Evapotranspiration Estimation with Simulated HyspIRI Data over Arid Lands

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USDA ars United States Department Of Agriculture
Agricultural Research Service

NASA

Need for Remote Sensing Evapotranspiration Research Over Arid Lands

- Population increases to 7 Billion+
- Increasing living standards increases demand for water
- Drought and climate change exacerbating water availability
- Food production needs to increase & this requires large increases in water availability
- Food production from irrigated agriculture especially important: 53% of market value on 17% of crop land (Clemmens et al., 2008)
- Conflicting demands upon arid lands: increased agricultural production, urbanization, preservation of wild lands
- Remote sensing is the only way to provide global to local scale decision and management support

Water Management & Decision Support

- Rangeland:
  - Effect of drought on vegetation health and livestock carrying capacity
  - Controlling invasive species
  - Determining effective and ineffective management practices
  - Remote sensing provides annual to decadal scale views of water needs and vegetation patterns
- Irrigated Lands:
  - Irrigation district decisions: infrastructure, water costs, water priority rights
  - Competition with urban users
  - Competition between tree crops and annual cropping systems
  - **Agronomy:**
    - **Responses to stress are fast & slow (stomata, roots)**
    - **Flash events: frost, heat wave**
    - **Detection of water stress critically dependent on phenology**
    - **Survival of severe stress not important**
    - **Genetics and climate change means water use patterns will change**

Objectives

- Show that remote sensing with a HyspIRI-like platform can assist with water problems
  - Rangeland assessment of vegetation and water use
  - Irrigated land monitoring
- Highlight some attributes of HyspIRI that are especially helpful:
  - Spatial resolution
  - Hyperspectral VSWIIR
  - Multispectral TIR
  - Overpass frequency

ET Estimation

- Vegetation Index
    - Empirical estimates based on standard green plant water use
    - Multiple sources of remote sensing data at <100m resolutions
    - Standardized ET results, stress detection difficult

- Surface energy balance
    - Physically based, uses land surface temperature to estimate evaporation and is an indicator for stomatal control
    - Remote sensing data less readily available, analysis more difficult than VI
    - Potentially rapid detection of plant stress

Surface Energy Balance Approaches

Two-Source Energy Balance:

•Considers differences in energy transfer between air, soil and vegetation.
•More physically realistic representation of the ET processes
•Sensitive to LST and air temperature uncertainties

METRIC/SEBAL:

•Internally calibrated LST based on scene context to estimate ET
•Less sensitive to LST and air temperature uncertainties.

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

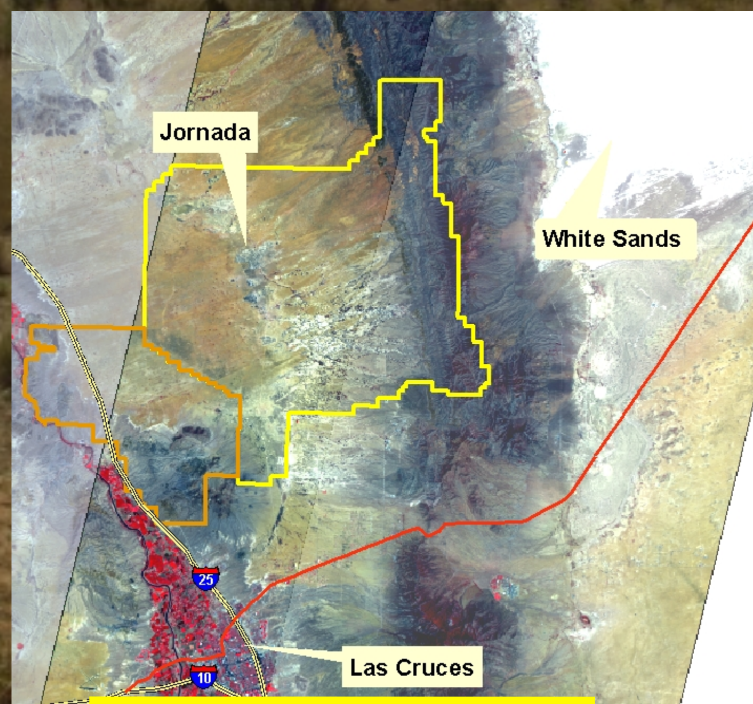
$$LE_C = f_g \alpha \left[\frac{\Delta}{\Delta+\gamma}\right] R_{n,C}$$

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.

The Jornada Study Site

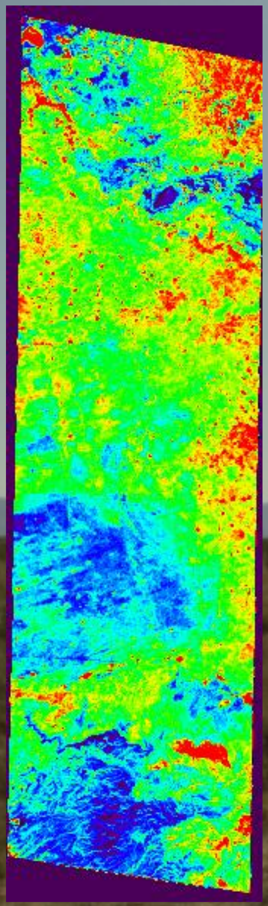
LTER (1990) & USDA Research Rangeland site since 1912. Desertification causes and trends.

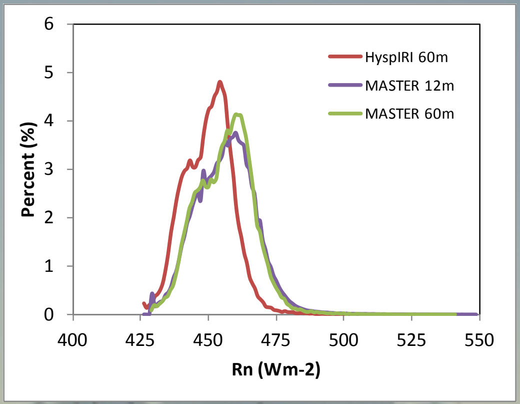
MASTER data collected 1998-2010 on 8 sorties. 3-12m resolution
AVIRIS data collected 1998-2002. 89+ scenes collected , georegistered, corrected and modeled.

