Estimation of Evapotranspiration over Jornada and Sevilleta, New Mexico Sites with Simulated HyspIRI Data

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USDA ars United States Department Of Agriculture Agricultural Research Service

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Need for Evapotranspiration Research Over Rangeland

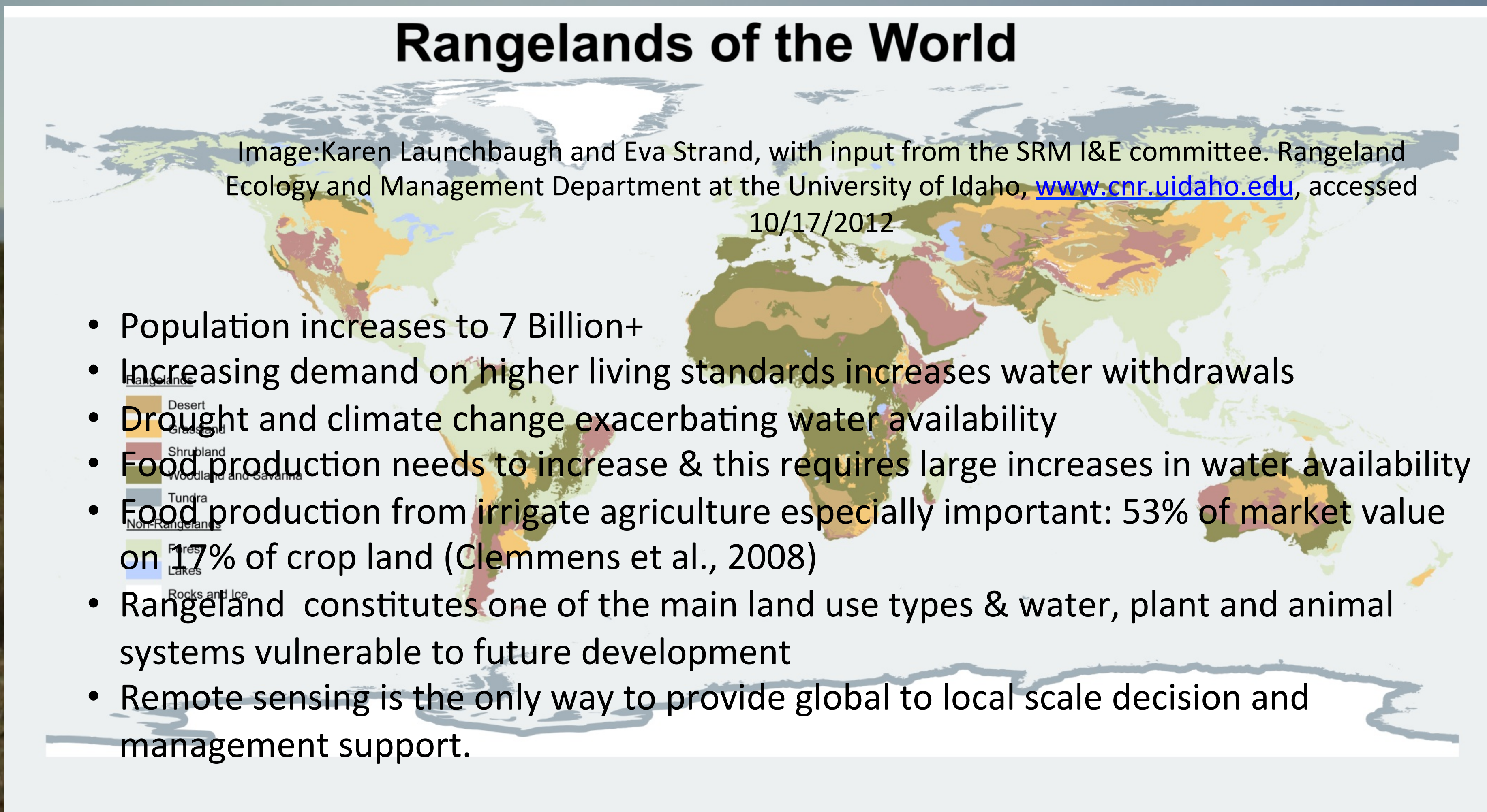


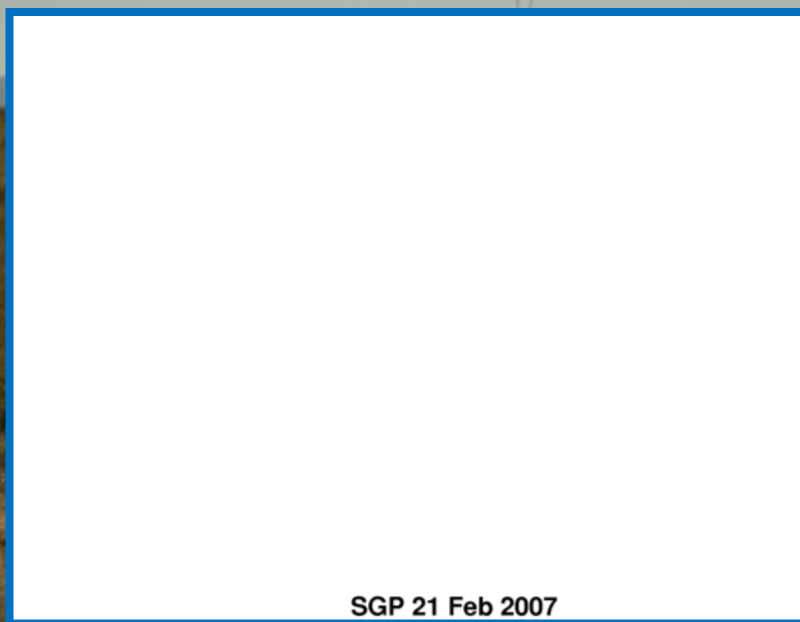
Image:Karen Launchbaugh and Eva Strand, with input from the SRM I&E committee. Rangeland Ecology and Management Department at the University of Idaho, www.cnr.uidaho.edu, accessed 10/17/2012

- Population increases to 7 Billion+
- Increasing demand on higher living standards increases water withdrawals
- Drought and climate change exacerbating water availability
- Food production needs to increase & this requires large increases in water availability
- Food production from irrigate agriculture especially important: 53% of market value on 17% of crop land (Clemmens et al., 2008)
- Rangeland constitutes one of the main land use types & water, plant and animal systems vulnerable to future development
- Remote sensing is the only way to provide global to local scale decision and management support.

