

Investigating the Use of LIS and Satellite Products to Improve Evapotranspiration Estimates

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H43H – Evapotranspiration: Measurement, Monitoring, and Modelling

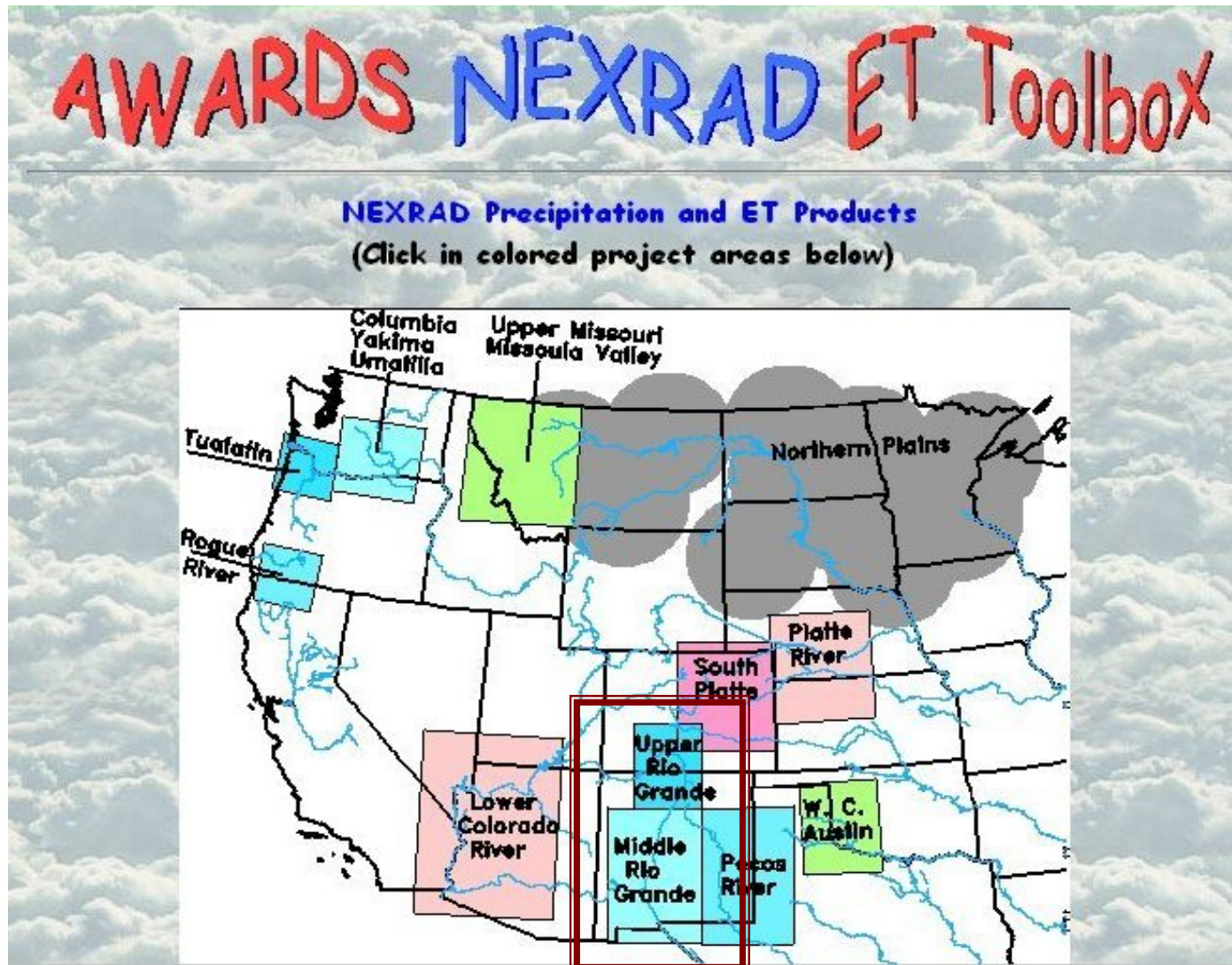
AGU Fall Meeting, San Francisco, CA

December 8, 2005

Objective

- ◆ To Validate and Compare U.S. Bureau of Reclamation's (Reclamation) AWARDS ET Toolbox Decision Support System (DSS) with
 - ◆ in-situ measurements,
 - ◆ satellite-derived ET, and
 - ◆ moisture and energy budget variables from the Land Information System (LIS) project
- Region :: Middle Rio Grande River Basin in New Mexico
 - From just above Cochiti Reservoir to just below Elephant Butte Dam.
- ◆ Goal :: To Improve Water Consumption and Loss Estimates for the Middle Rio Grande River and provide the more well tested and improved products into other Reclamation DSSs – RiverWare and URGWOM

AWARDS - ET Toolbox System Operational Areas in U.S. Bureau of Reclamation



<http://www.usbr.gov/rsmg/nexrad/>

AWARDS – ET Toolbox System

AWARDS:

(Agricultural WAtER Resources Decision Support)

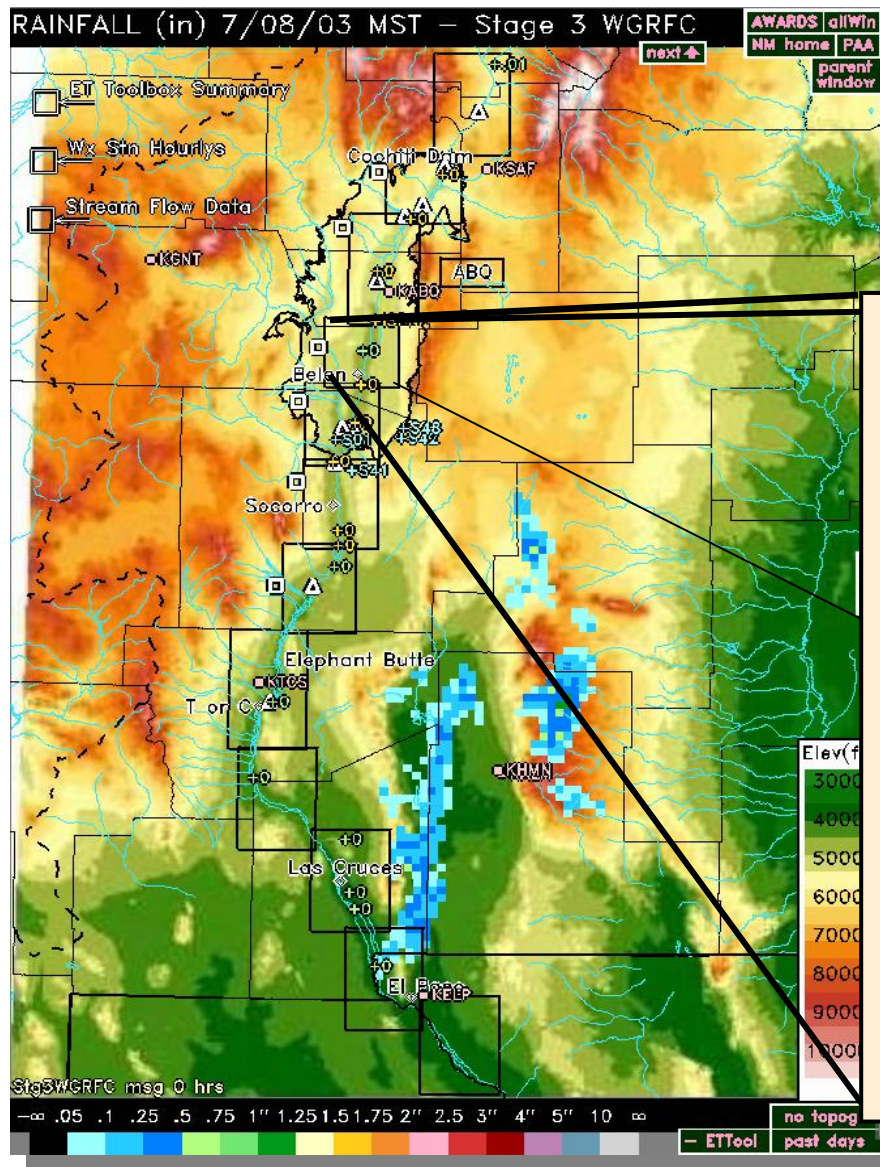
An automated information system to assist water users by providing easy access to rainfall and daily crop water use estimates.

ET (EvapoTranspiration) Toolbox:

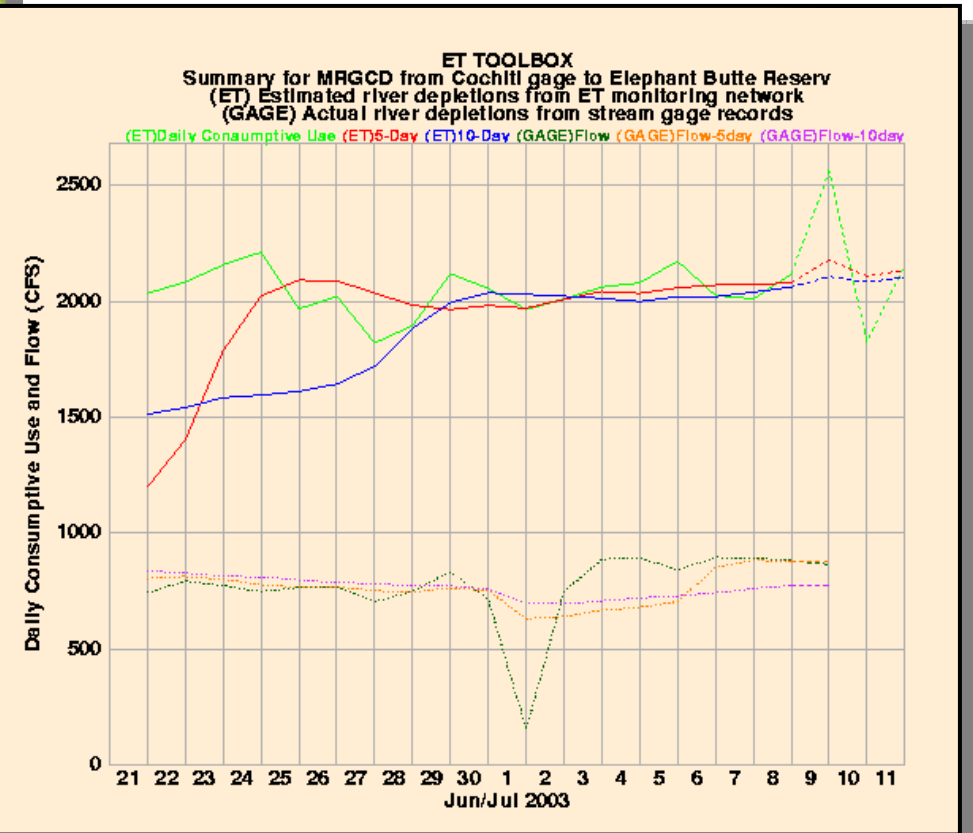
A water resources decision support tool that builds on AWARDS. The primary purpose of the ET Toolbox is to estimate high resolution daily rainfall and water depletions (crop, riparian, and open water evaporation).