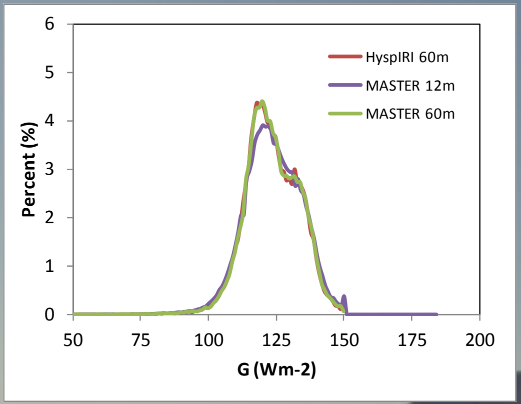


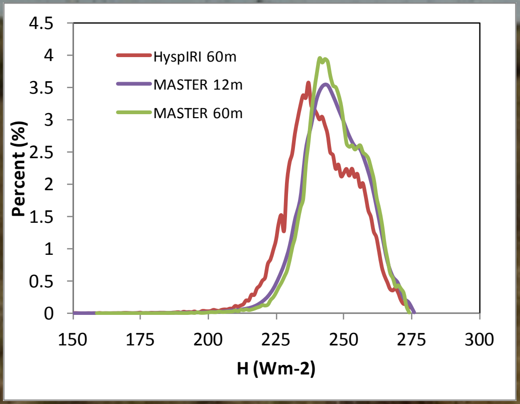
JORNADA

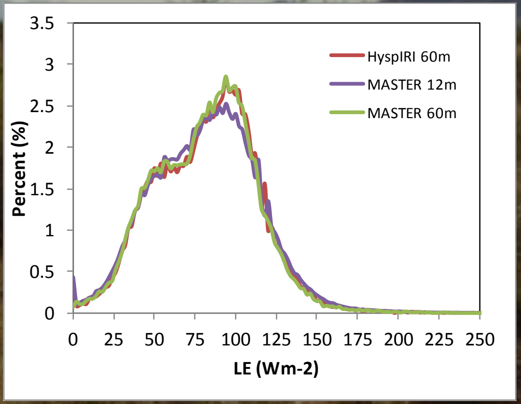
HyspIRI Simulations with MASTER
N-S transect over key grassland and mesquite dune sites







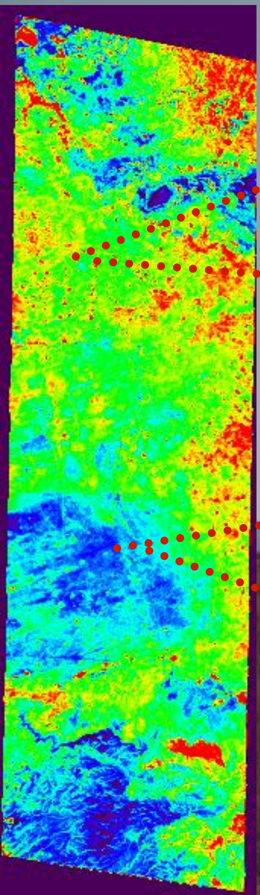




HYSPIRI/MASTER (60m)	Bias	RMSE
Rn	-4	5
G	-0.09	0.6
H	-5	5
LE	0.8	1.9

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

Local Validation of ET Modeling at Jornada



3*3 (60 m)

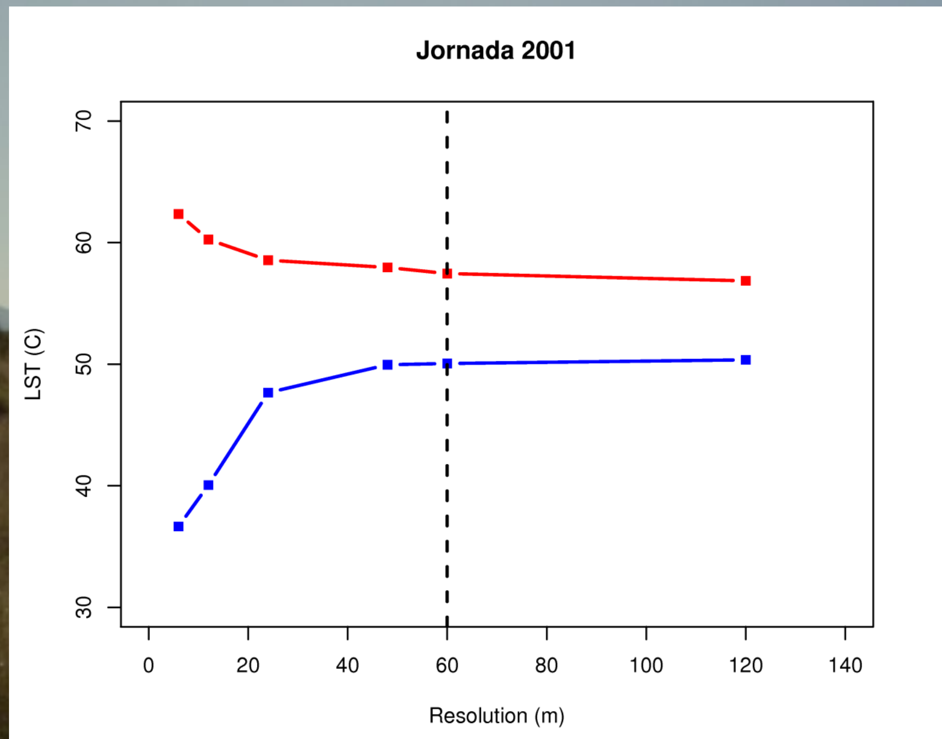
Mesquite

3*3 (60 m)

Grass

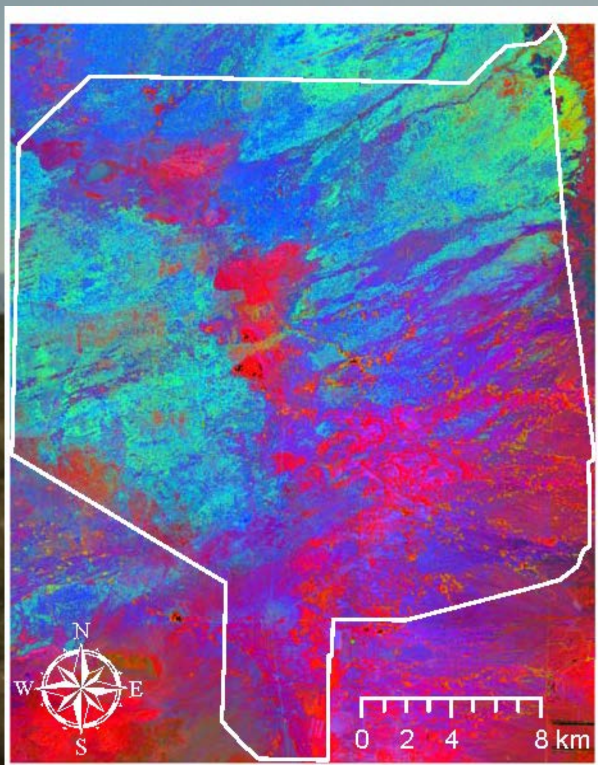
Date	Time	Grass/Mesquite	Rn			G		H			LE		
			Observed	Predicted	Diff.	Observed	Predicted	Observed	Predicted	Diff.	Observed	Predicted	Diff
20-May-04	17:36	G	562	441	-121	x	124	374	263	-111	31	51	20
	17:53	M	540	460	-80	x	116	364	258	-106	27	82	55
	18:42	G	564	441	-123	x	135	392	257	-135	30	45	15
	18:42	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**	