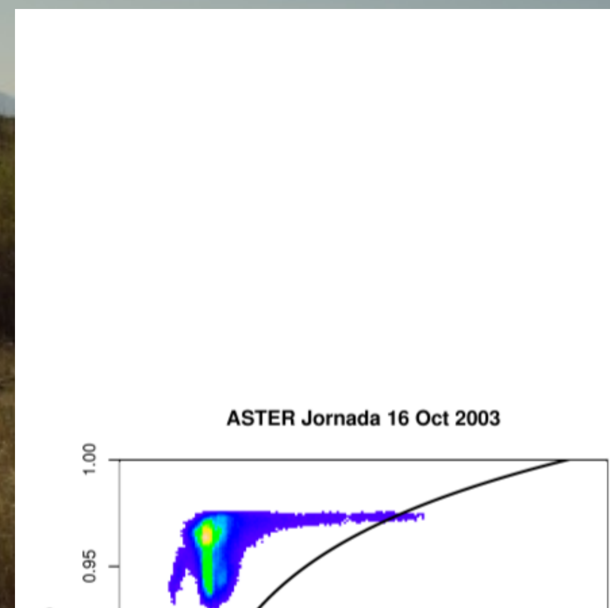
What Can HyspIRI Do to Advance the Science of ET?

- Higher spatial resolution 60 m.
- High overpass frequency 5-19 days.
- Hyperspectral VSWIR remote sensing for land cover classification, albedo quantification & net radiation estimation.
- Multispectral thermal remote sensing for land surface temperature and emissivity.
- Subtext: is Landsat good enough?

HyspIRI Spectral Attributes that help ET Estimation



Improved estimation of net radiation in longwave (and shortwave?)



Spectral emissivities provide surface roughness information independent of VI

Objectives

- Evaluate spatial resolution effects of HyspIRI 60-m data on ET estimates
- Evaluate utility of multispectral thermal infrared data on ET estimation
- Incorporate hyperspectral VSWIR data into ET modeling.

ET Estimation Approaches

- Vegetation Index
    - Empirical estimates based on standard green plant water use
    - Remote sensing data commonly available at <100m resolutions
- Standardized ET : Penman-Monteith

$$\mathrm{LE} = \frac{\Delta}{\Delta + \gamma}\left[\mathrm{R_n} - \mathrm{G}\right] + \frac{\gamma}{\Delta + \gamma}\rho \mathrm{c_p}\left[\mathrm{e}^{\star} - \mathrm{e_a}\right]/\mathrm{r_a}$$

- Surface energy balance
    - Physically based estimates using land surface temperatures
    - Can detect anomalous plant water use & plant stress much more quickly than VI methods
    - Remote sensing data less readily available, analysis more difficult than VI

Surface Energy Balance Approach

Two-Source Energy Balance:

•Incorporation of land surface temperatures to detect non-standard fluxes
•Considers differences in surface roughness between soil and vegetation, thus handling sparse vegetation in a more rigorous way than with single source models.
•Sensitive to LST errors

METRIC/SEBAL:

•Single source approach based on contextual scene-based calibration of ET end members
•Appears to be robust but difficult to implement globally

$$LE = \frac{\Delta}{\Delta + \gamma}[R_n - G] + \frac{\gamma}{\Delta + \gamma}\rho c_p [e^* - e_a]/r_a$$

$$LE_C = f_g \alpha \left[\frac{\Delta}{\Delta + \gamma}\right] R_{n,C}$$

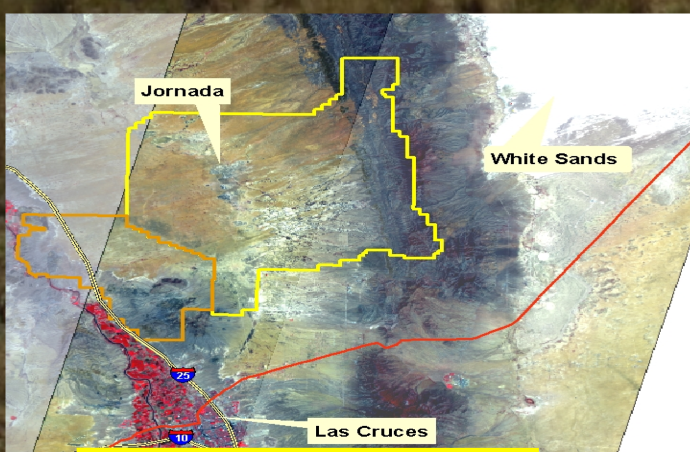
1. Transpiration (E**T** of vegetation): first gues
2. Sensible heat component from LST
3. Evaporation (ET of soil): key part of TSEB
4. Transpiration if LST canopy known.

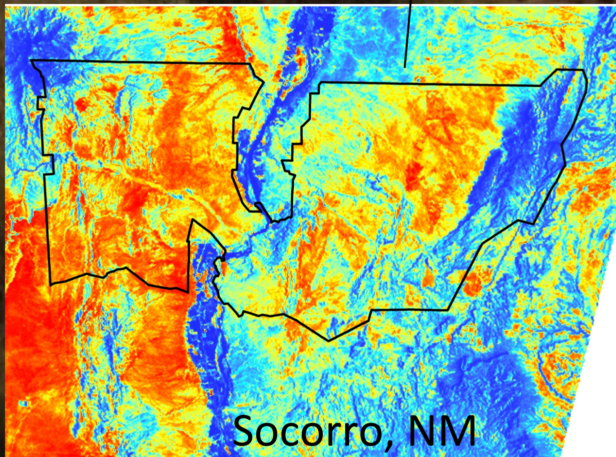
Study Sites & Remote Sensing Data

Jornada:
LTER (1982) & USDA Research Rangeland site since 1912. Desertification causes and trends.