RiverWare Enhancement:

The goal is to improve the efficiency of water management by using the ET Toolbox to calculate daily crop ET estimates for automatic input in RiverWare.



➡ Middle Rio Grande River, New Mexico



Parameterizing and assimilating MODIS, Landsat and ASTER data into LIS models to be tested in the AWARDS ET-Toolbox

ET Toolbox in New Mexico

Within the ET Toolbox, and for each crop, the evapotranspiration,

$$ET = K_c ET_0$$

and measured in $[mm \cdot day^{-1}]$ is

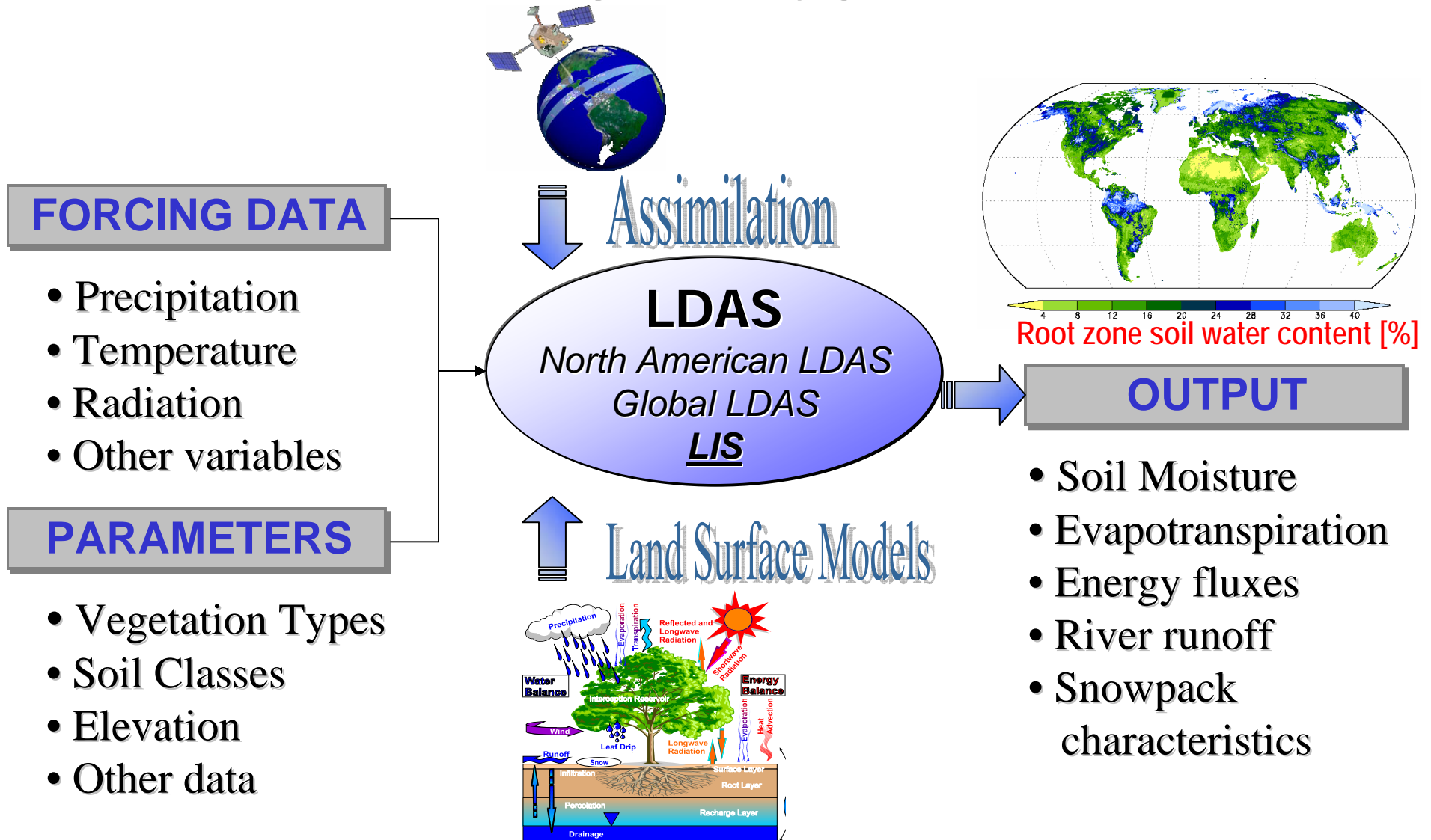
$$ET_0$$

is the reference evapotranspiration and is calculated with a **modified Penman equation**, such that:

$$ET_0 = \frac{\Delta R_n + \gamma w_f [e_s(T_{avg}) - e(T_{avg})]}{(\Delta + \gamma)\lambda}$$

Land Information System (LIS)

Background: Software developed to parameterize, force, and constrain multiple, land surface models with data from ground and space-based observing systems. It builds onto the original NASA/GSFC Land Data Assimilation System (LDAS) projects.



LIS/LDAS Background

- **The Land Data Assimilation System (LDAS) and the Land Information System (LIS), developed at NASA Goddard Space Flight Center, are being used and customized for this project.**
- **Three land surface models (LSMs) are used and evaluated for this project:**
 - Mosaic LSM – NASA GSFC
 - The Community Land Model, version 2 (CLM2)
 - NOAA's Noah Land Surface Model, version 2.7.1
- **Forcing:**
 - NOAA's Eta Data Assimilation System data (EDAS)
 - Merged Stage II Doppler Radar and CPC Rain gage products
 - UMD (Pinker et al.) GOES Radiation Products
- **Terra/Aqua 1 km Moderate Resolution Imaging Spectroradiometer (MODIS) products:**
 - Land Cover
 - Leaf Area Index
 - Continuous Veg. Fraction
 - Land Surface Temperature

LDAS/LIS Parameter Specifics

- Spatial Extent: State of New Mexico and Southern Colorado
- Domain:
 - 32° N to 38° N, and 107° W to 102° W
- Spatial Resolutions: 0.125 deg. (~12 km), 0.01 deg (~ 1 km), and sub-1 km UTM domains
- Temporal Resolution: model time steps -- =/< 15 minute ,
output fields – hourly to 3 hourly
- Elevation Definition: GTOPO30 DEM, NED, SRTM
- Vegetation Definition:
 - AVHRR and MODIS vegetation class maps
- Soils Definition:
 - 1km Penn State STATSGO and USDA SSURGO
 - 5 minute ARS FAO data

CLM2 LSM Physics and Methods for Calculating Evapotranspiration

The transfer of water and CO₂ into and out of vegetation is described by a photosynthesis-conductance model. **Surface evapotranspiration** consists of evaporation from wetted stems and leaves:

$$E_w$$

transpiration through the plant:

$$E_{tr}$$

and initial evaporation from the ground:

