Effect of image spatial and spectral characteristics on mapping semi-arid rangeland vegetation using MESMA

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Introduction

- Rangeland degradation
  - Livestock overgrazing
  - Drought
  - Climate change
- Invasive shrub encroachment
- Reduced grass vegetation
- Permanent landscape effects
  - Soil erosion
  - Hydrologic alterations
  - Reduced biodiversity
- Novel remote sensing technology
  - Instrumentation
  - Algorithms
  - Vegetation mapping and monitoring

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Introduction

- Instrumentation
  - HyspIRI imaging spectrometer
    - 380 nm to 2500 nm in 10 nm bands
    - 60 m spatial resolution
  - Simulated with existing AVIRIS data (15 m)
- Algorithm
  - Multiple Endmember Spectral Mixture Analysis (MESMA)
  - Unmix image spectra using “pure” endmember spectra
  - Tests multiple endmember combinations for each image pixel
  - Obtain fractional cover maps for each endmember
- Objectives
  - Investigate MESMA for mapping rangeland vegetation
  - Test MESMA sensitivity to spatial and spectral degradations

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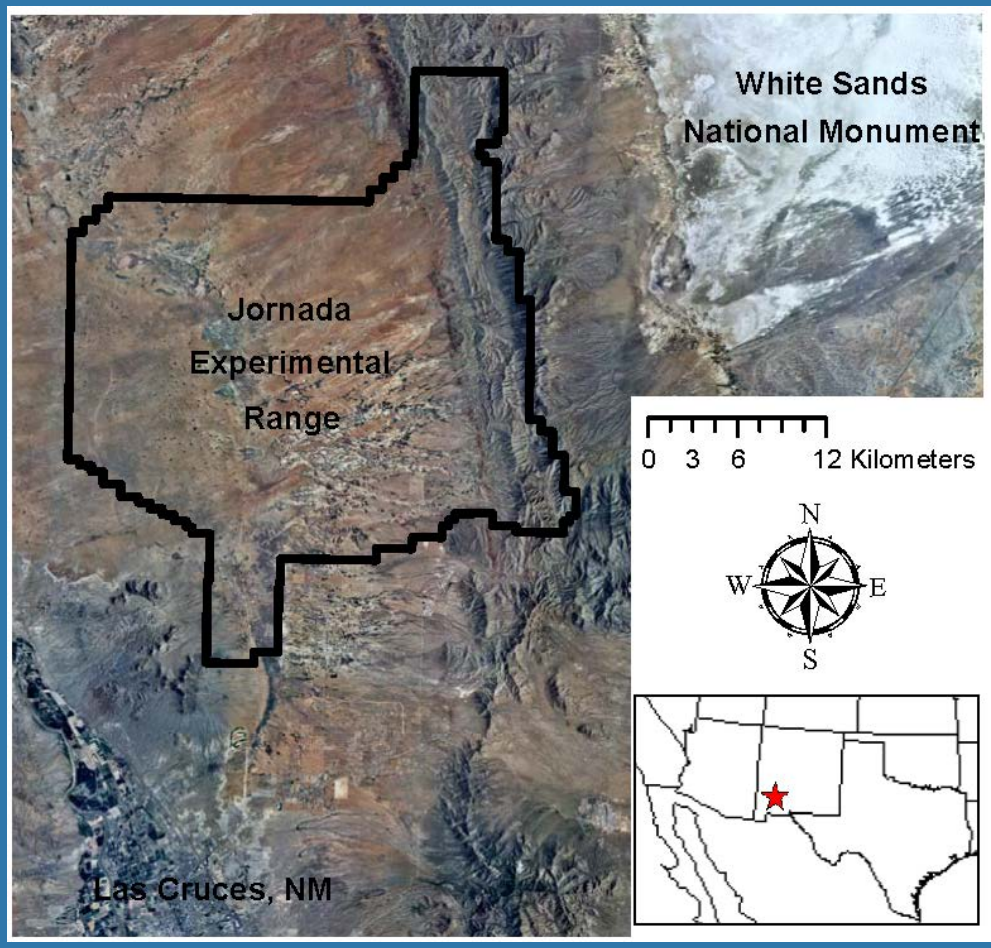
Study Site