Effect of Spatial Resolution on ET Estimates

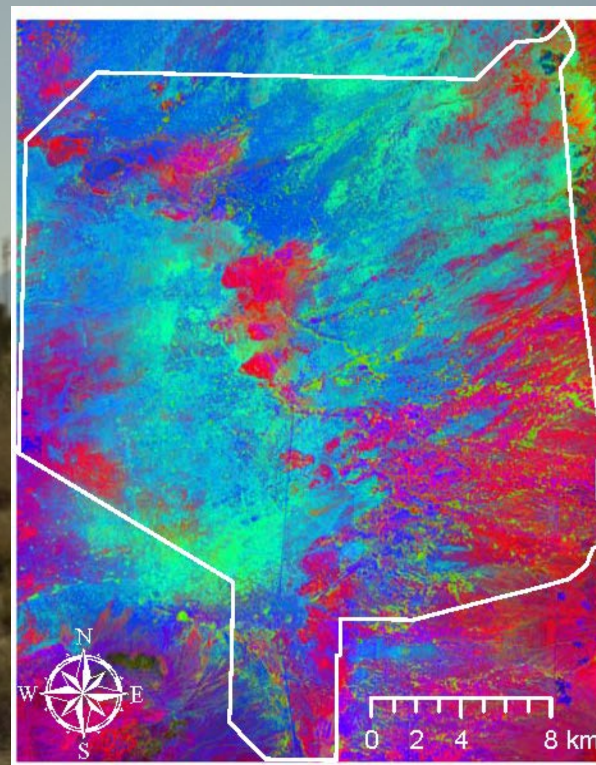


Shrub level heterogeneity at Jornada is less than 10 m
However landscape scale ET homogeneous at 60 m

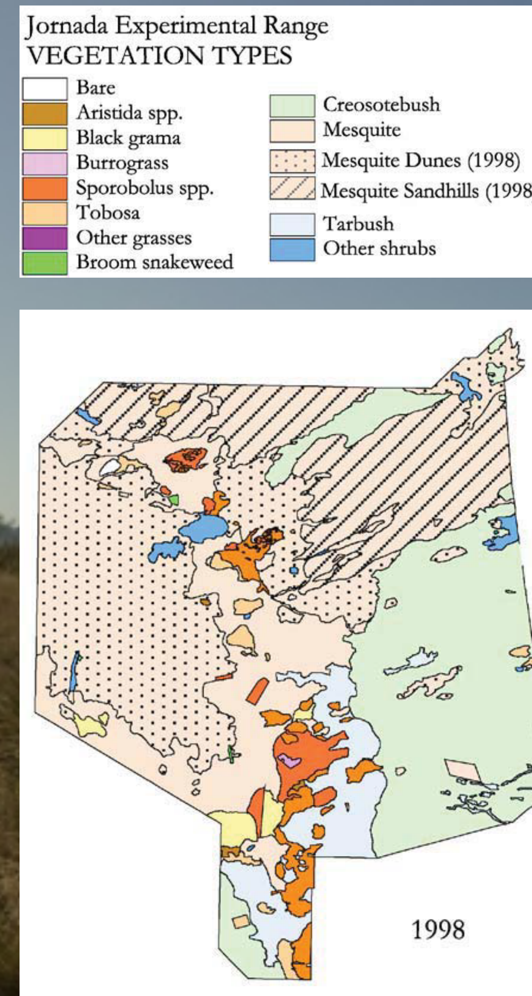
MESMA Results: Spectral Resolution Overcomes Limitations with Spatial Resolution