$$E_g$$

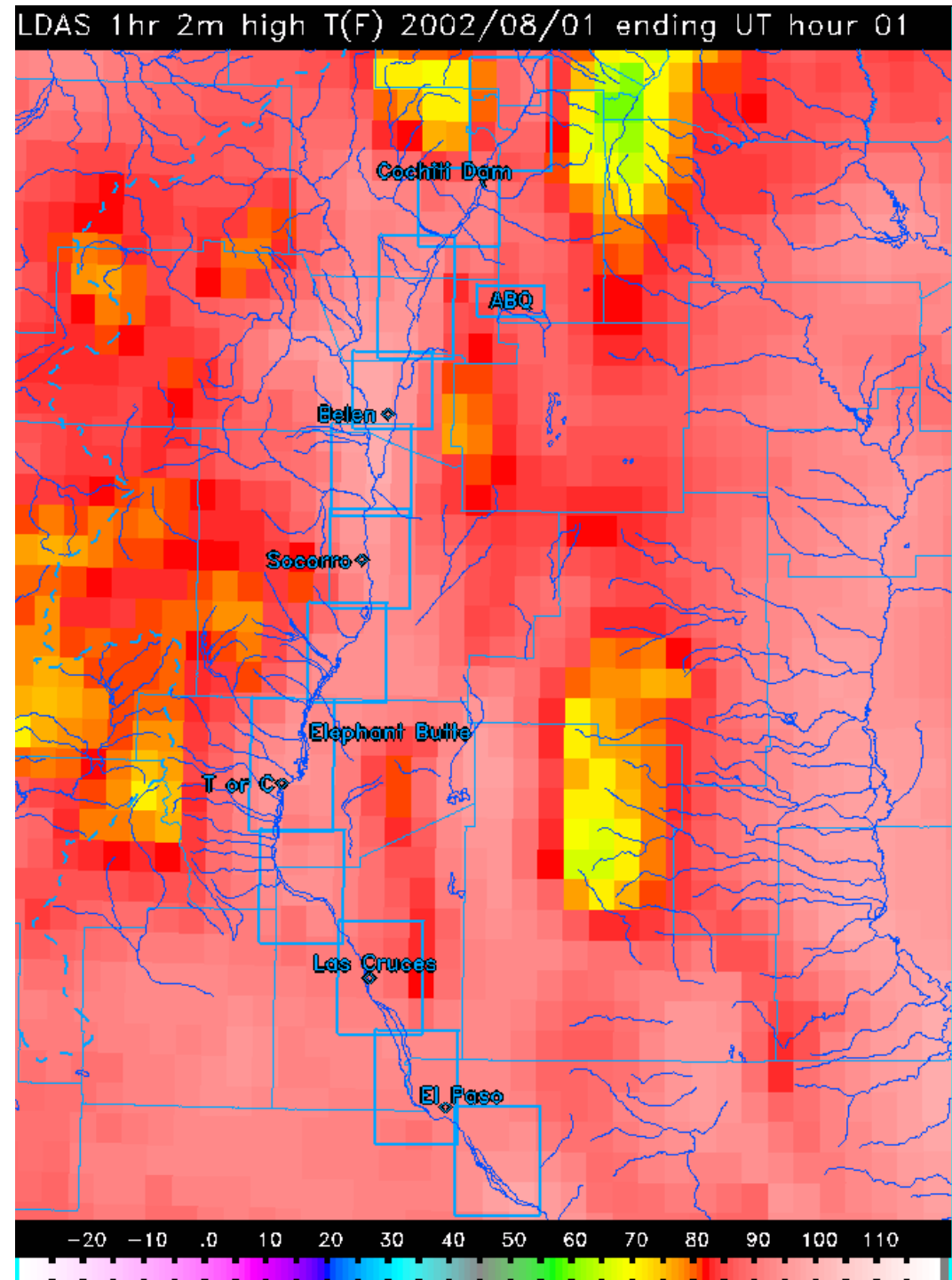
(e.g., bare soil and snow sublimation).

The model accounts for ten unevenly spaced layers for soil temperature and soil moisture, multi-layer parameterization for snow processes (up to 5 layers) and explicit treatment of the mass of liquid water and ice water, and their phase change within the snow and soil system.

Use of Original 0.125 deg LDAS Products – Real-time updates

Example of LDAS-
Mosaic LSM 2m Air
Temperature used in
AWARDS ET-Toolbox

On July 8, 2003



0.125 deg NLDAS Forcing versus MRGCD Station Data in Albuquerque Region

May-02	Name	Jarales	Luis Lopez	North Bosque	Pena Blaca
2m Air Temp: (deg F) <u>Overestimation</u>	Std Dev	12.99341	12.35560	12.65506	12.29485
	R^2	<u>0.78876</u>	<u>0.82409</u>	<u>0.80776</u>	<u>0.82587</u>
	Eta average	74.61522	72.39188	71.91385	66.68957
	MET average	64.95704	67.08865	66.32897	64.30466

Jun-02	Name	Jarales	Luis Lopez	North Bosque	Pena Blaca
2m Air Temp: (deg F)	Std Dev	12.98258	12.24547	12.64903	12.38224
	R^2	<u>0.77845</u>	<u>0.80909</u>	<u>0.78835</u>	<u>0.81154</u>
	Eta average	86.53377	84.29965	83.80143	78.54462
	MET average	75.33832	77.29538	76.80252	74.85146

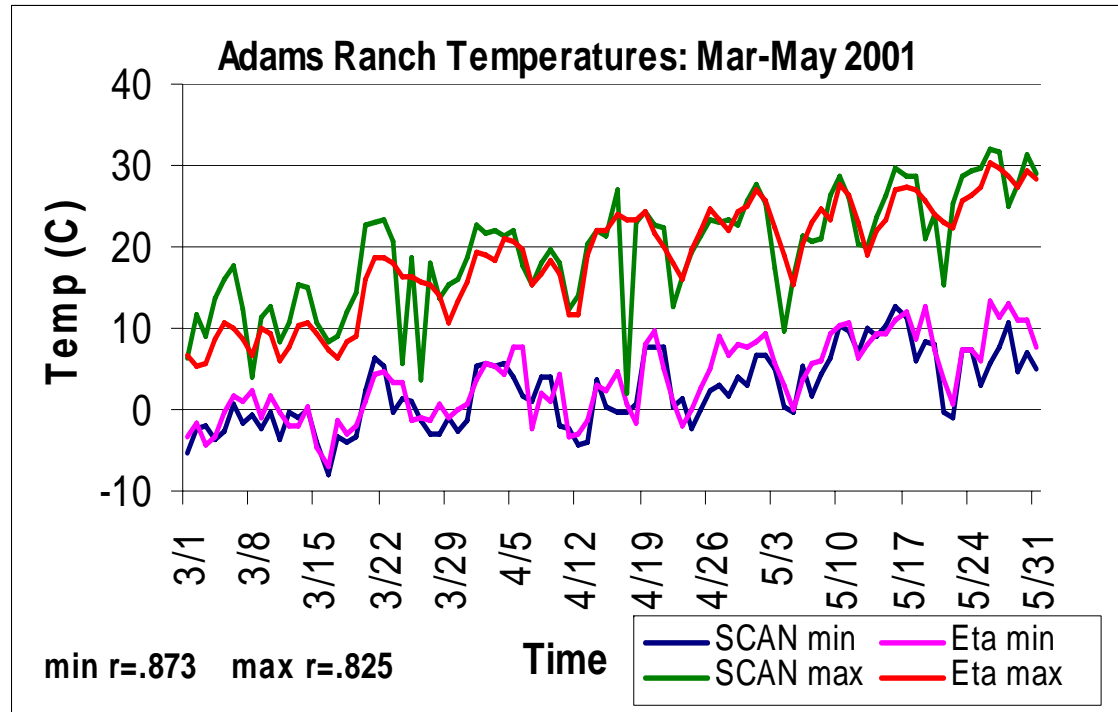
Jul-02	Name	Jarales	Luis Lopez	North Bosque	Pena Blaca
2m Air Temp: (deg F)	Std Dev	11.43423	10.25146	10.40661	10.28510
	R^2	<u>0.77124</u>	<u>0.72113</u>	<u>0.72503</u>	<u>0.80218</u>
	Eta average	85.76215	82.79735	82.17877	78.62278
	MET average	74.37672	75.44446	74.77540	74.74247

Validation of the 0.125 deg LDAS Output: Soil Moisture and 2m Temperature

Adams Ranch, NM

Lon:105.42° W

Lat: 34.25° N



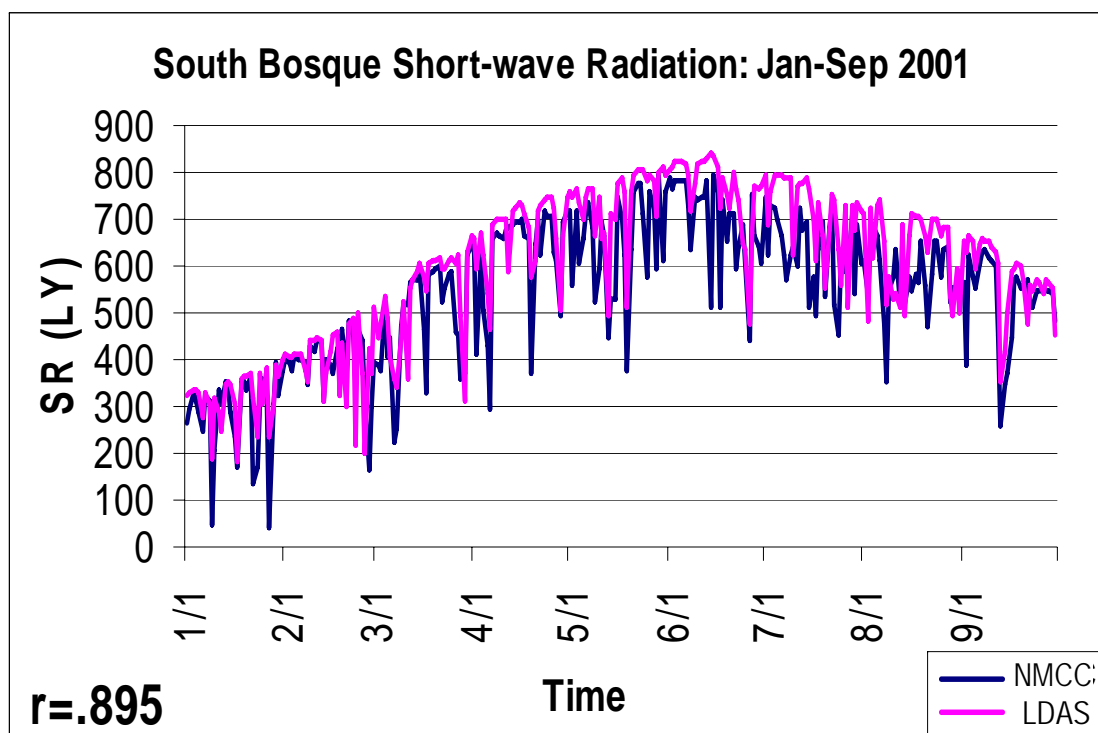
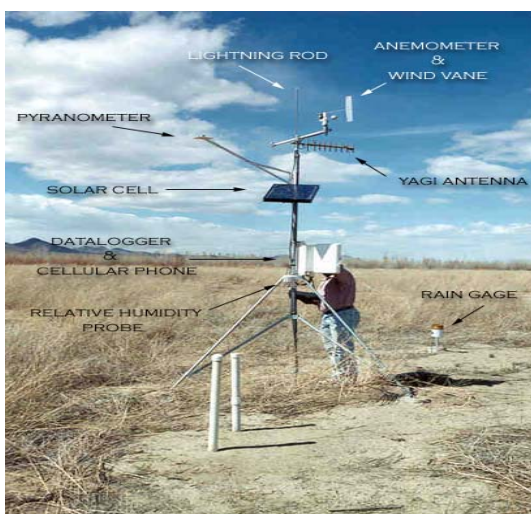
Time	Soil Moisture		Temperature	
	SCAN vs. MOS		SCAN vs. Eta	
	10cm	1m	Min	Max
Spring 2001	.921	.943	.873	.825
Summer 2001	.746	.781	.594	.716