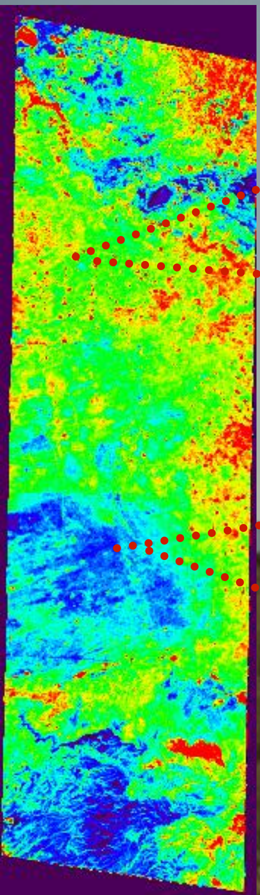
Sevilleta: LTER rangeland site in central NM since 1989. Biotioc and Abiotic ecosytem drivers of change in grasslands, shrublands & riparian zones.

MASTER data collected 1998-2010 on 8 sorties. 3-12m resolution
AVIRIS data collected 1998-2002. 89+ scenes collected , georegistered, corrected and modeled.





Local Validation of ET Modeling at Jornada



3*3 (60 m)

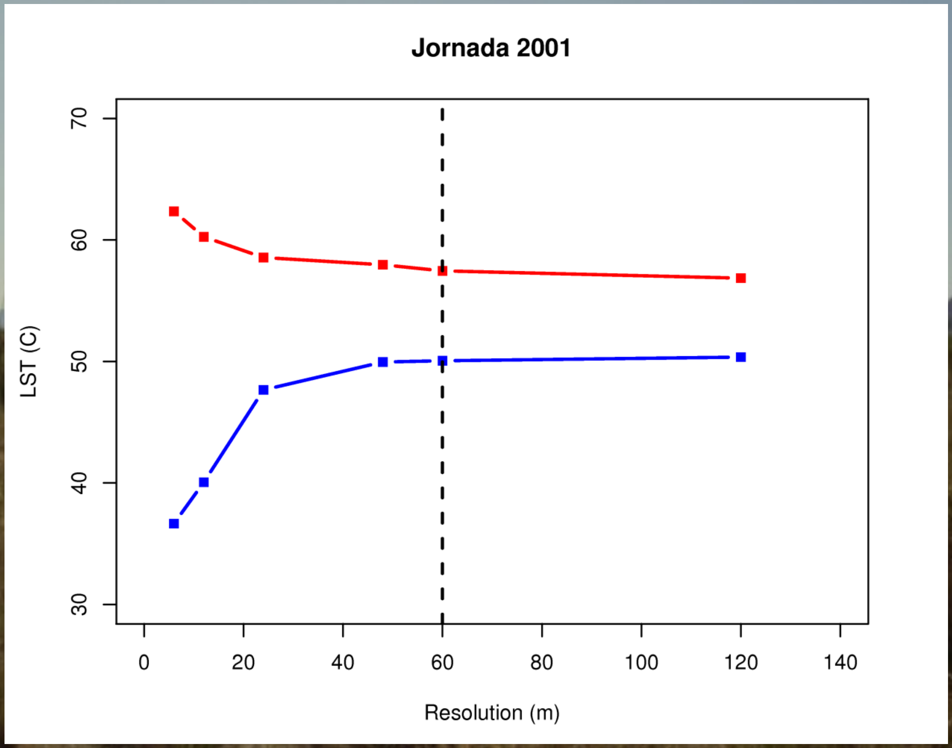
Mesquite

3*3 (60 m)

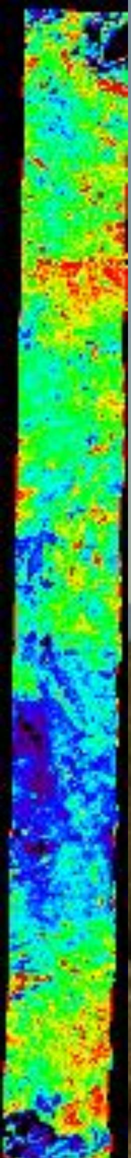
Grass

Date	Time	Grass/Mesquite	Rn			G		H			LE		
			Observed	Predicted	Diff.	Observed	Predicted	Observed	Predicted	Diff.	Observed	Predicted	Diff.
20-May-04	17:36	G	562	441	-121	x	124	374	263	-111	31	51	20
	17:53	M	540	460	-80	x	116	364	258	-106	27	82	55
	18:42	G	564	441	-123	x	135	392	257	-135	30	45	15
	18:42	M	610	452	-158	x	123	348	241	-107	34	85	51
4-Oct-07	17:19	M	457	407	-50	x	91	280	175	-105	28	139	111
22-Oct-08	17:45	G	424	380	-44	x	92	224	231	7	26	55	29
	18:52	G	386	357	-29	x	84	214	253	39	24	17	-7
Mean/Bias			*506*	*420*	*-86*		*109*	*314*	*240*	*-74*	*29*	*68*	*39*
RMSE				**97**					**97**			**53**	
%				**19**					**31**			**185**	

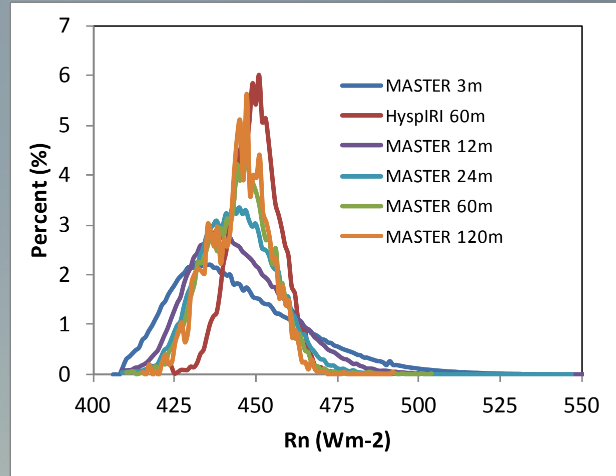
Results: Effect of Spatial Resolution on ET Estimates