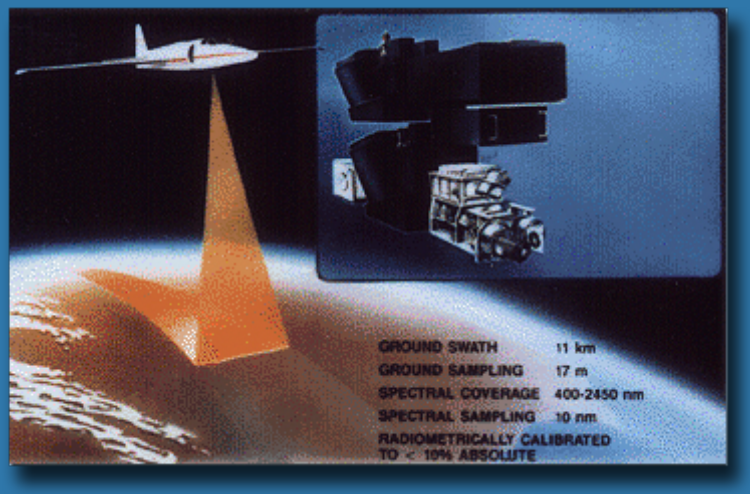
- Jornada Experimental Range
  - Field research lab
  - Established 1912 by USDA
  - 783 km^2
  - 37 km NE Las Cruces, NM
  - 40 km W White Sands



Imaging Spectroscopy

- AVIRIS imagery
  - Jornada overflights
    - June 15, 2001
    - October 9, 2002
    - Five flightlines
  - Simulate HyspIRI spectral data
- Georeferenced to an orthophoto
- Atmospheric correction using “6S” algorithm
- Mosaick five flightlines for each date