June 15, 2001

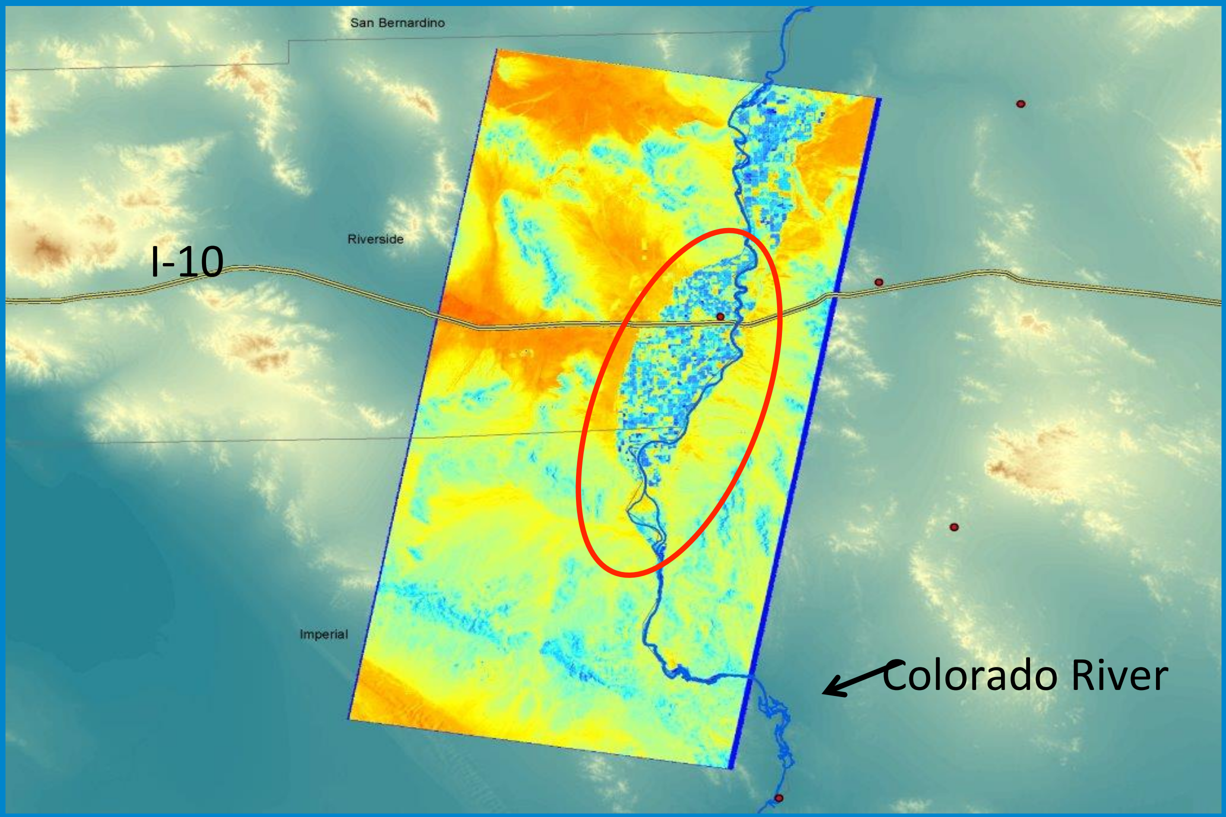


October 9, 2002



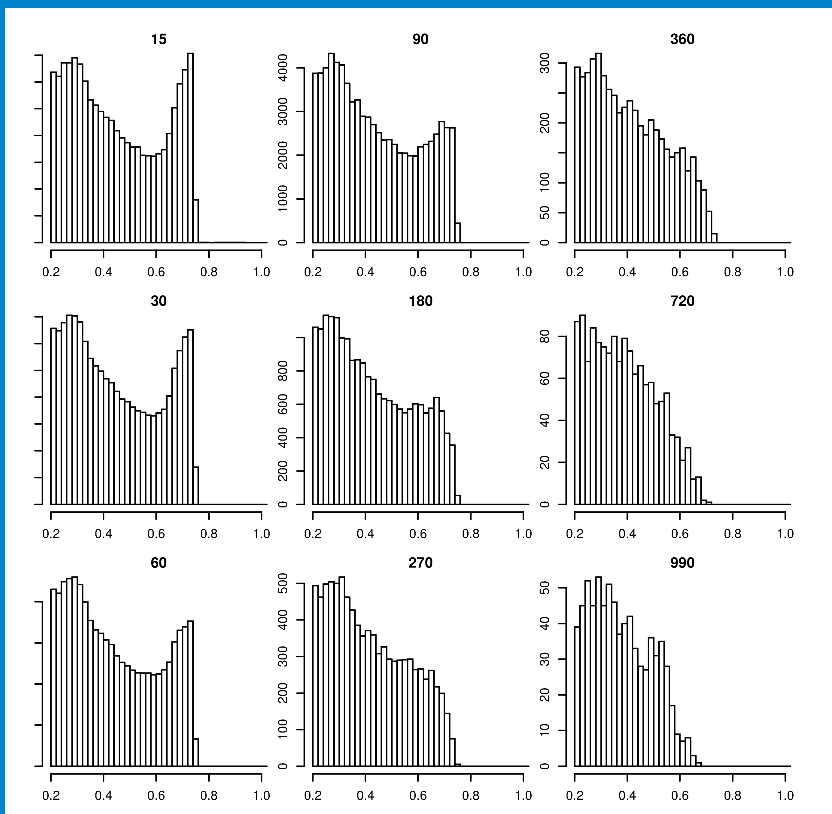
1998
Gibbens et al. (2005)

ET Modeling over Palo Verde Irrigation District, California, June 17, 2007
ASTER LST, Emissivities & NDVI

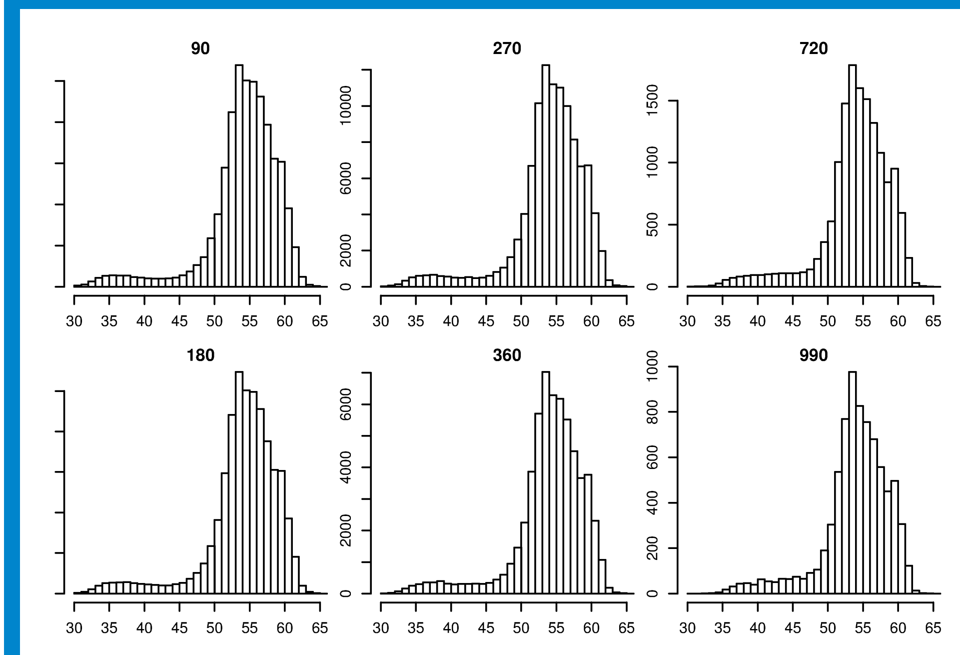


Role of Spatial Resolution for Irrigated Land
Palo Verde Irrigation District

Bi-Modal Distributions
Where two modes disappear indicates critical resolution
At PVID that scale is 200-300 m