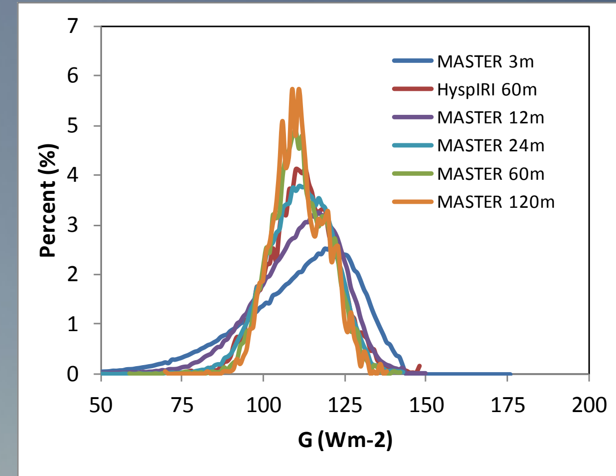


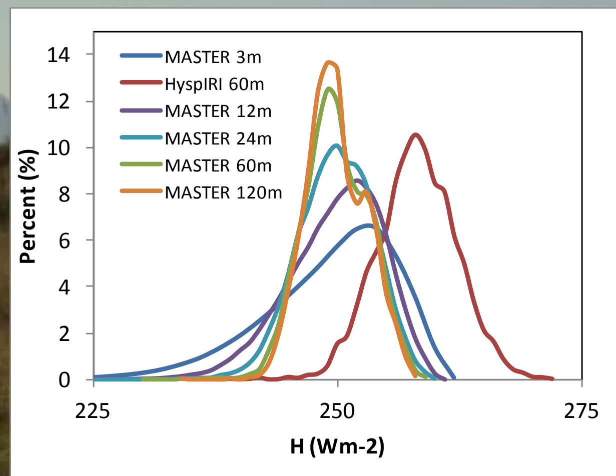
Spatial heterogeneity at Jornada is less than 10 m
-No proposed sensor would resolve at this level
-Are the resulting ET estimates nevertheless accurate on aggregate?

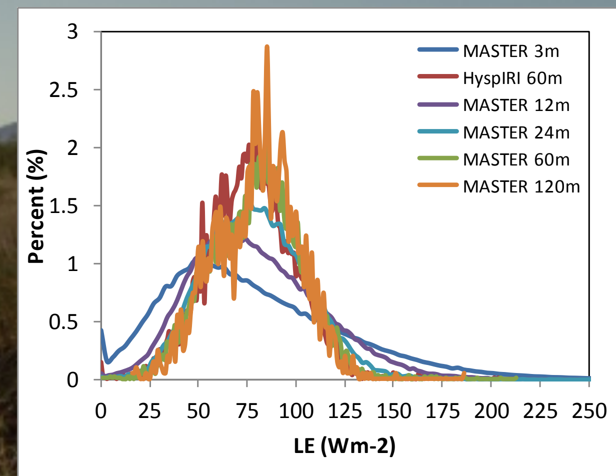


20 MAY 2004 17:36 (JORNADA)





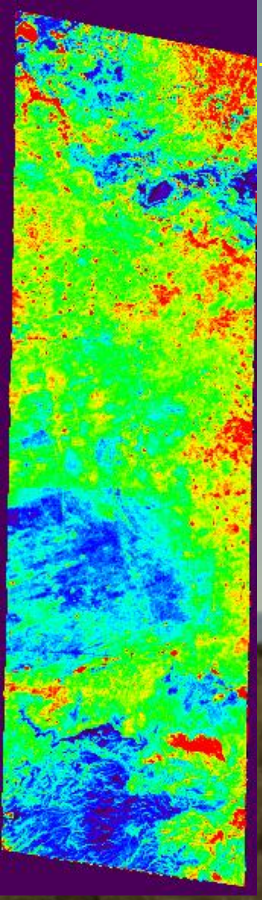




HYSPIRI/MASTER (60m)	Bias	RMSE
Rn	5	6
G	0.8	2.1
H	8	8
LE	-3	4

MASTER: N-S transect over key grassland and mesquite dune sites

	MASTER 3m		MASTER 12m		MASTER 24m		MASTER 60m		MASTER 120m		HYSPIRI 60m	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Rn	445	21	445	15	445	12	445	10	445	9	450	8
G	111	18	111	13	111	10	111	9	111	8	112	11
H	250	7	250	5	250	4	250	3	250	3	258	4
LE	80	47	80	33	80	27	80	23	79	21	76	22