AVIRIS

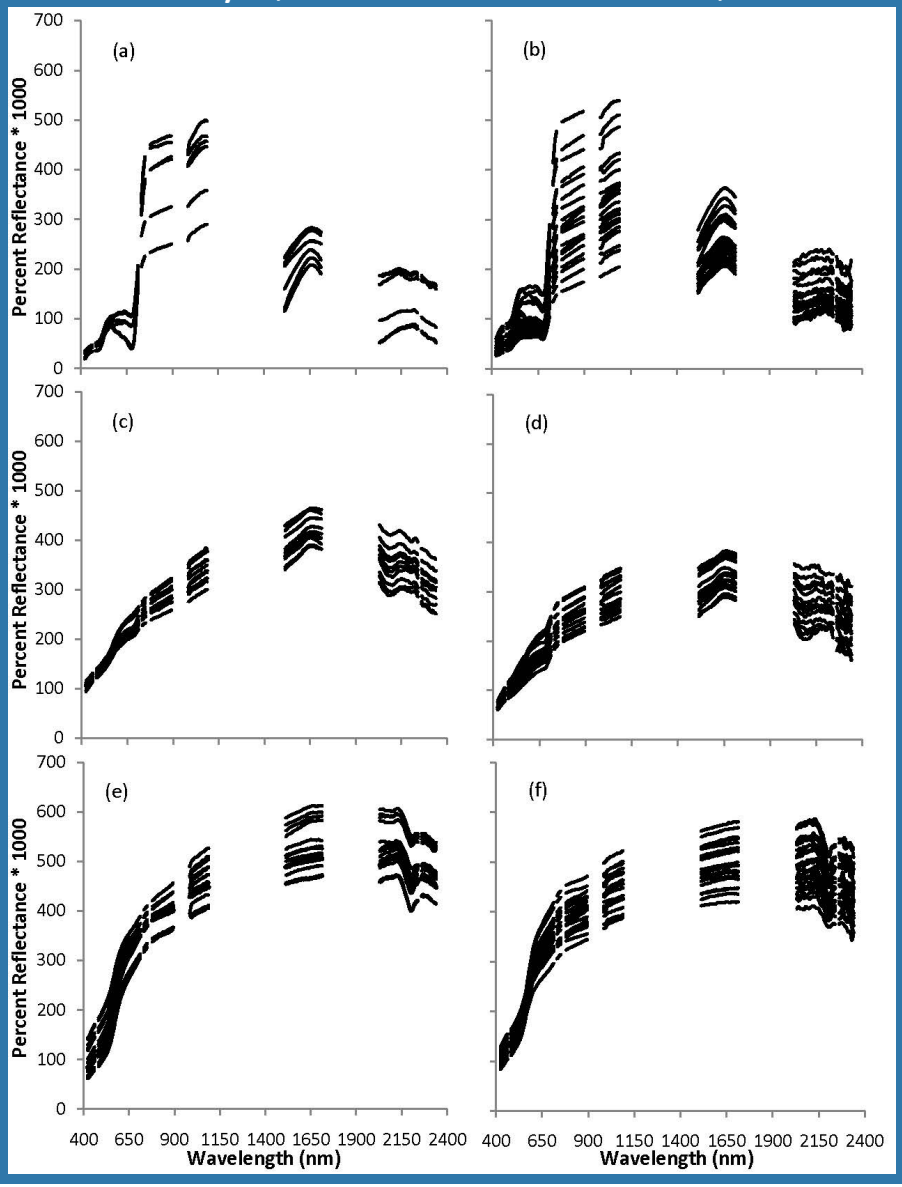


Endmember Spectra

- Field spectroradiometer
  - ASD FieldSpec Pro
  - 350 nm to 2500 nm in 1 nm bands
  - 99% Spectralon panel
  - Prior to AVIRIS overflights
  - Five transects across the range
    - Shrubs: mesquite, creosote, tarbush
    - Grass
    - Transition
  - Documentation
- Dr. Jerry Ritchie (1937-2009)

Endmember Spectra

- Selection of endmember spectra
  - Graphical methods
  - Quantitative methods
  - MESMA methods
  - Goal: spectral separability
- Three final endmembers
  - Green shrub vegetation
  - Nonphotosynthetic grass vegetation
  - Bare soil
- Waveband elimination
  - Ground spectra & AVIRIS data
  - Low signal-to-noise ratio
  - Errors in atmospheric correction



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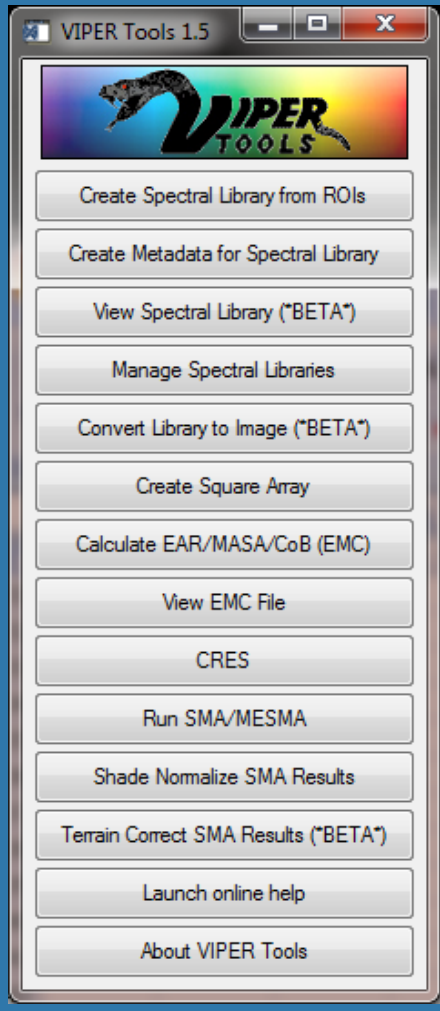
MESMA

- VIPER Tools (www.vipertools.org)
  - Plug-in for ENVI software
  - Conducts MESMA and related algorithms
- Analysis
  - Independent MESMA for each year (2001 & 2002)
  - Four endmembers (Shrub, Grass, Soil & Shade)
  - Resulting fractional cover map for each endmember
- Evaluation
  - Compare MESMA to Jornada vegetation map
  - Compare MESMA between 2001 and 2002 years
  - Compare MESMA to spectral indices from AVIRIS (15 m)
  - Compare MESMA to spectral indices from IKONOS (4 m)