Validation of the 0.125 deg LDAS Output: Soil Moisture and 2m Temperature

South Bosque, NM

Lon: 106.87° W

Lat: 33.80° N



Time	Temperature		Precipitation	SW Radiation
Jan 1-Sep 30, 2001	NMCC vs. Eta		NMCC vs LDAS	NMCC vs LDAS
	Min	Max		
R-Values	.884	.971	.07	.895

LDAS Validation – Mosaic LSM at 0.125 deg

Corona, NM

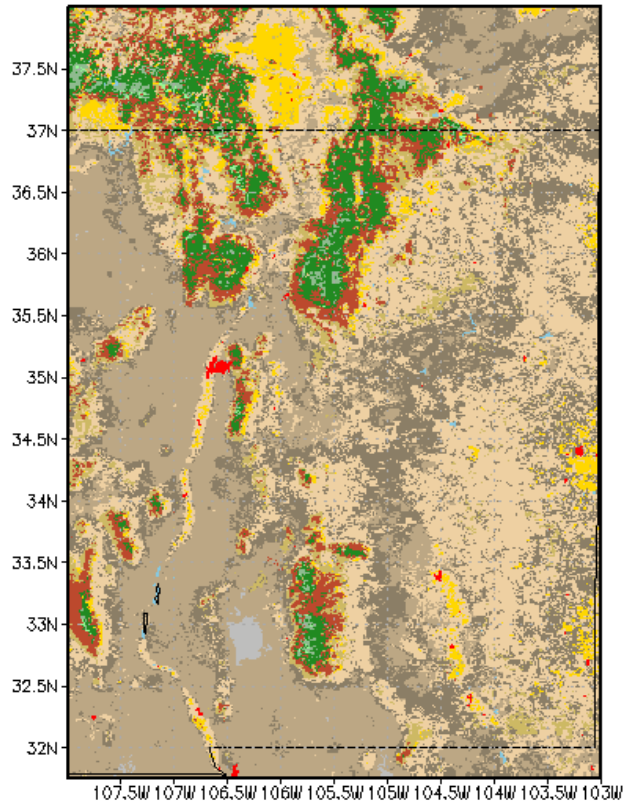
Site	Time	Precipitation NMCC vs. Eta	Evapotranspiration NMCC vs. Eta
Corona, NM	Jan 1-Sep 30, 2001	.410	.010

- Why are the correlation values low?
 - The evapotranspiration was figured using the ET (Penman) equation for a wet grassland area. However, the area is a closed shrubland and grassland area.

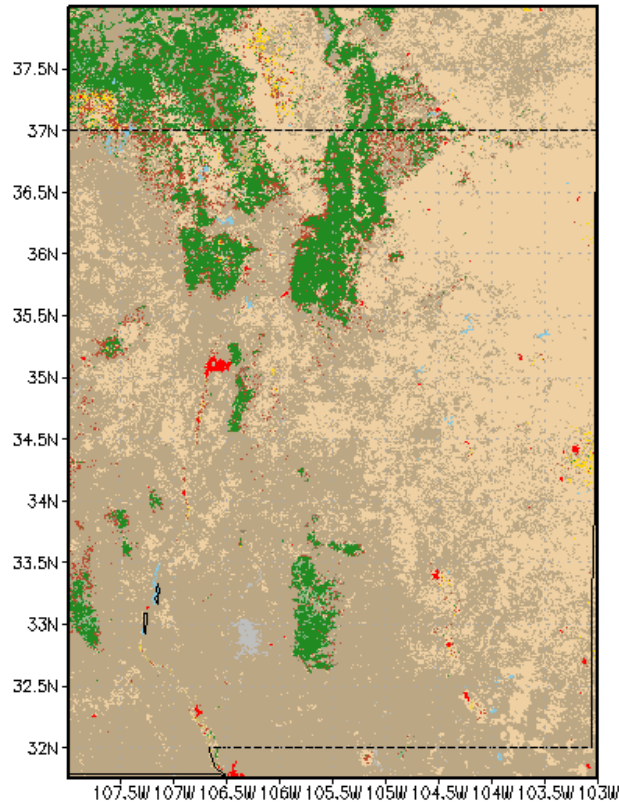
Given its relatively coarse spatial resolution, the standard configuration of LDAS 0.125 degree runs is however not ideal for aiding water resources management at the local and regional scales in this region.

In effect, the average width of the irrigated crop zone along the Middle Rio Grande is about 8 km, i.e. approximately $\frac{2}{3}$ the size of the current resolution of the LDAS 0.125 deg model runs.

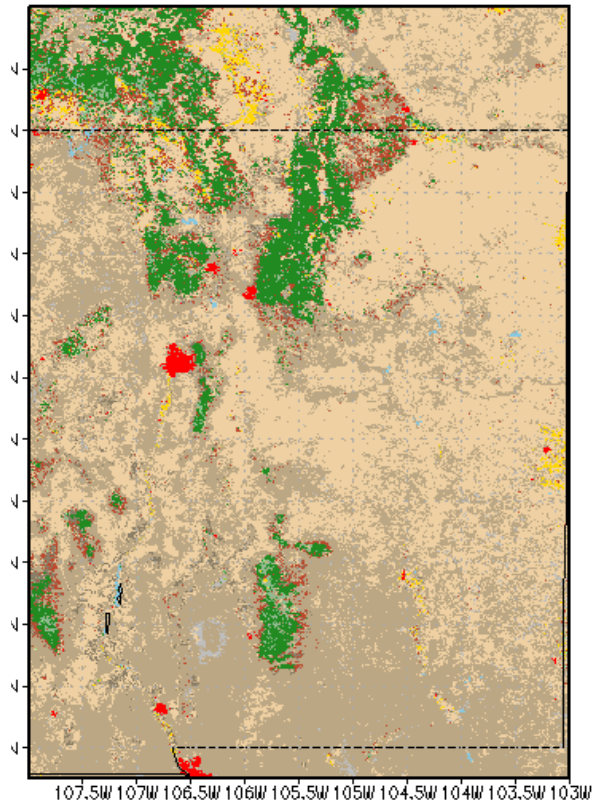
1km LIS LSM Simulations - Examining Impacts of the Differences of the Satellite-derived Land Cover Classes on Energy and Moisture Budgets