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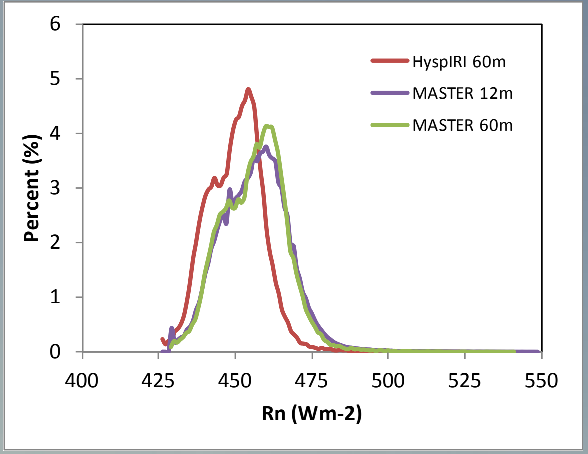
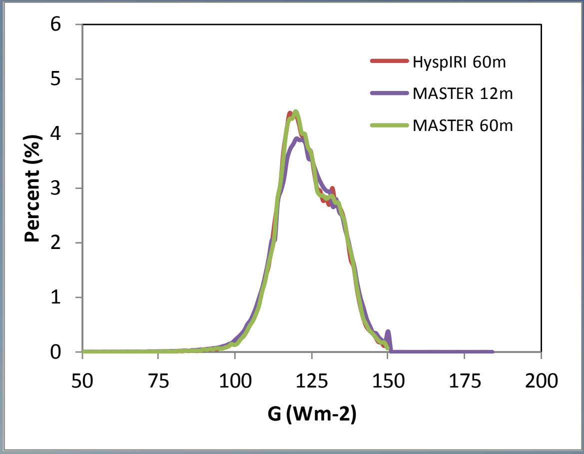
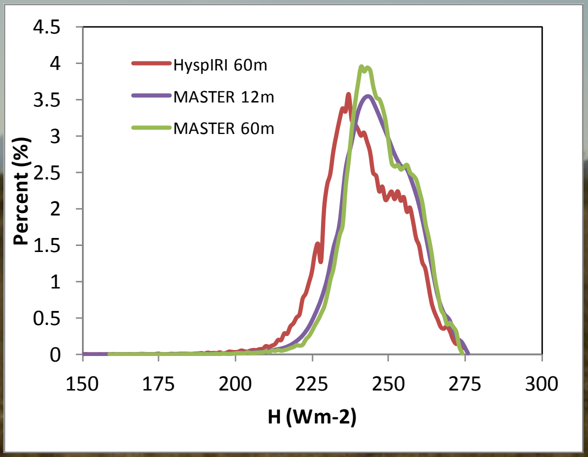
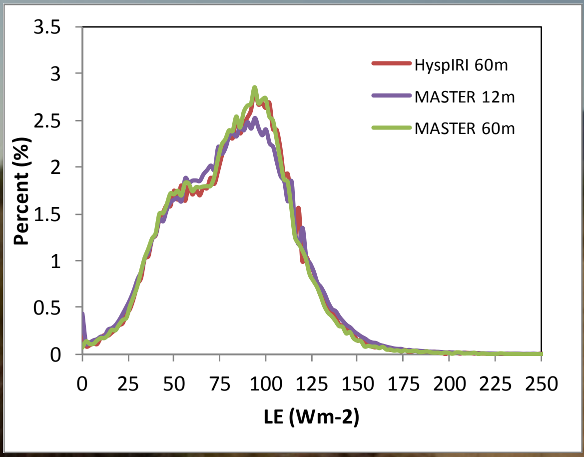
JORNADA









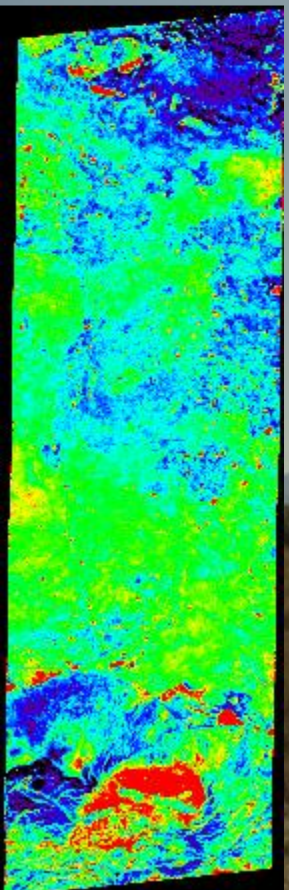
MASTER: N-S transect over key grassland and mesquite dune sites

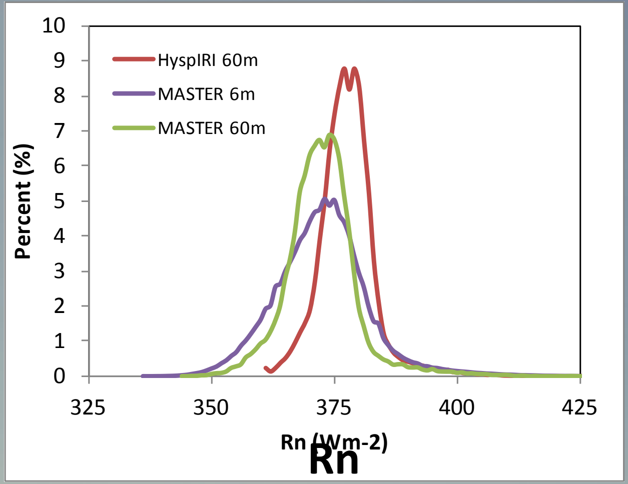
HYSPIRI/MASTER (60m)	Bias	RMSE
Rn	-4	5
G	-0.09	0.6
H	-5	5
LE	0.8	1.9

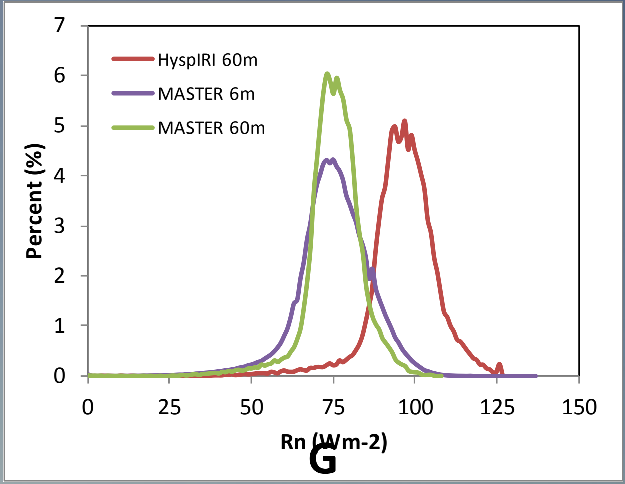
	MASTER 12m		MASTER 60m		HYSPIRI 60m	
	Mean	SD	Mean	SD	Mean	SD
Rn	456	11	456	10	452	9
G	124	11	124	10	124	10
H	247	12	247	11	242	13
LE	82	34	82	31	83	32