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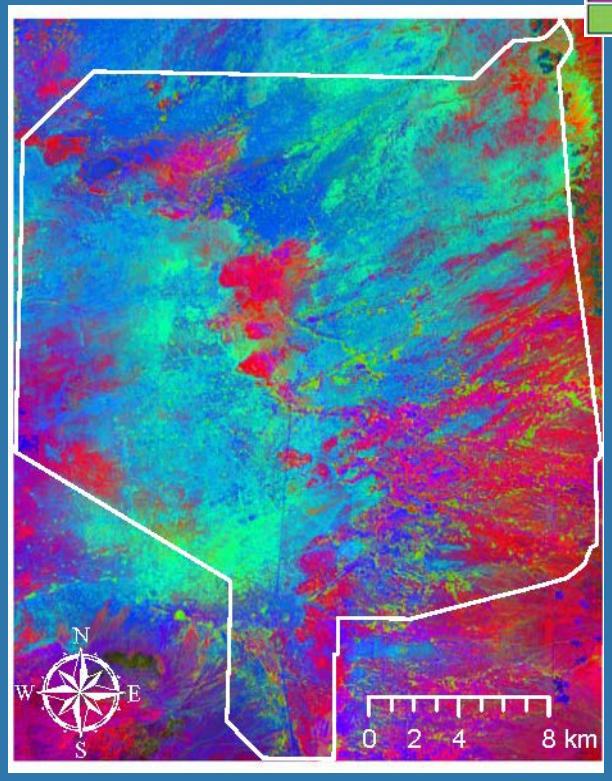
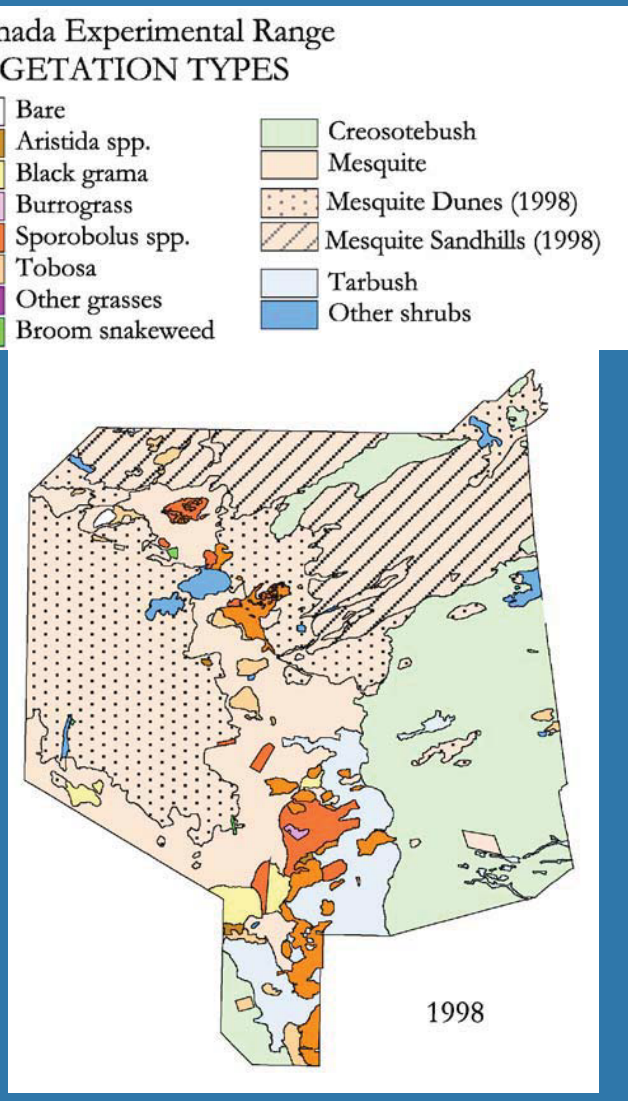
MESMA Results

June 15, 2001



October 9, 2002



1998
Gibbens et al. (2005)

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MESMA Results

- Pearson's r correlations
  - Between 2001 & 2002 MESMAs
    - Shrubs (0.66), Grass (0.67), Soil (0.39)
  - Between shrub endmember and AVIRIS NDVI
    - 2001 (0.73), 2002 (0.58)
  - Between shrub+grass endmembers and AVIRIS CAI
    - 2001 (0.59), 2002 (0.60)
  - Between soil endmember and AVIRIS CAI
    - 2001 (-0.89), 2002 (-0.79)
  - Between 2001 shrub endmember and IKONOS NDVI
    - Southwest subset (0.71), Northwest subset (0.57)