NDVI

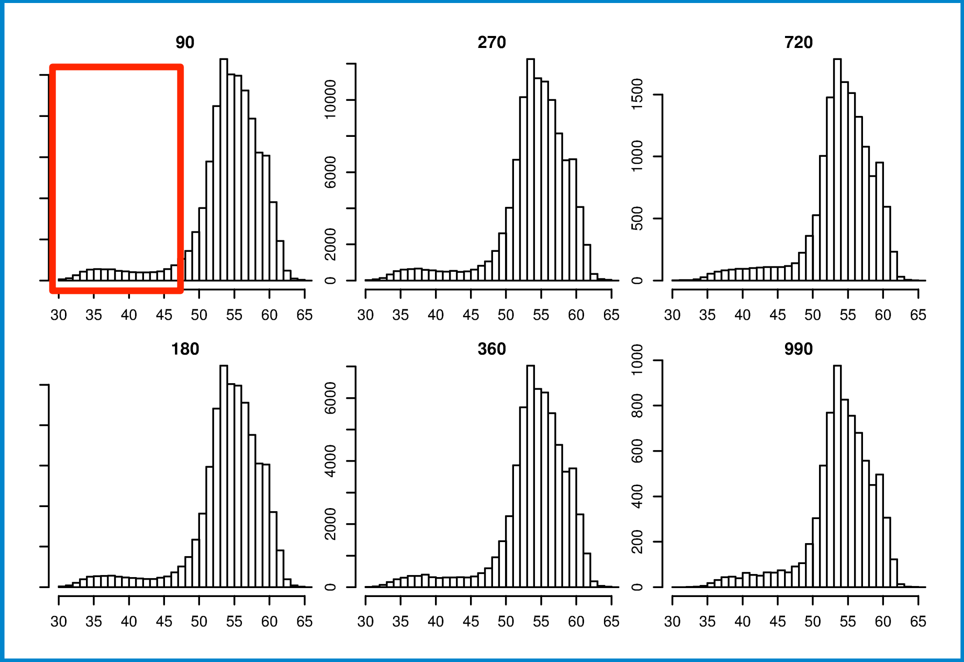


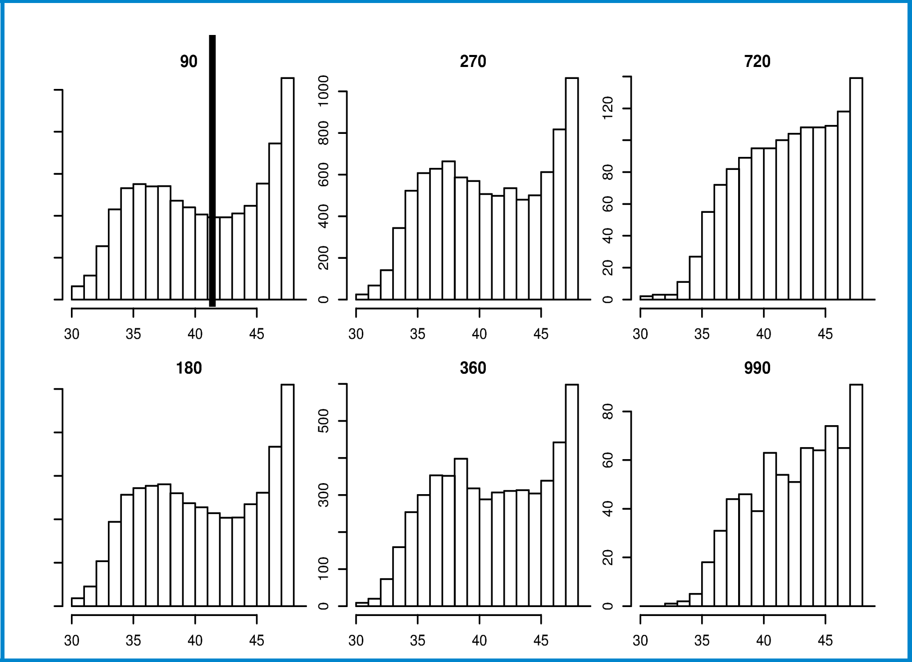
LST

Spatial Scaling of Land Surface Temperatures at PVID

Crops 30-42 C; Desert >45 C
Critical scale ~ 300 m

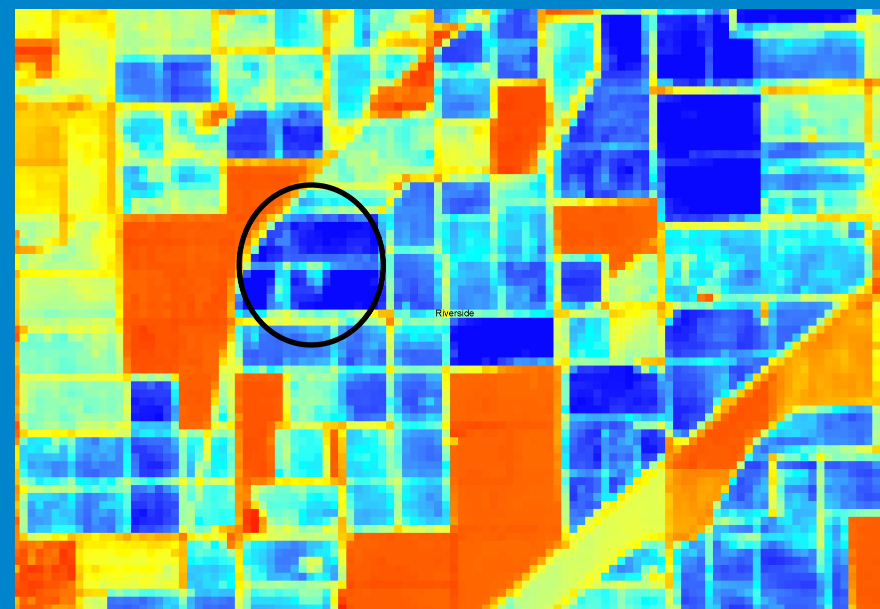
90 m　　270 m　　720 m





180 m　　360 m　　990 m

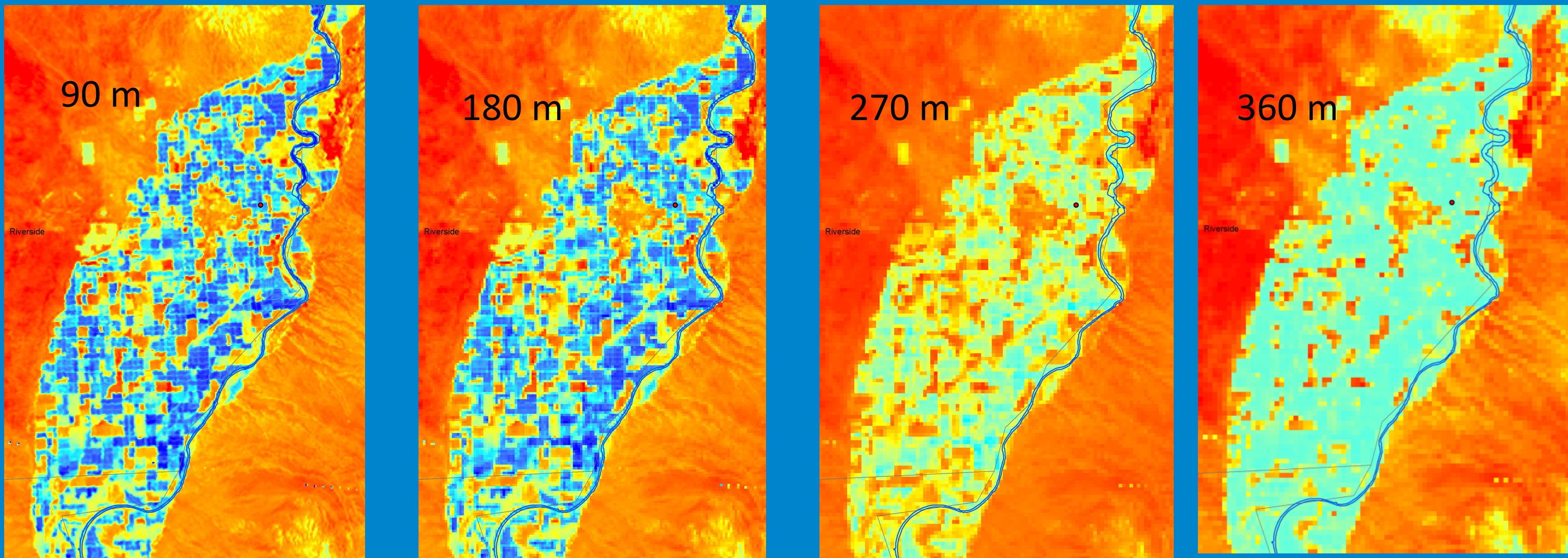
NDVI at Palo Verde
Sub-Field Scale Variability Observed at 60 m