AVHRR
UMD land cover



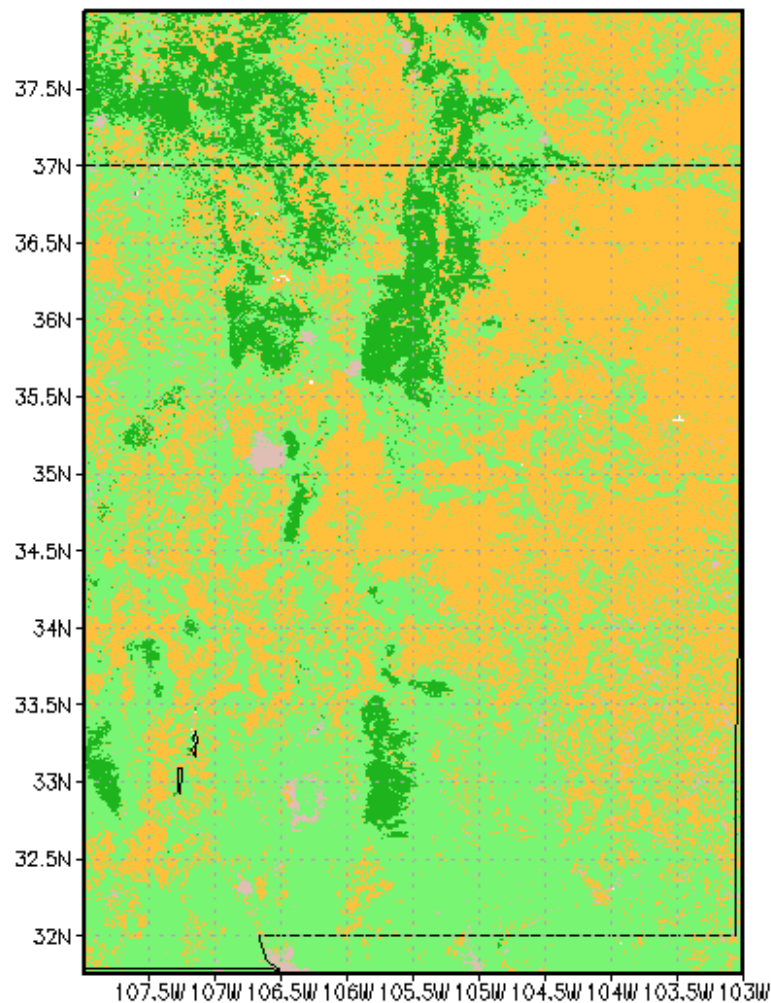
MODIS V3
UMD land cover



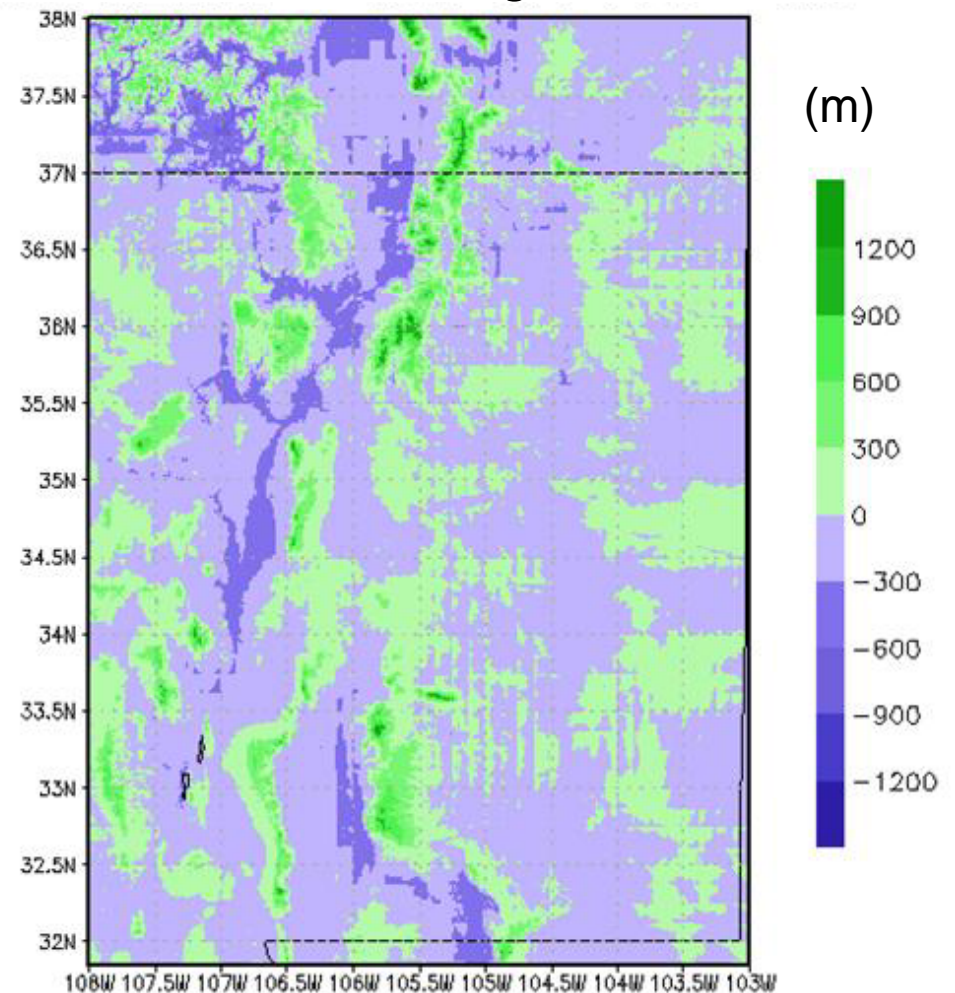
MODIS V4
UMD land cover

Example of Parameters Used in 1km LIS Runs

Four-year climatology of 1km MODIS v4 LAI for September for the region

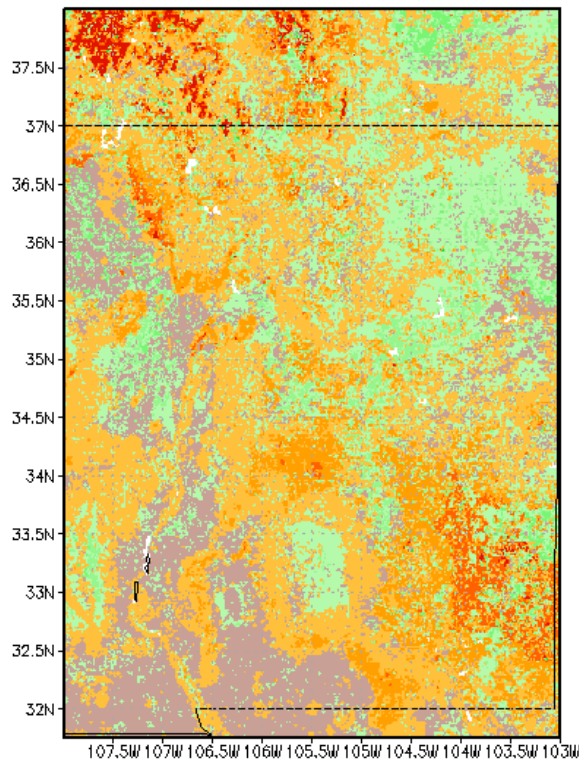


Meteorological field adjustment using standard environmental lapse rate – for difference with model forcing fields

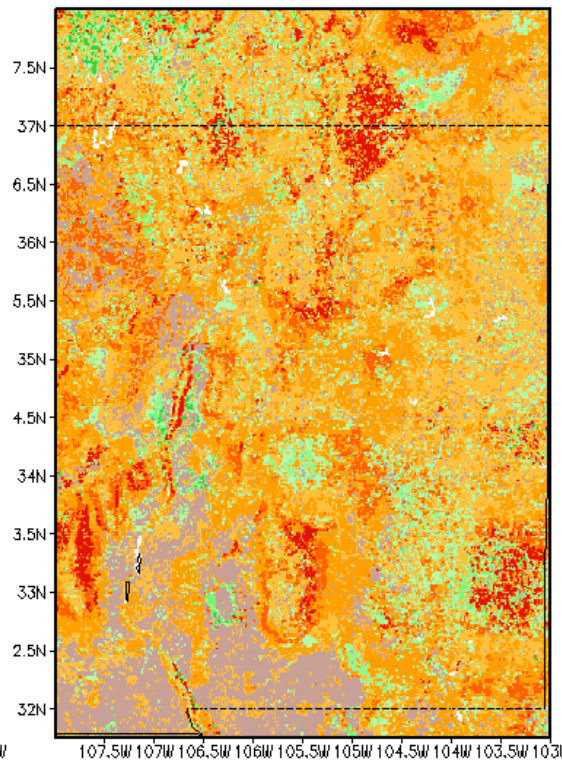


Differences between (1) AVHRR run and (2) MODIS runs for May 30, 2002 (18 Z)

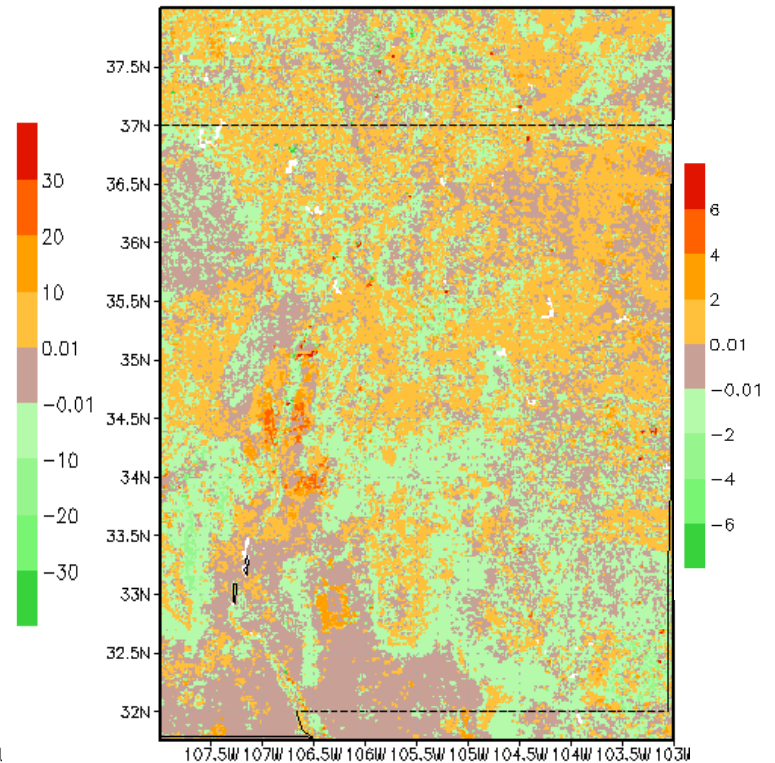
Latent Heat Flux
(W m⁻²)



Sensible Heat Flux
(W m⁻²)

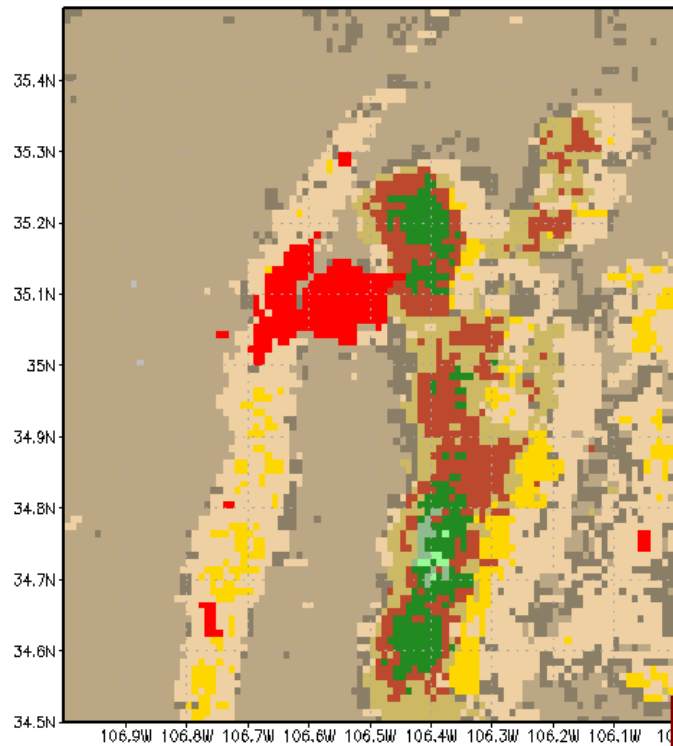


Top 10 cm Soil Temperature
(Celsius)

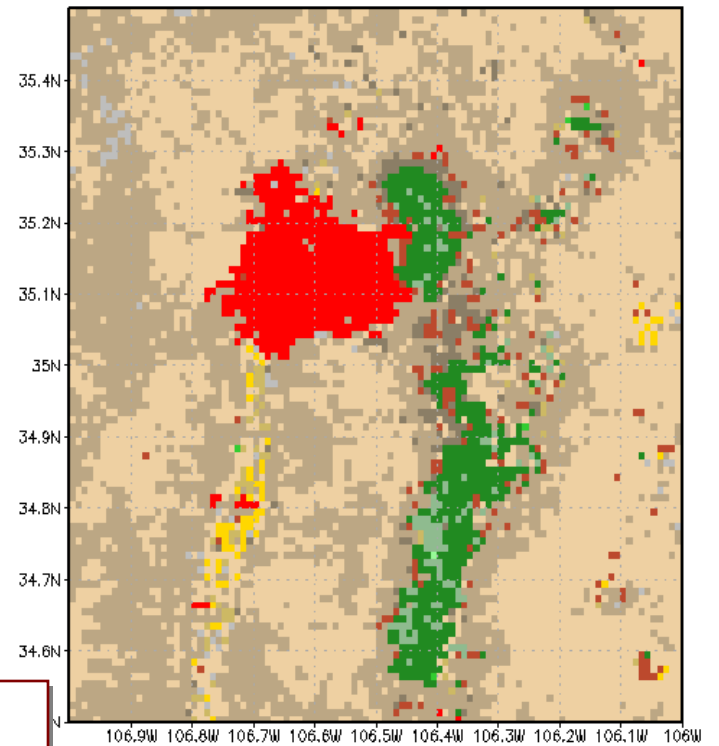


The differences in latent heat flux, sensible heat flux and the top layer soil temperature for the Noah 2.7 LSM.