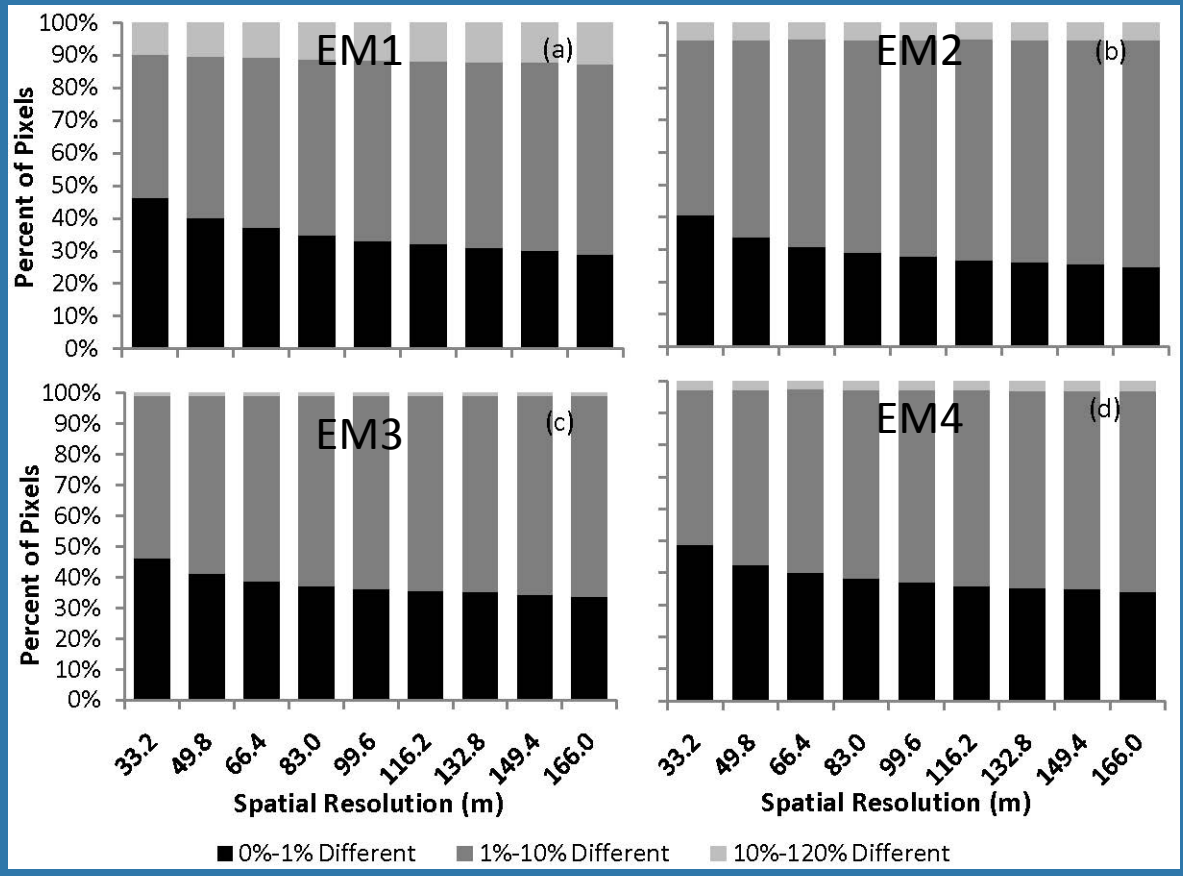
Image Spatial Degradations

- Spatial degradations
  - Ten multiples of original resolution
  - Aggregate AVIRIS images
  - Run MESMA on degraded AVIRIS
  - Aggregate original MESMA as 'Truth'
  - Compare fractional cover results

Multiple	AVIRIS	Degraded MESMA	'Truth' MESMA
1	Original	→	MESMA
2	Aggr. 2x	→ MESMA	Aggr. 2x
3	Aggr. 3x	→ MESMA	Aggr. 3x
.	.	.	.
10	Aggr. 10x	→ MESMA	Aggr. 10x

2001 Spatial Scale Effects

- Avg. Bias < 0.006
- 2nd Multiple:
  - 45% pixels
  - < 1% different
- 10th Multiple:
  - 30% pixels
  - < 1% different
- 90% pixels < 10% different



