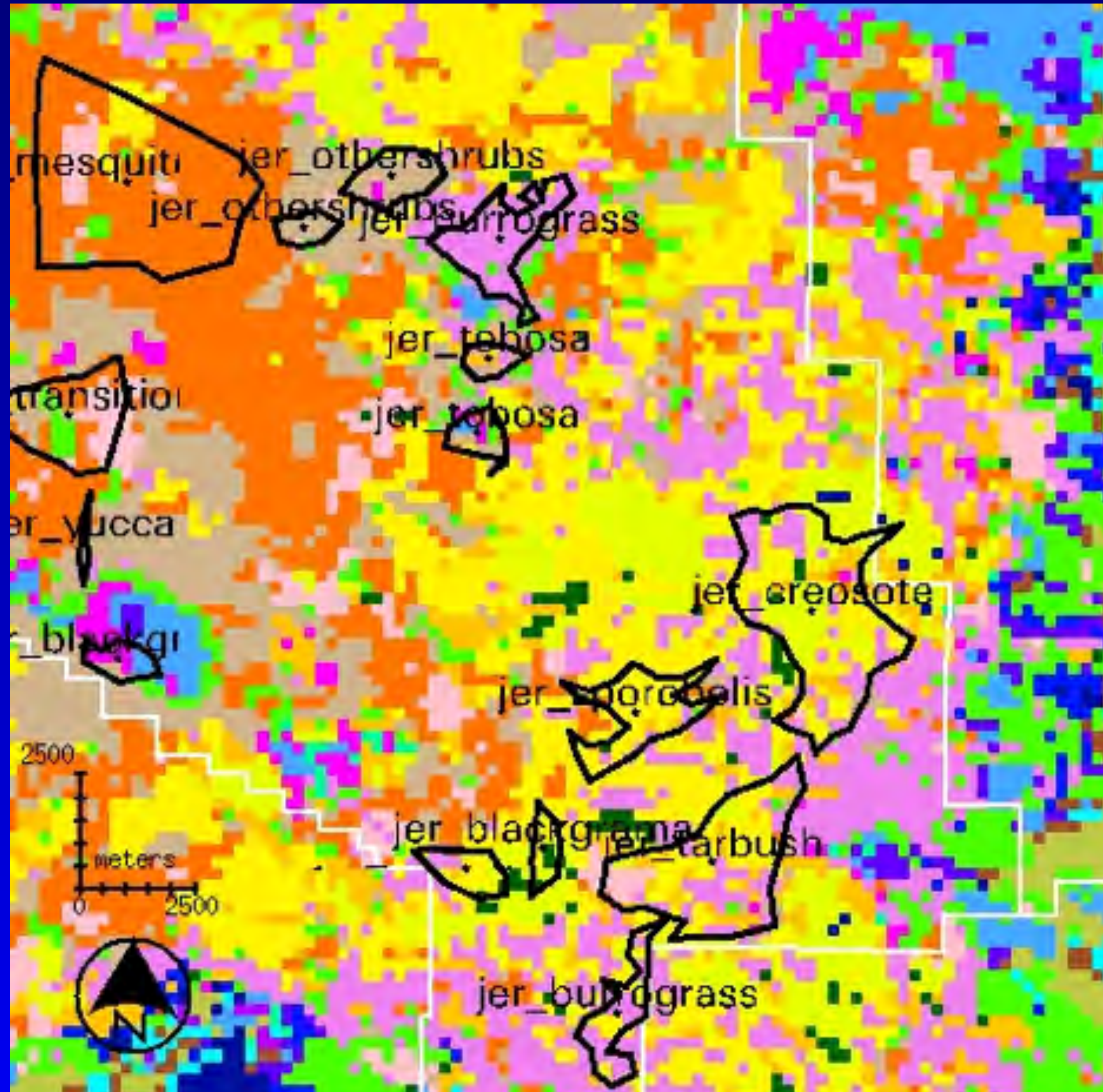
Contingency tests

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

[1] Kremer, R.G. and Running, S.W. 1993. Community type differentiation using NOAA/ AVHRR data within a sagebrush steppe ecosystem. *Remote Sensing of Environment* 46(3): 311-318.