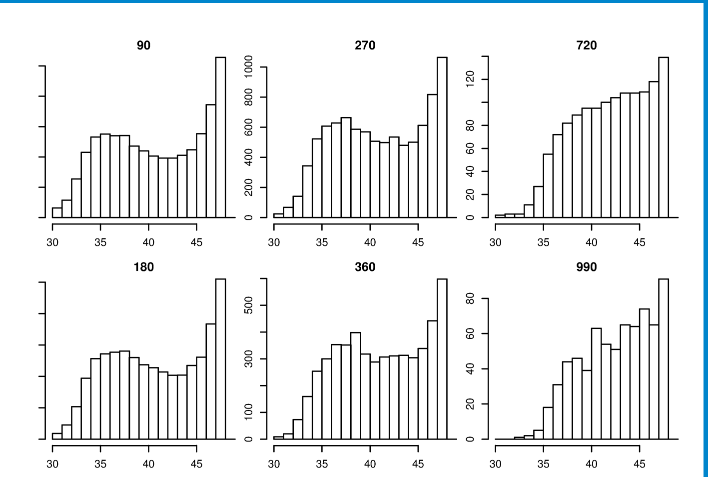


15 m

60 m

Effect of Spatial Resolution on ET Estimation At Palo Verde Irrigation District

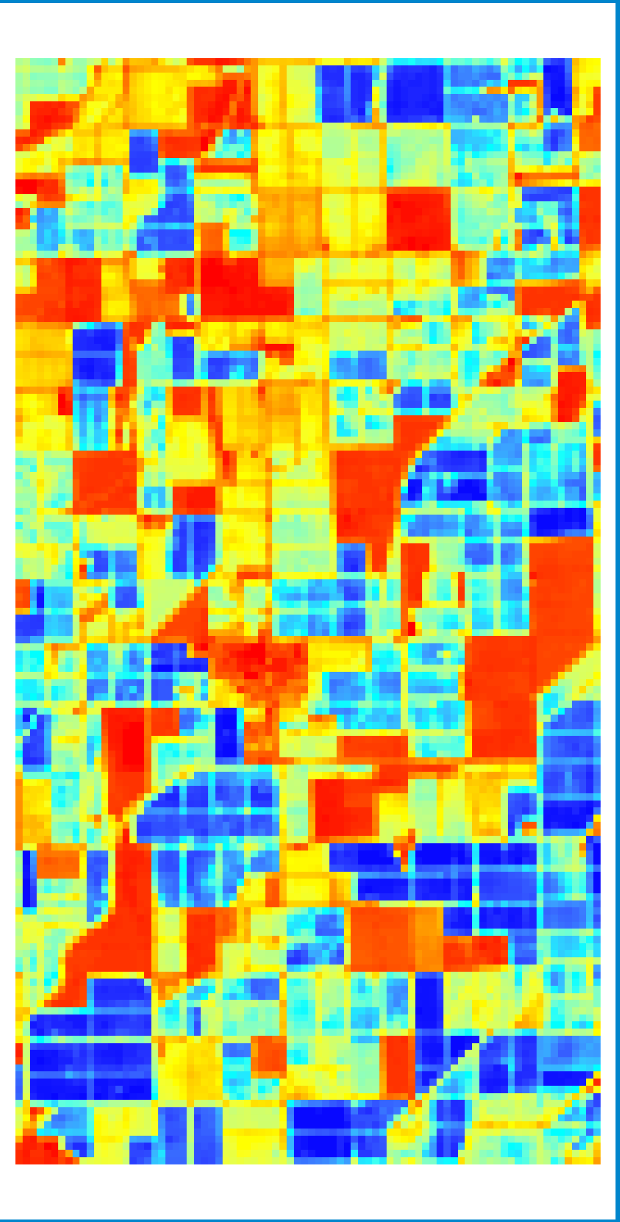




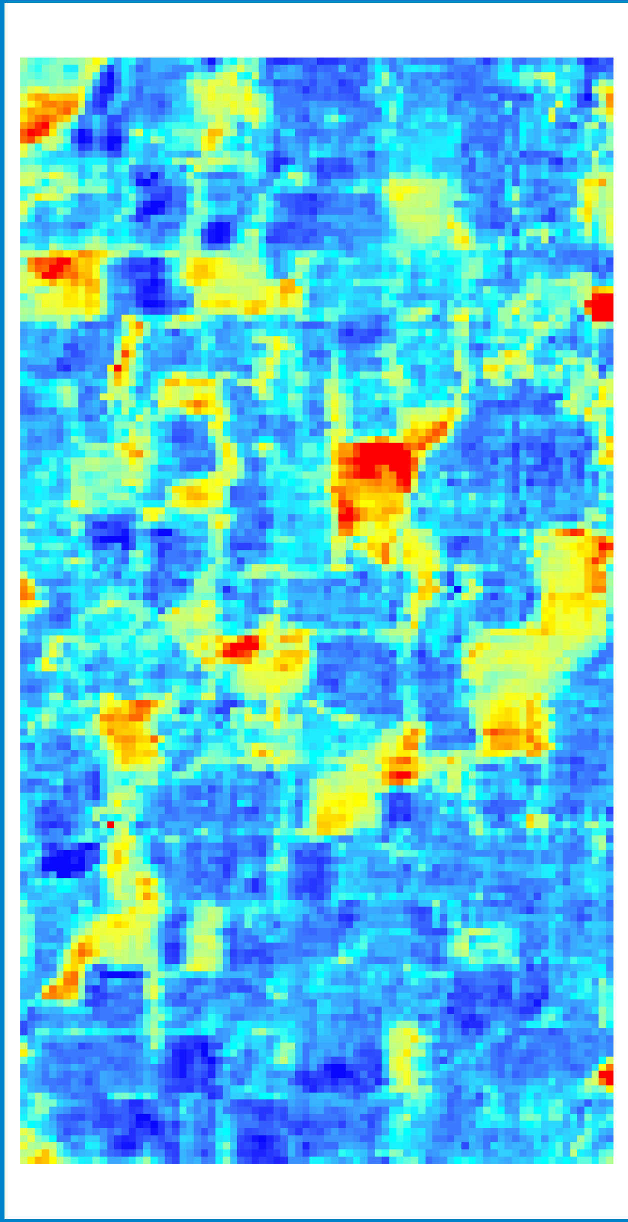
Large systematic changes in LE Flux distributions > 200 m