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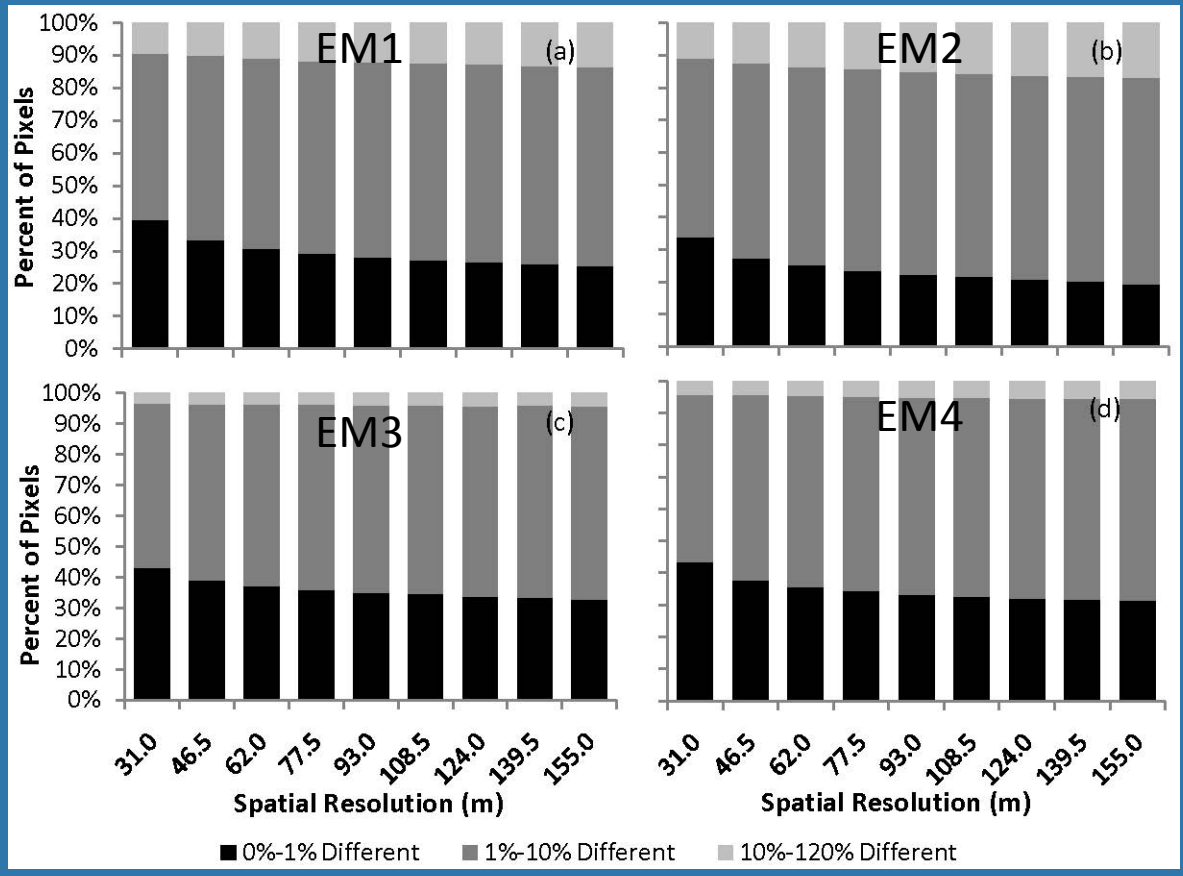
2002 Spatial Scale Effects

- Avg. Bias < 0.02
- 2nd Multiple:
  - 40% pixels
  - < 1% different
- 10th Multiple:
  - 25% pixels
  - < 1% different
- 90% pixels < 10% different



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Spatial Scale Effects at Jornada

- Method of Woodcock and Strahler (1987)
- Effect of spatial scale to resolve 'truth' image features
- Calculate local standard deviation of each endmember
- 60 m HyspIRI will not resolve spatial features at Jornada