Albuquerque, NM Region



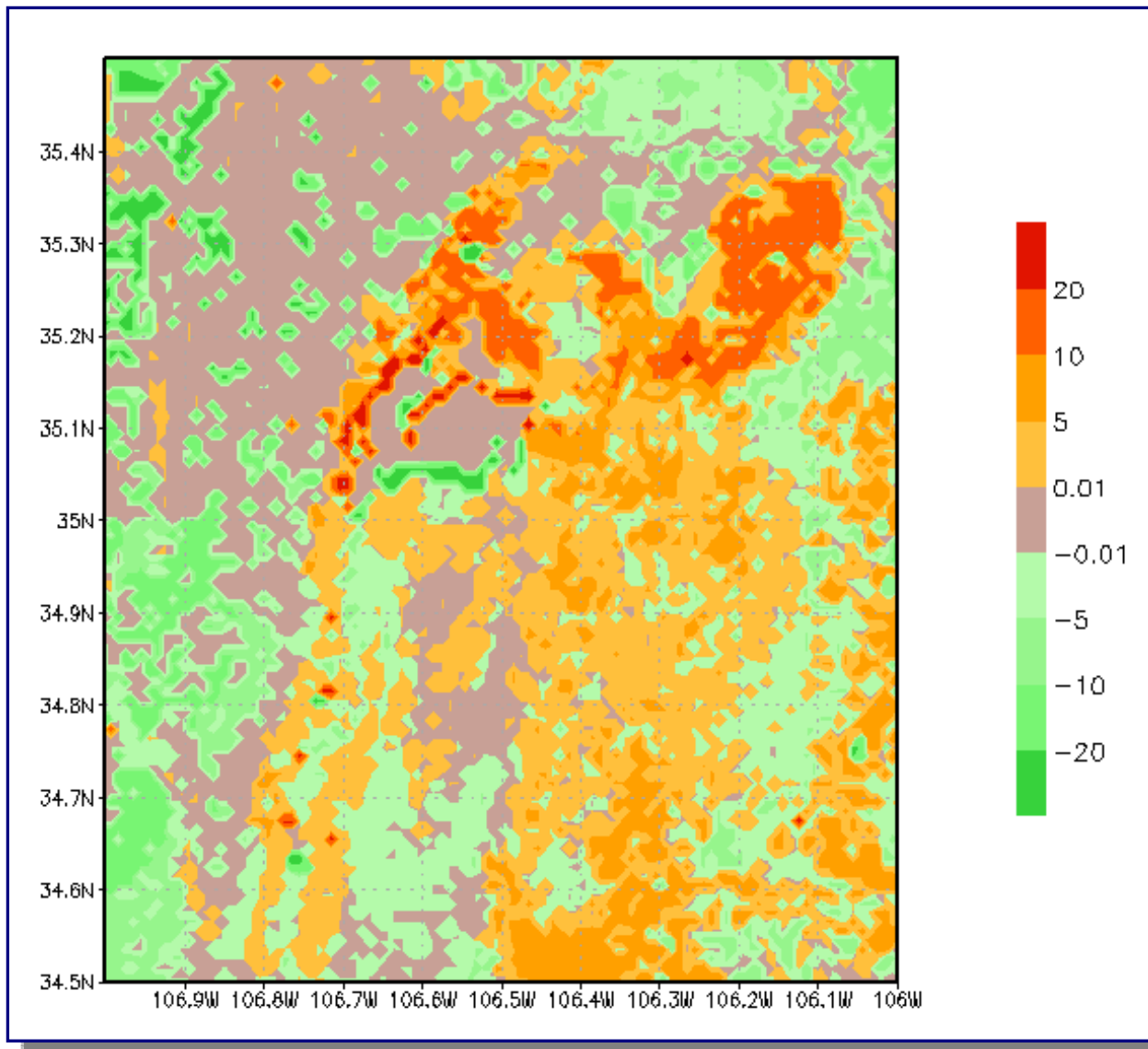
AVHRR
UMD Land Cover
Classes



MODIS V4
UMD Land Cover
Classes



Latent Heat Flux (W m⁻²): AVHRR run – MODIS run



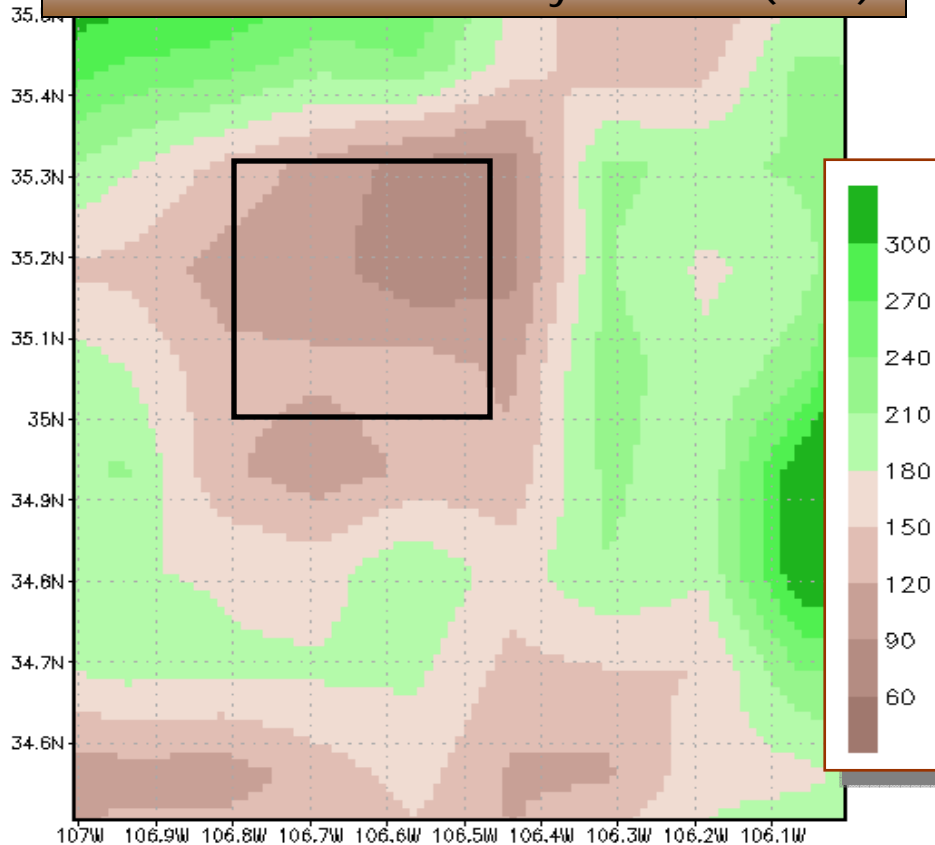
Albuquerque, NM area – May 30, 2002 (18Z)

Albuquerque, NM

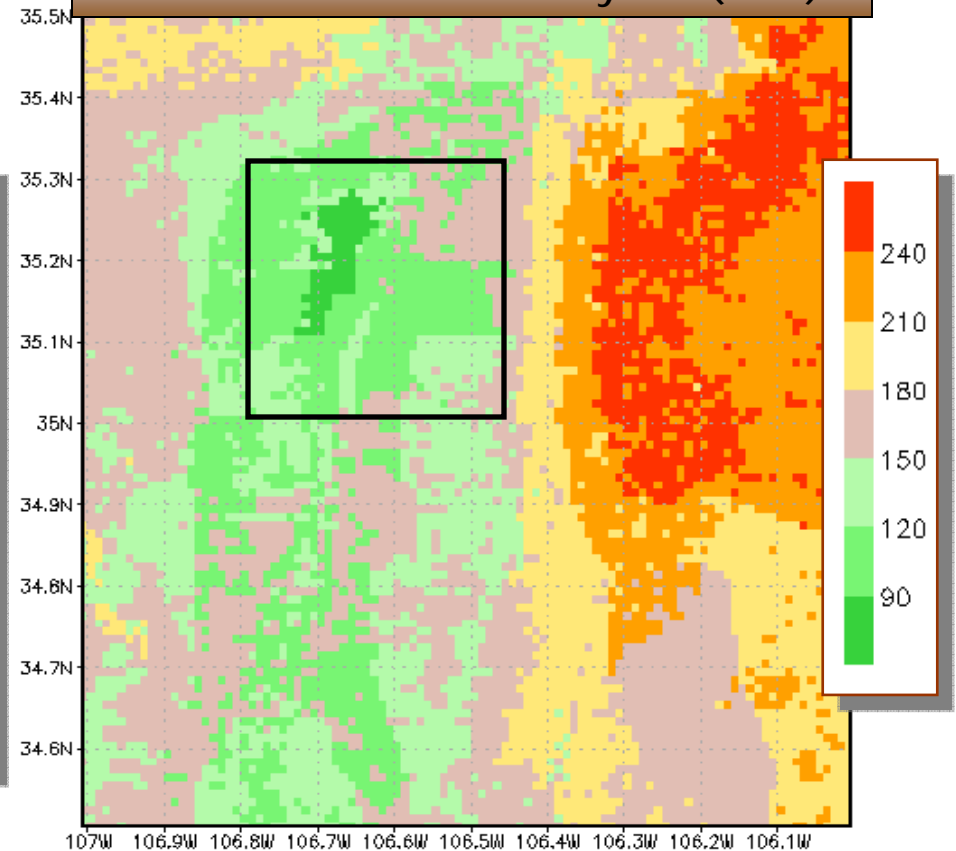
- ◆ LIS LSM output for August of 2003
- ◆ ET-Toolbox Total ET For Central ALBQ: 175.3 mm
- ◆ ET-Toolbox – Total ET for Urban Classes Only: 132.3 mm