[2] Chopping, M. J., Rango, A., & Ritchie, J. C. (2002). Improved semi-arid community type differentiation with the NOAA AVHRR via exploitation of the directional signal. *IEEE Transactions on Geoscience and Remote Sensing*, 40(5): 1132– 1149.

[3] Pinty, B., Widlowski, J.-L., Gobron, N., Verstraete, M. M., & Diner, D. J. (2002, July). Uniqueness of multiangular measurements: Part 1. An indicator of subpixel surface heterogeneity from MISR. *IEEE Transactions on Geoscience and Remote Sensing*, 40(7): 1560–1573.

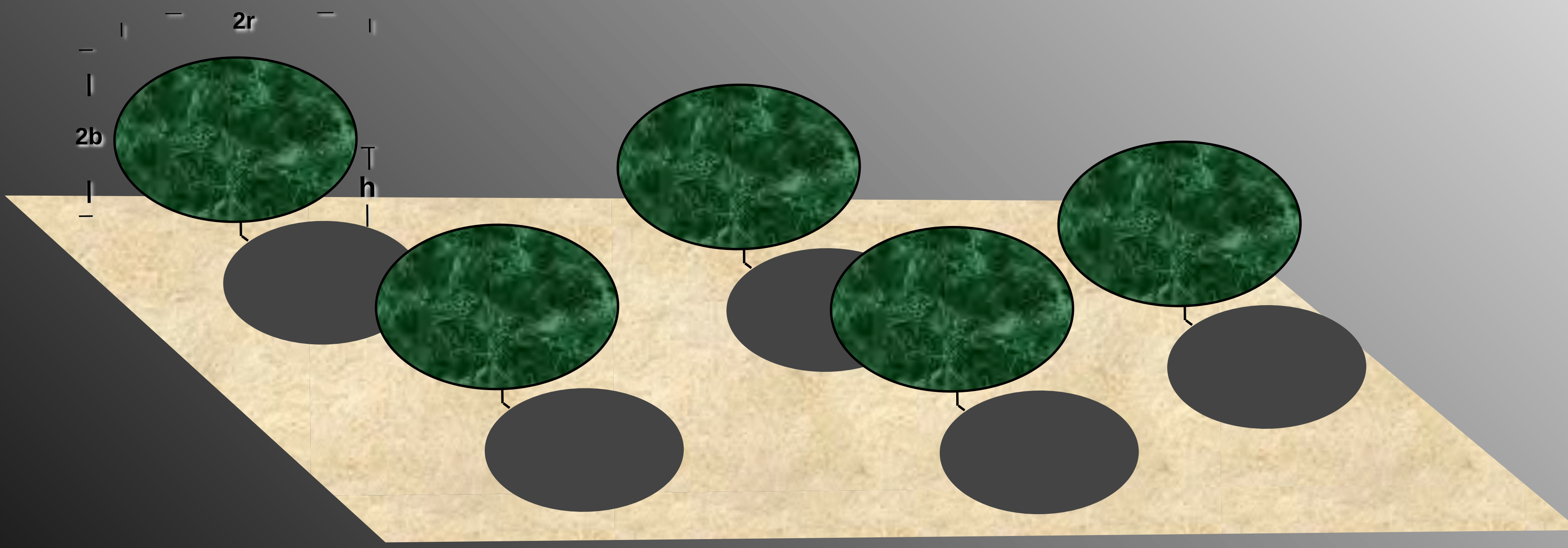
[4] Gao, F., Schaaf, C.B., Strahler, A.H., Jina, Y., Li, X. (2003), Detecting vegetation structure using a kernel-based BRDF model, *Remote Sensing of Environment* 86: 198–205.

[5] Chen, J.M., Liu, J., Leblanc, S.G.. Lacaze, R., Roujean, J-L. (2003), Multi -angular optical remote sensing for assessing vegetation structure and carbon absorption, *Remote Sensing of Environment*, 84: 516-525.