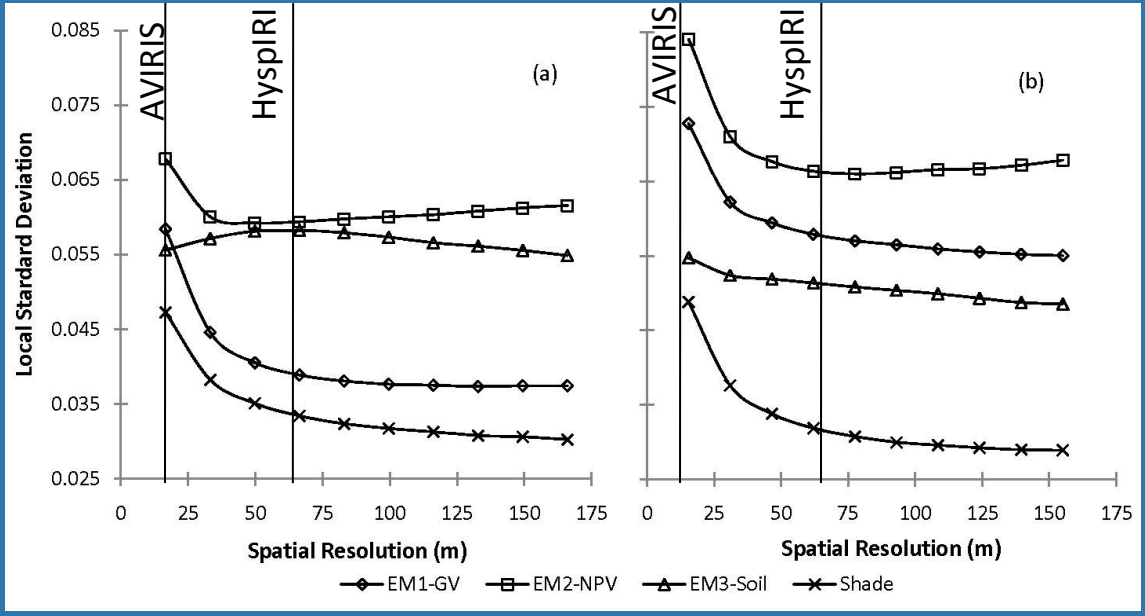

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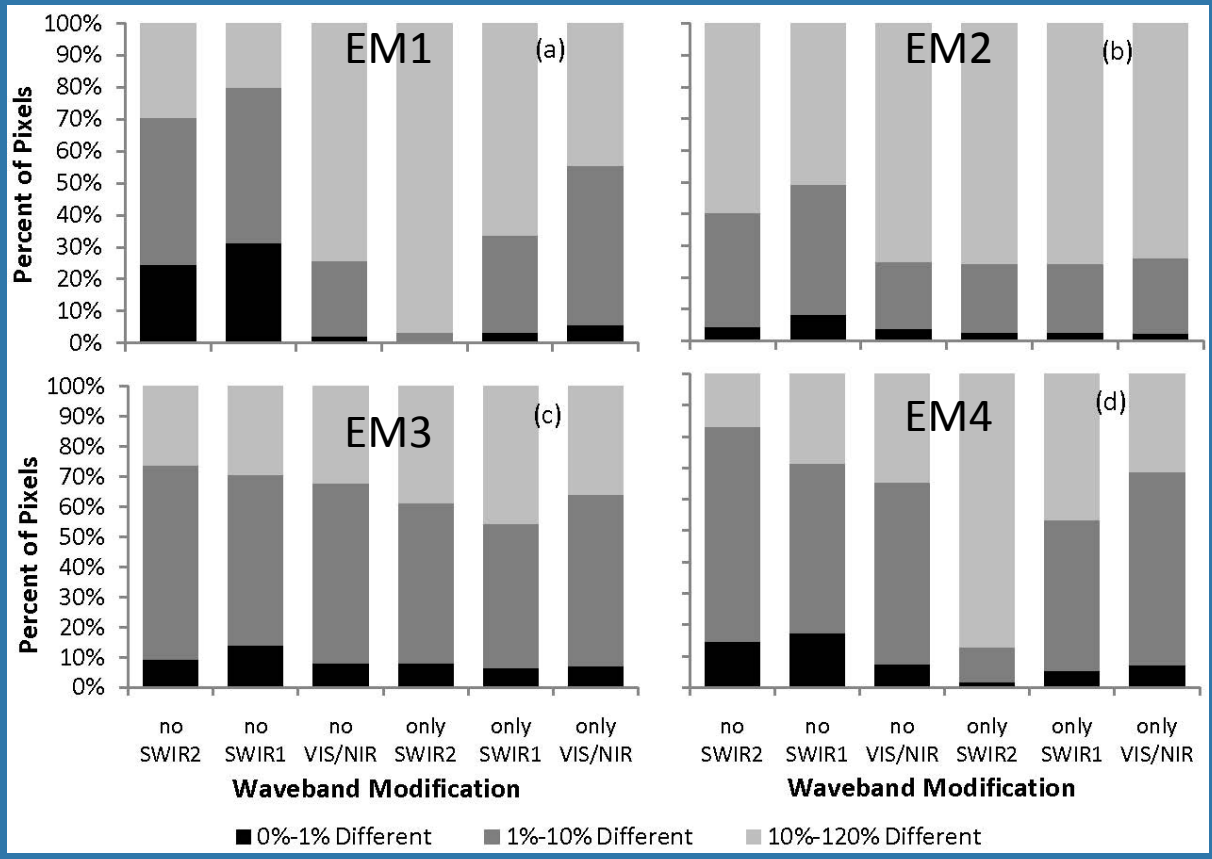
Image Spectral Degradations

- Spectral degradations
  - 6 cases with key waveband eliminated
    - Exclude VIS/NIR (422 nm to 1088 nm)
    - Exclude SWIR1 (1513 nm to 1712 nm)
    - Exclude SWIR2 (2030 nm to 2339 nm)
    - VIS/NIR only (422 nm to 1088 nm)
    - SWIR1 only (1513 nm to 1712 nm)
    - SWIR2 only (2030 nm to 2339 nm)
  - Run MESMA for each case
  - Compare results to original MESMA with all wavelengths included