Using **MODIS v.4** Land Cover Classes (MOD12) and LAI (MOD15)

LIS-Noah Total Monthly Rainfall (mm)



LIS-Noah Total Monthly ET (mm)



New Merged LIS-LUTA Runs

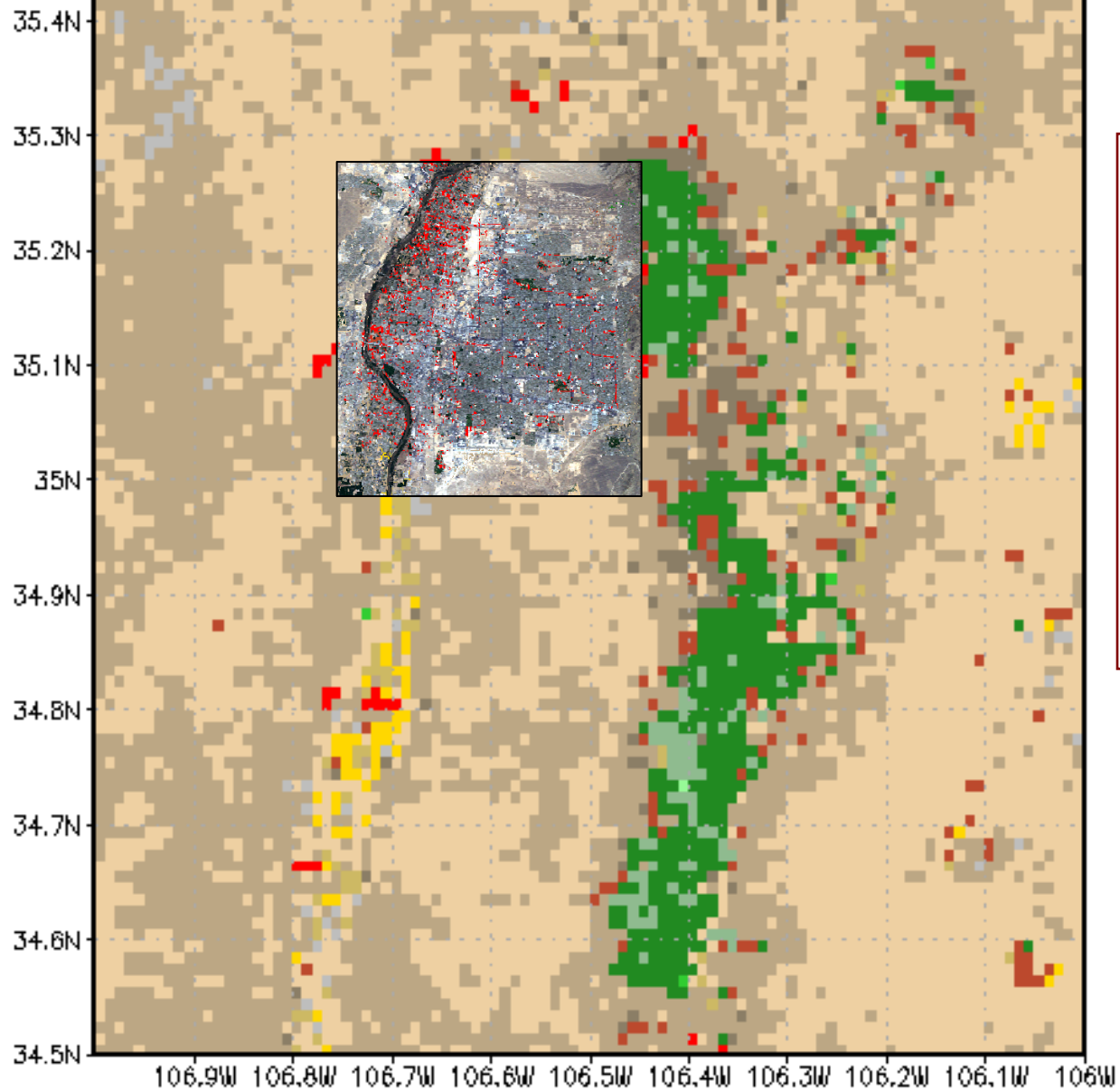
- ◆ The Land Use Trend Analysis (LUTA) land cover classes used in the ET-Toolbox have been mapped to three major other LU/LC classifications datasets for use in LIS:
 - ◆ the UMD classification (currently used in LIS),
 - ◆ IGBP classification (used for LIS-GSWP and other runs)
 - ◆ USGS National Land Cover Dataset (NLCD) high resolution map
- ◆ Region :: Middle Rio Grande River Basin in New Mexico
-- From just above Cochiti Reservoir to just below Elephant Butte Dam.
- ◆ Two approaches are being developed and tested on an UTM projection in LIS:
 - ◆ LUTA classes act as sub-grid tiles to 1km UTM mapped land cover classes
 - ◆ Parameters are being derived for each LUTA land cover to be incorporated appropriately into all three LSMs

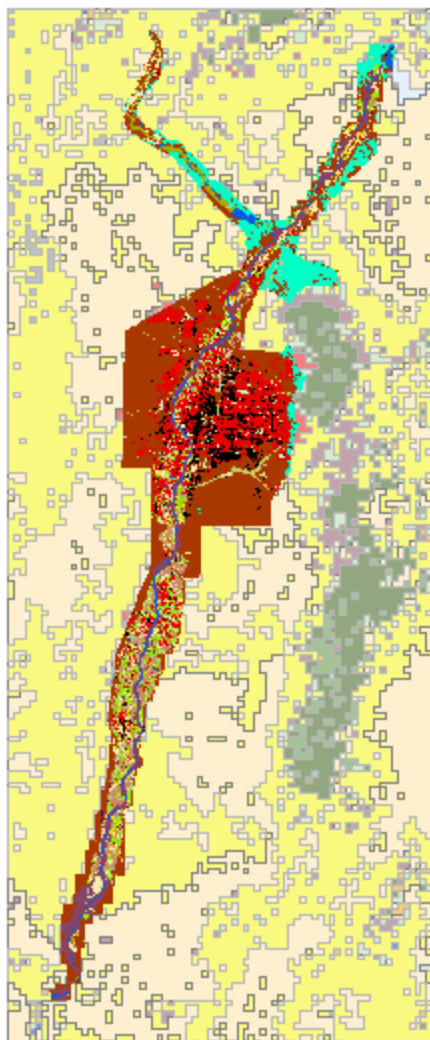
MODIS v.4 Land Cover Classes (MOD12)

Albuquerque, NM
region

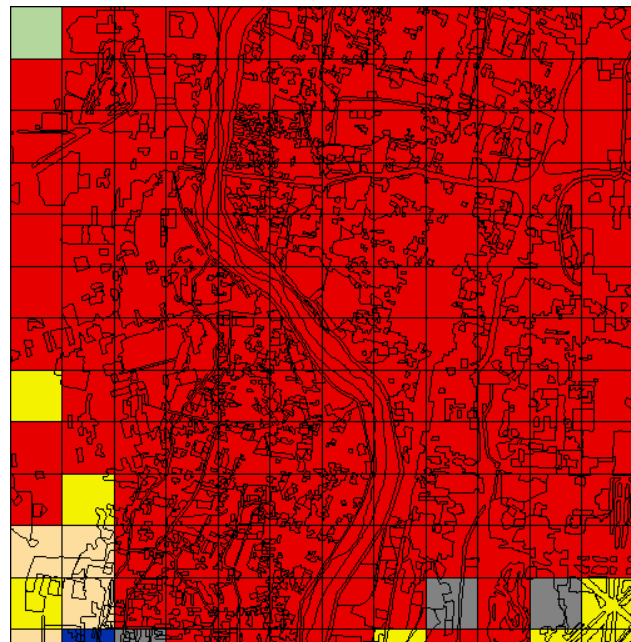
- River or Lake
- Evergreen needleleaf forest
- Evergreen broadleaf forest
- Deciduous needleleaf forest
- Deciduous broadleaf forest
- Mixed cover
- Woodland
- Wooded grassland
- Closed shrubland
- Open shrubland
- Grassland
- Urban areas
- Cropland
- Barren or sparsely vegetated