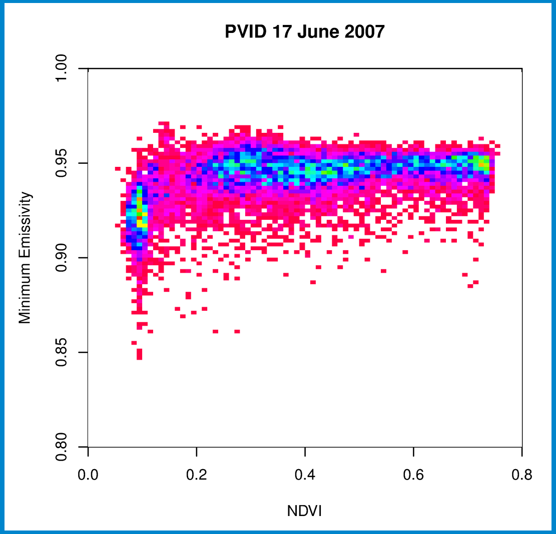
Multispectral TIR: Potential Surface Soil Moisture Indicator

NDVI

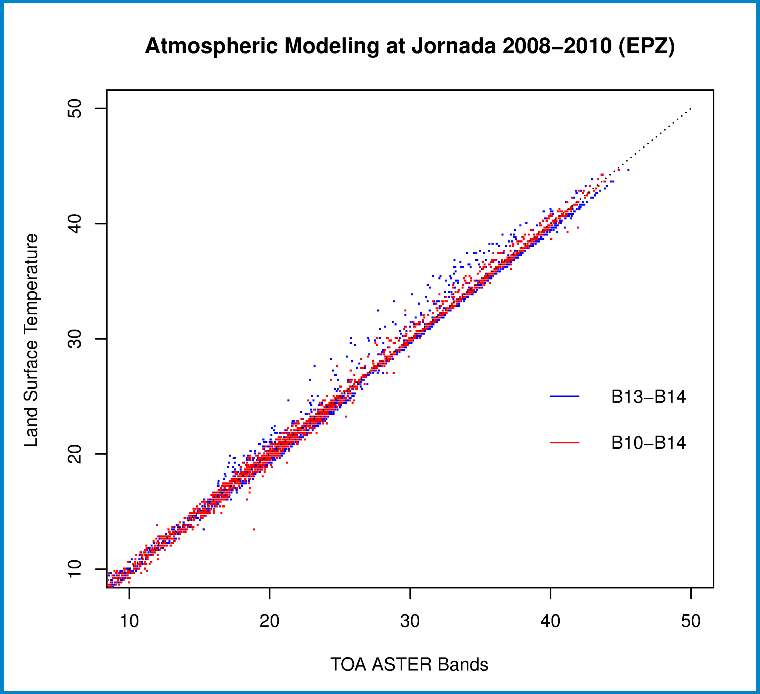


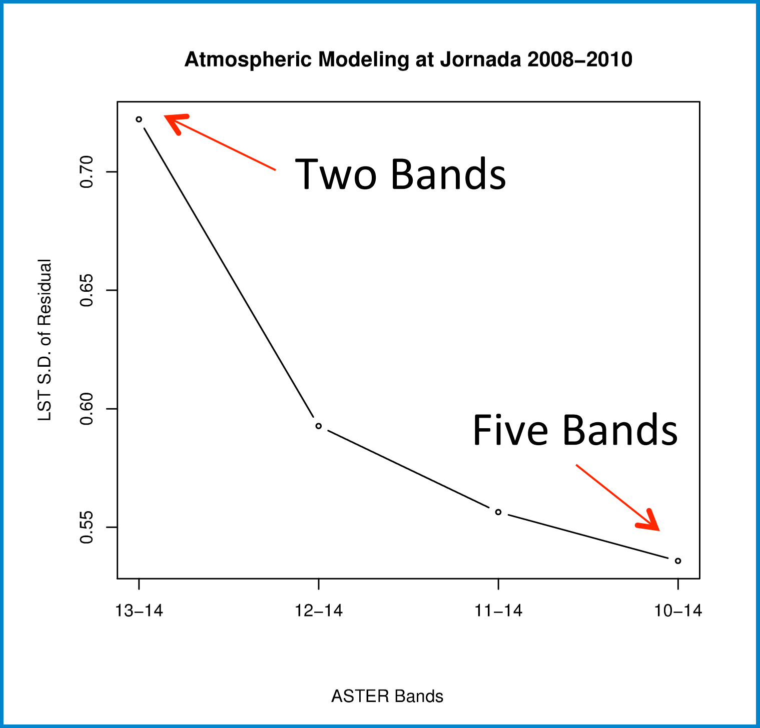
Emissivity Contrast

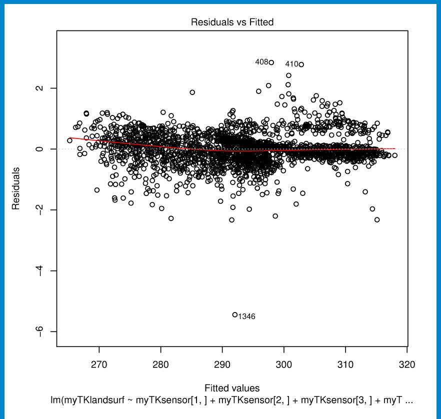


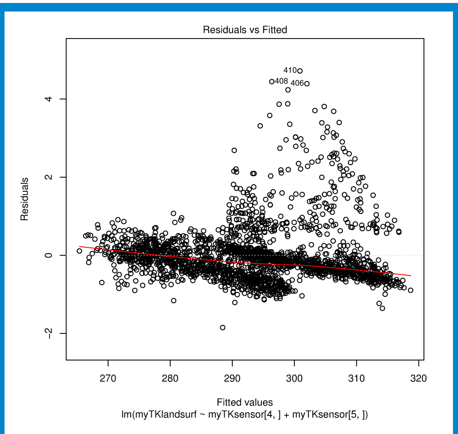


Multiple Thermal Bands Improve Surface Temperature Estimates









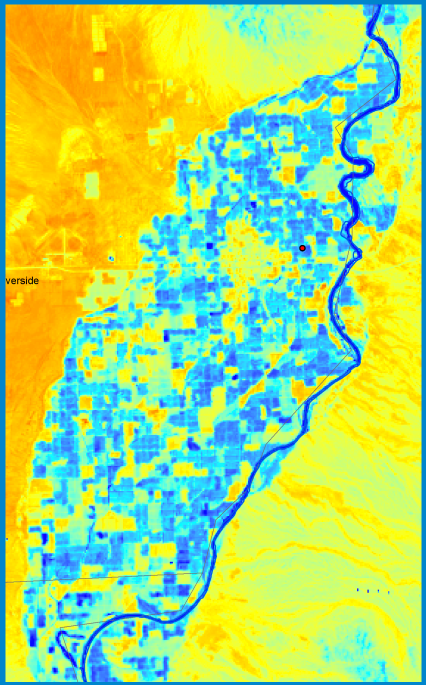
Conclusions

•HyspIRI design offers substantial benefits for ET mapping in arid lands
•For rangeland can reasonably estimate low ET values while discriminating shrubs, grasses, senescent vegetation
•For irrigated lands can map ET at sub-field scales
•Multispectral thermal can improve LST estimation and discriminate wet and dry soils
•5-day periodicity helps address agronomic needs for stress detection