GO modeling
in Desert Grasslands

BRDF / CR Model Inversion (ongoing work)

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:

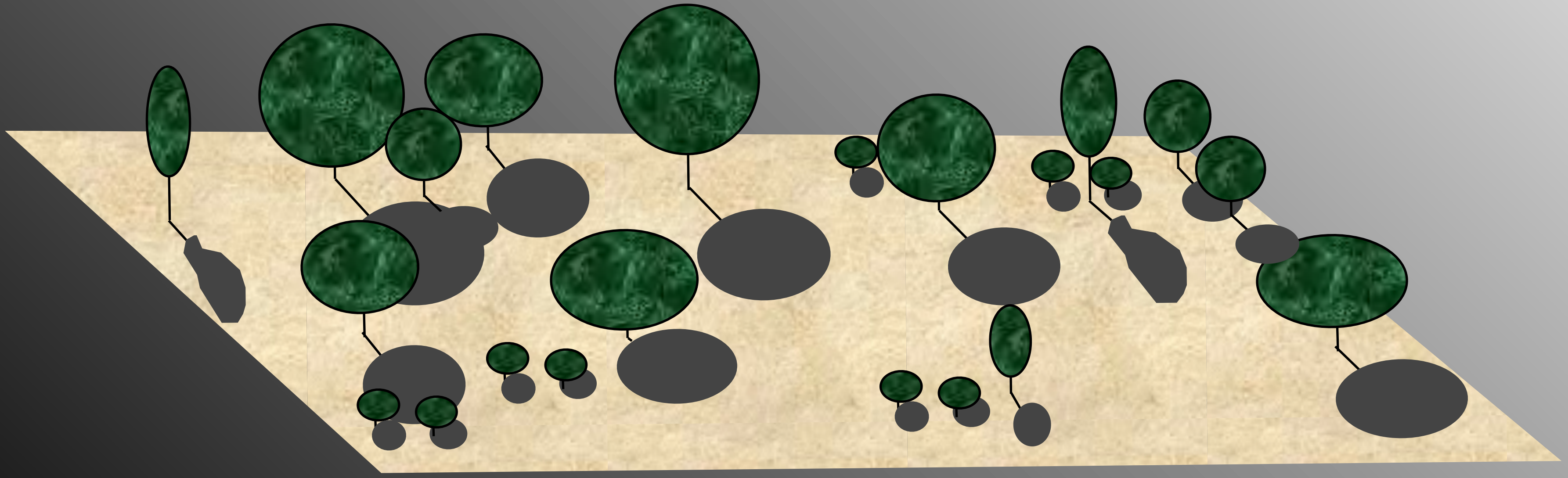


BRDF / CR Model Inversion (ongoing work)

How does a GO model respond to very heterogeneous canopies?