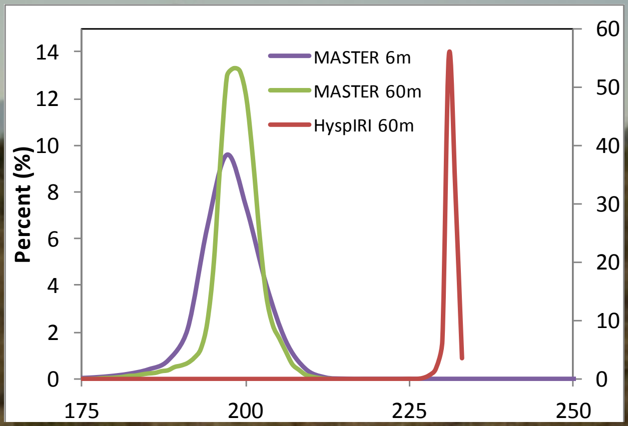
22 OCTOBER 2008 17:45

(JORNADA)









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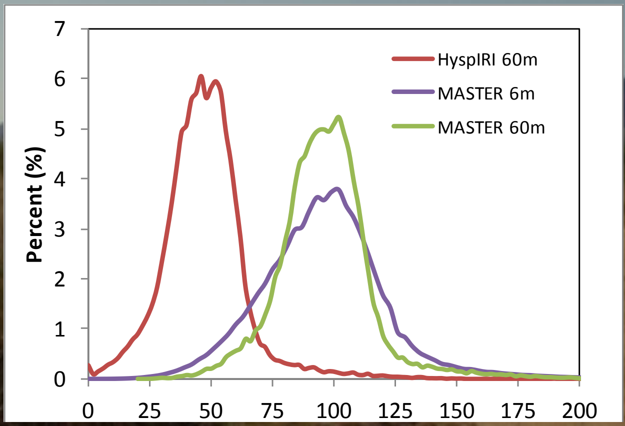


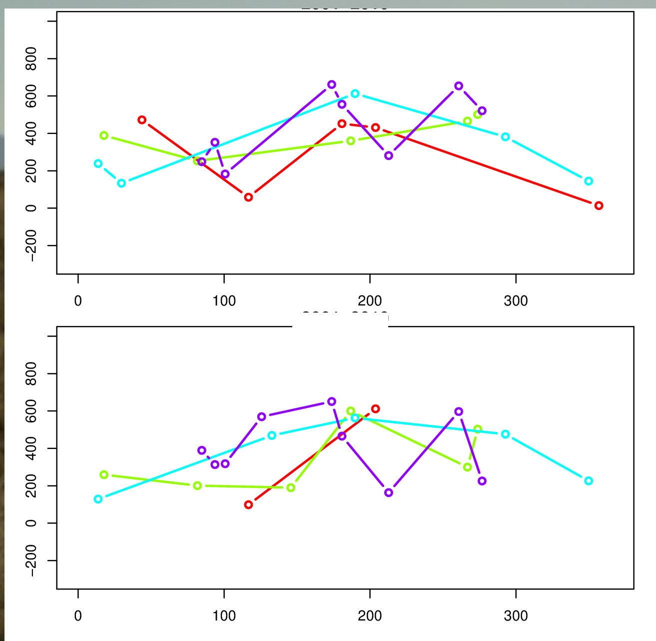
LE

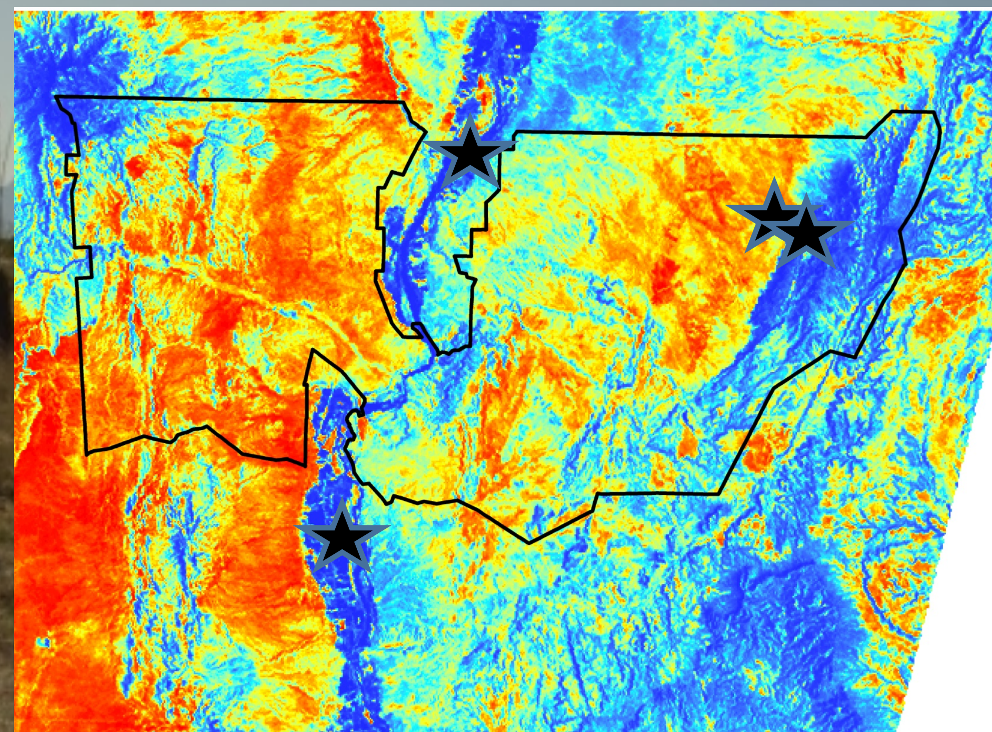
MASTER: N-S transect over key grassland and mesquite dune sites