2001 Spectral Waveband Effects

- Avg. Bias > 0.01
  - 10 or 100 times greater than for spatial effects
- Few pixels < 1% different
- More pixels >10% different
- Need VIS/NIR



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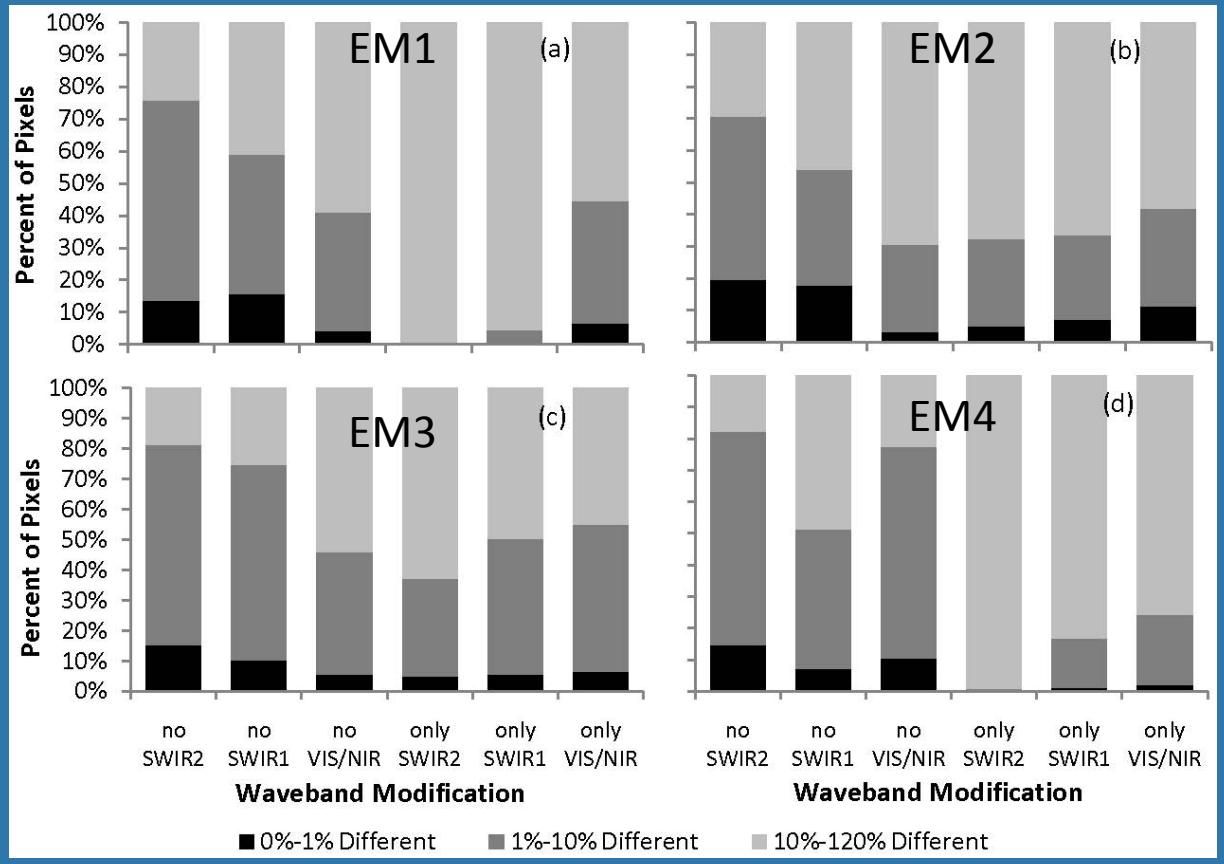
2002 Spectral Waveband Effects

- Avg. Bias > 0.01
  - 10 or 100 times greater than for spatial effects
- Few pixels < 1% different
- More pixels >10% different
- Need VIS/NIR



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Conclusions

- MESMA
  - MESMA effective for distinguishing grass from shrubs
  - MESMA not effective at distinguishing between shrub species
  - MESMA very sensitive to spectral wavebands included
  - MESMA substantially less sensitive to image spatial resolution
- HyspIRI
  - HyspIRI not able to resolve spatial feature at Jornada
  - AVIRIS not able to resolve spatial features at Jornada
  - Optimum spatial resolution < 15 m at Jornada
  - MESMA works at suboptimal spatial resolution
  - Spectral considerations are more important than spatial

Questions?