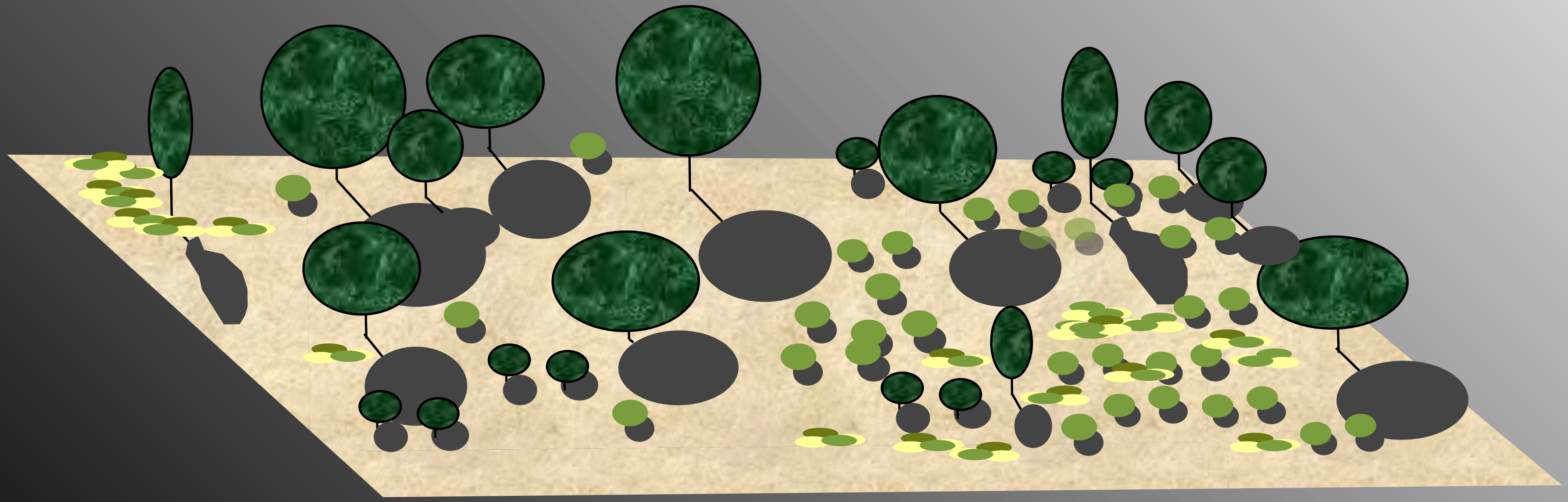
-- are GO principles violated in this case?

-- do GO models operate on mean parameter values?



BRDF / CR Model Inversion (ongoing work)

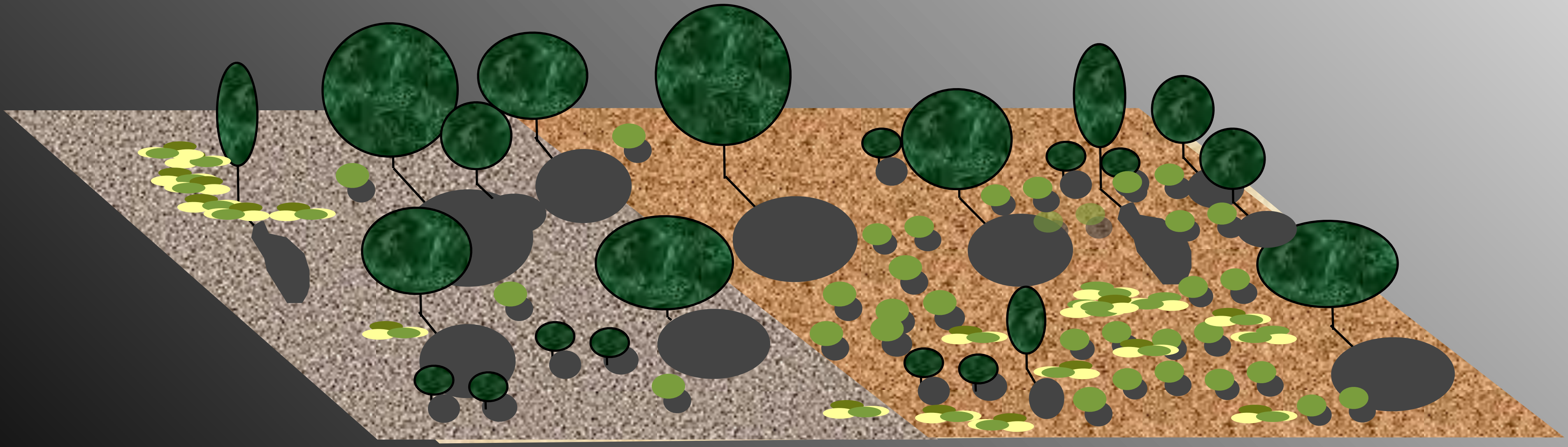
Can GO models work for very heterogeneous canopies which have a highly variable and bright understorey?



Note: MODIS/MISR fields of view are appropriate.

BRDF / CR Model Inversion (ongoing work)

Can GO models work for very heterogeneous canopies which have highly variable and bright understoreys, on different soils?



BRDF / CR Model Inversion (ongoing work)

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.