HYSPIRI/MASTER (60m)	Bias	RMSE
Rn	5	5
G	21	21
H	33	33
LE	-49	49

	MASTER 6m	MASTER 60m			HYSPIRI 60m	
	Mean	SD	Mean	SD	Mean	SD
Rn	373	10	373	7	378	6
G	75	11	75	9	97	10
H	198	5	198	4	231	2
LE	97	26	97	20	48	17

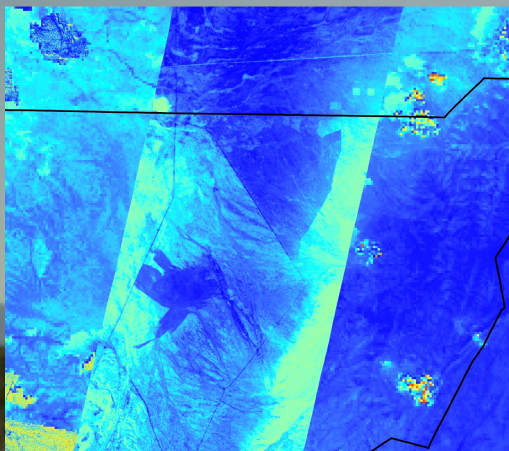
Temporal & Spatial Variability of ET at Sevilleta 2003



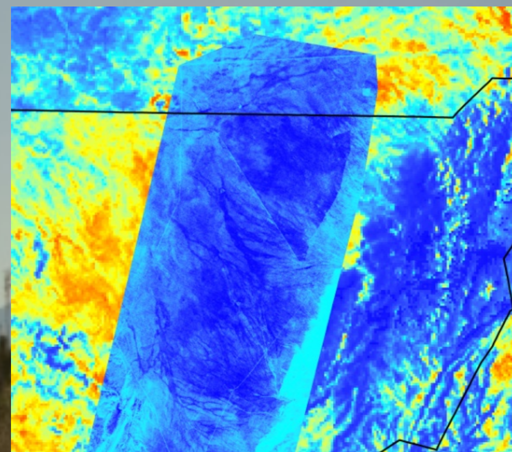


- Two-Source Energy Balance Modeling of latent heat fluxes detect seasonal changes at fine spatial scales
- Riparian vegetation- crops and tamarisk (Blue and Purple) follow unimodal pattern
- Grassland and burned area (Red and Green) show less LE flux and reflect rainfall events