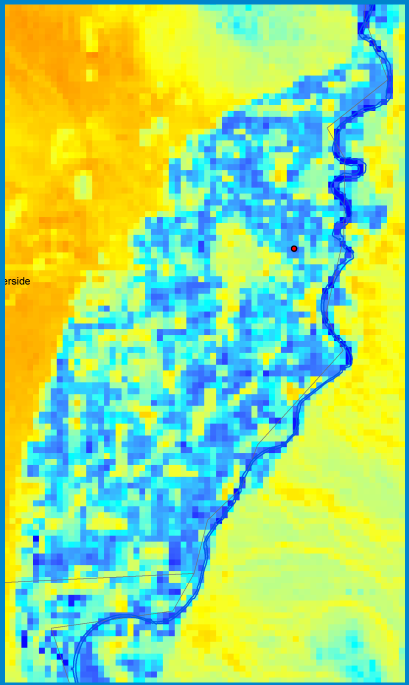
Effect of Spatial Resolution on ET Estimation At Palo Verde Irrigation District

Large systematic changes in LE Flux distributions > 200 m

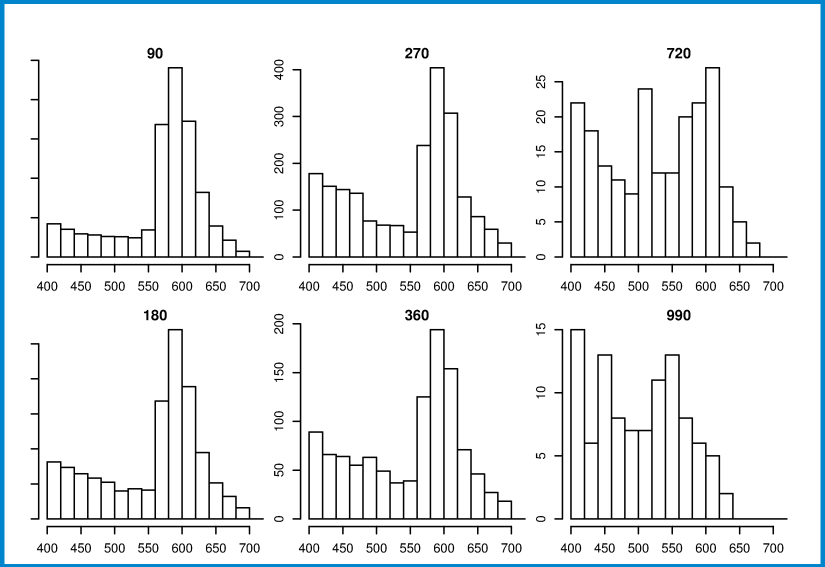
LE Flux

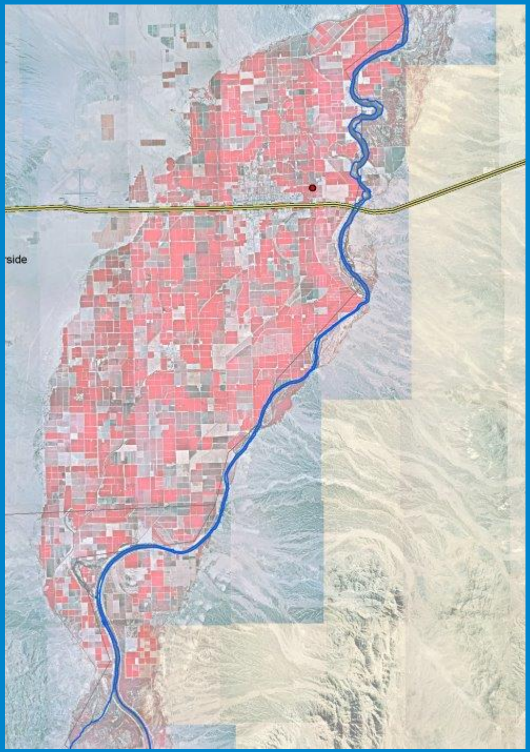


90 m



360 m

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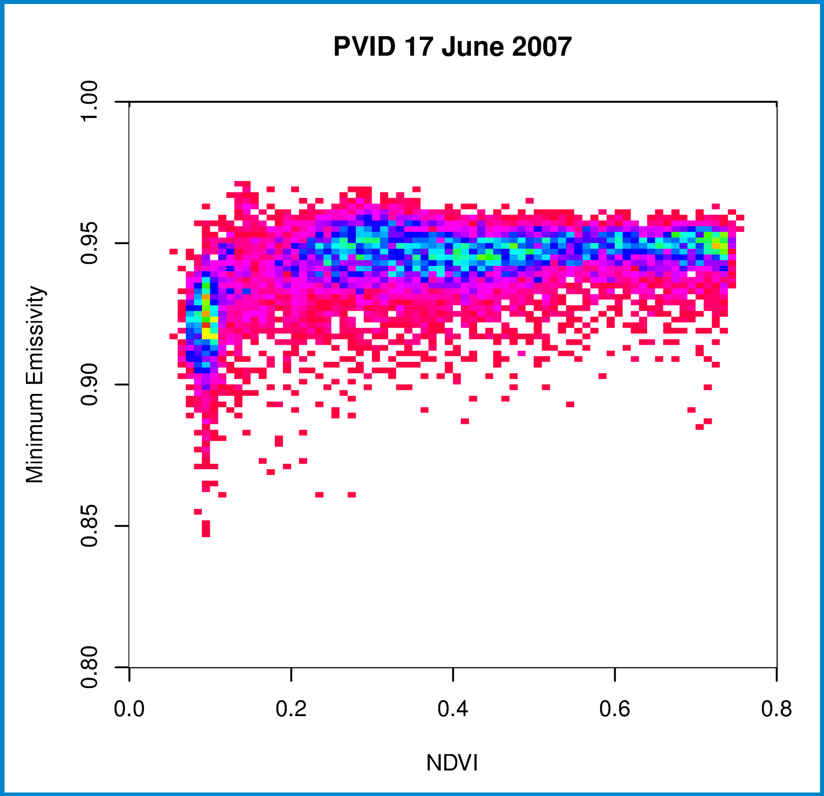
PVID 17 June 2007
Minimum Emissivity
NDVI
1.00
0.95
0.90
0.85
0.80
0.0
0.2
0.4
0.6
0.8