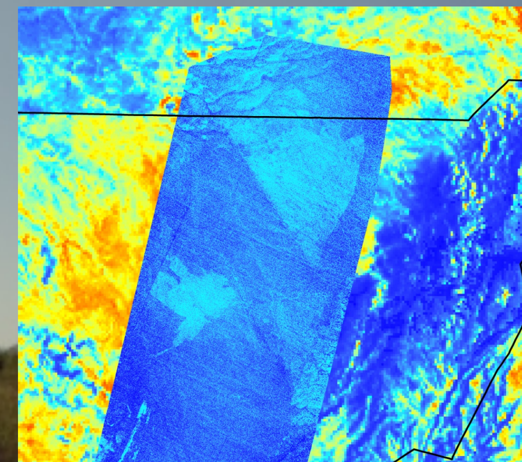
Modeling ET Sevilleta Burned Areas



NDVI



Land Surface Temperature



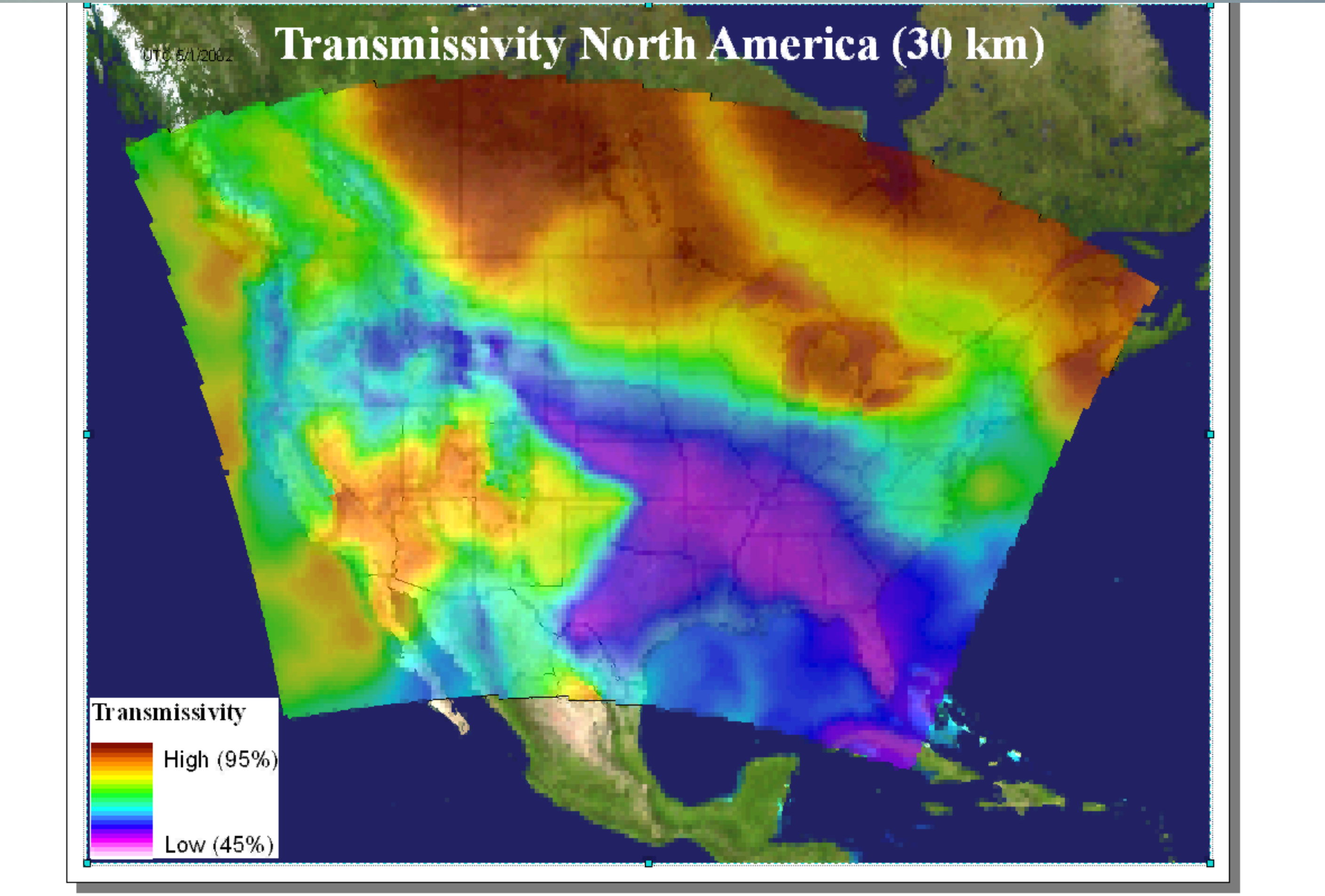
Emissivity Contrast

All three components provide distinctly different information about land cover
ET modeling uses NDVI for transpiration component, LST for Sensible Heat Flux, Emissivity of momentum roughness length

Simulated HyspIRI data modeling issues

- Georegistration of airborne data
- Calibration of airborne data
- Land surface temperature and emissivity estimation
  - Atmospheric profile uncertainties & corrections
  - Suitability of self-contained corrections
  - Instrumental calibration
  - ET need for multispectral data: use of emissivities to represent land surface roughness; how many bands and how much do they improve LST accuracy?
- Spatial resolution
- Overpass time of day for ET and water stress detection
- Potential for improved net radiation estimation with VSWIR

Assessment of LST Uncertainty: Computation of Atmospheric Transmissivity Time Series (3 hour steps)

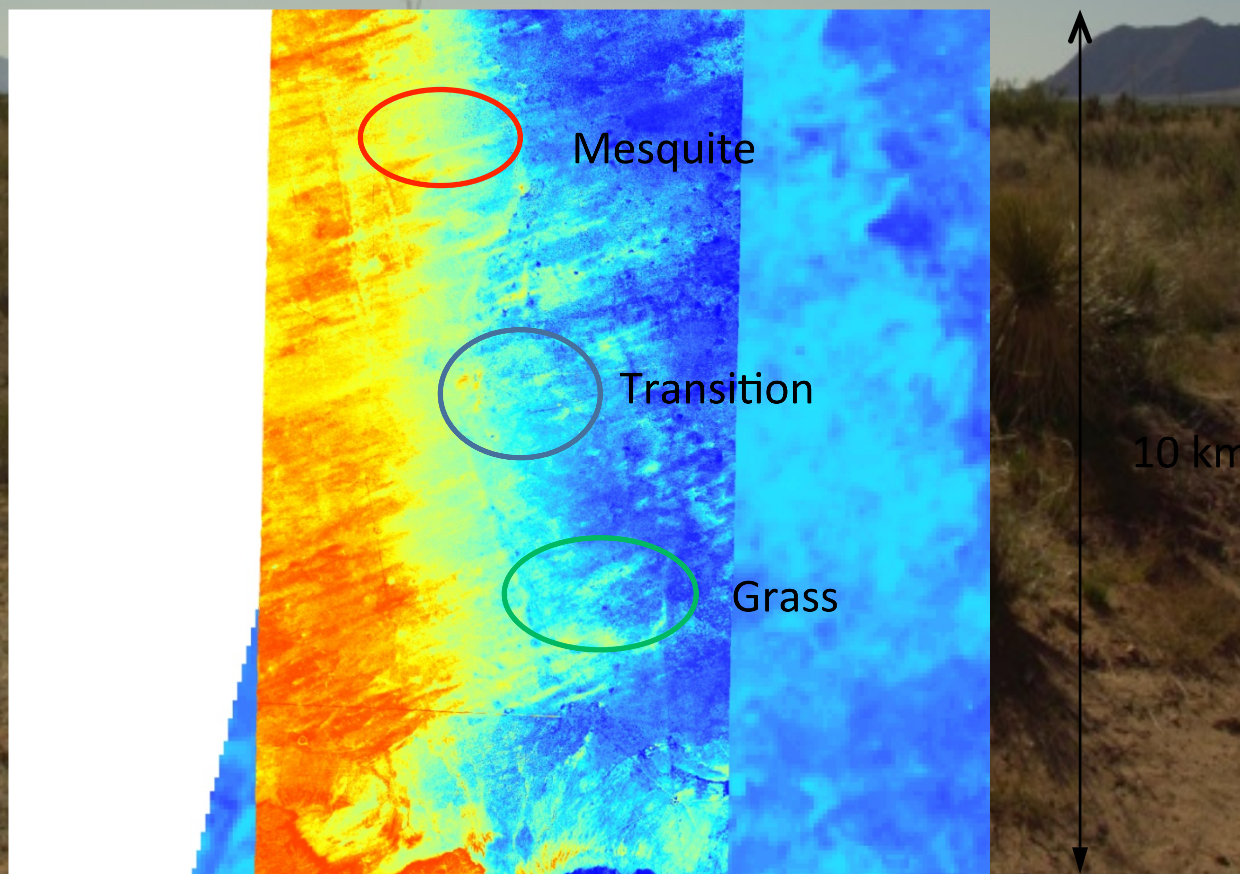


METRIC-based ET:

MASTER overlay on ASTER

Grass-Transition-Mesquite Transect

- View angle variation of LST > 10 K
- Do we need multispectral TIR for ET



Conclusions

- Simulated HyspIRI data derived from 86 MASTER scenes validated over two rangeland sites
- The HyspIRI resolution of 60m sufficient for monitoring of ET over arid rangeland
- Time series data from combining ASTER and MASTER observations show that the 5-19 day periodicity from HyspIRI resolves seasonal ET trends
- Multispectral TIR capability of HyspIRI adds a new dimension to ET modeling by detecting surface roughness variations weakly correlated to VNIR data