***LandSat 7
Image blended
with MODIS v4
UMD land cover
classification***



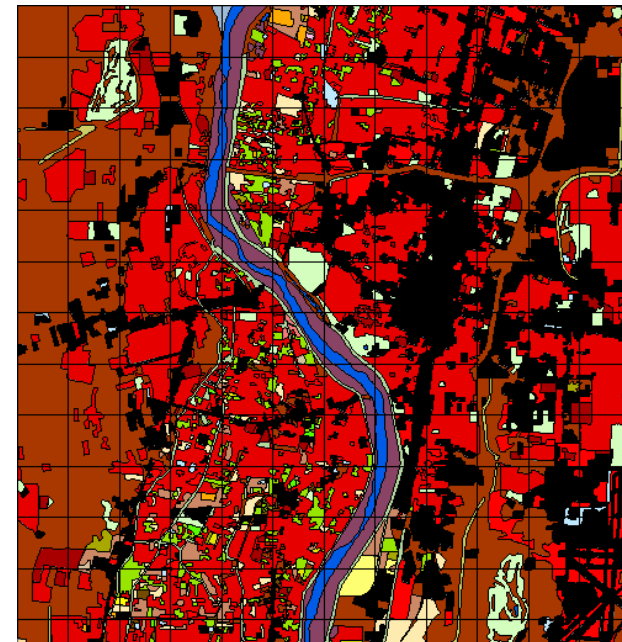


LUTA land cover area w/
transparent MODIS in the
background



MODIS w/ LUTA land cover
boundaries

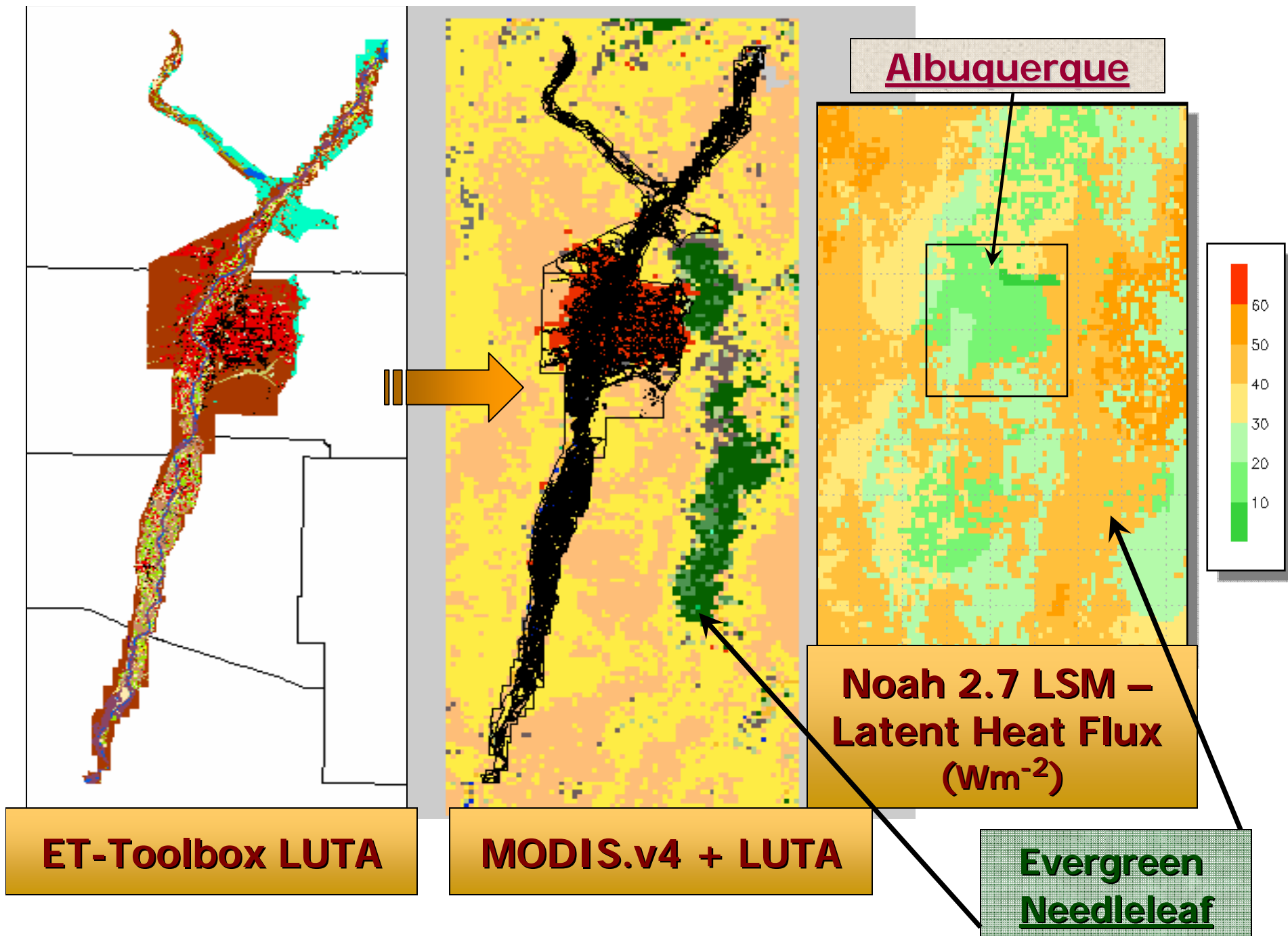
- Water
- Evergreen Needleleaf Forest
- Evergreen Broadleaf Forest
- Deciduous Needleleaf Forest
- Deciduous Broadleaf Forest
- Mixed Forest
- Closed Shrublands
- Open Shrublands
- Woody Savannas
- Savannas
- Grasslands
- Croplands
- Urban and Built-Up
- Barren and Sparsely Vegetated
- Unclassified



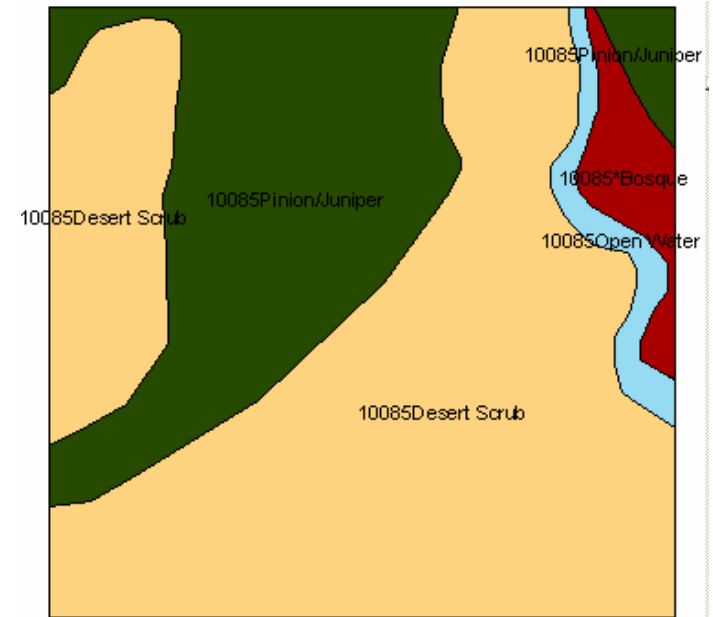
LUTA land cover classes (black lines =
MODIS pixel boundaries)

- TYPE
- *Bosque
- Alfalfa
- Arroyo - Desert Scrub
- Chile Peppers
- Cochiti Dam
- Commercial/Industrial
- Corn
- Desert Scrub
- Fallow Agriculture
- Feeding Farms
- Grapes
- Idle Agriculture
- Marsh Vegetation
- Melons
- Misc. Fruit
- Misc. Grasses
- Misc. Vegetables
- Nursery Stock
- Oats
- Open Water
- Parks and Golf Courses
- Pasture Grasses
- Pinion/Juniper
- Residential
- Residential - dense
- Riparian Shrub
- Riparian Woodland
- River Channel (Jemez)
- Saltcedar
- Sand/Gravel Pit
- Sorghum/Sudex
- Tree Fruit
- Urban Residential Irrig
- Urban Vacant
- Wheat

The MODIS polygon/landcover shapefile was intersected
with the Land Use Trend Analysis (LUTA) shapefile.



Areas were calculated again for each of the LUTA land cover polygons falling within each MODIS cell and the percent land cover polygon per MODIS pixel was calculated

$$(LUTA_AREA/MODIS_AREA)*100$$


ID_TYPE	FIRST_FID_	FIRST_GRID	FIRST_TYPE	FIRST_LUCL	FIRST_TY_1	FIRST_MODI	SUM_LUTA_A	SUM_LUTA_P
10081Pinion/Juniper	10081	7	Open Shrublands	21	Pinion/Juniper	858634.761018	372524.122237	43.385633
10082Desert Scrub	10082	10	Grasslands	20	Desert Scrub	858634.679877	106978.326834	12.459120
10082Pinion/Juniper	10082	10	Grasslands	21	Pinion/Juniper	858634.679877	751656.35722	87.540880
10083Pinion/Juniper	10083	10	Grasslands	21	Pinion/Juniper	858634.761018	858634.684055	99.999991
10084Desert Scrub	10084	10	Grasslands	20	Desert Scrub	858634.761018	459841.989369	53.555017
10084Pinion/Juniper	10084	10	Grasslands	21	Pinion/Juniper	858634.761018	398792.771104	46.444983
10085*Bosque	10085	10	Grasslands	34	*Bosque	858634.679877	34087.678063	3.969986
10085Desert Scrub	10085	10	Grasslands	20	Desert Scrub	858634.679877	542083.262944	63.133167
10085Open Water	10085	10	Grasslands	23	Open Water	858634.679877	26757.496000	3.116284
10085Pinion/Juniper	10085	10	Grasslands	21	Pinion/Juniper	858634.679877	255706.170629	29.780555
10086*Bosque	10086	10	Grasslands	34	*Bosque	858634.761018	555107.678875	64.650036
10086Desert Scrub	10086	10	Grasslands	20	Desert Scrub	858634.761018	69802.555287	8.129482
10086Open Water	10086	10	Grasslands	23	Open Water	858634.761018	130796.944173	15.233129
10086Pinion/Juniper	10086	10	Grasslands	21	Pinion/Juniper	858634.761018	102927.582137	11.987353
10087*Bosque	10087	10	Grasslands	34	*Bosque	858634.679877	619501.997428	72.149659

Dissolved Table

A new text field was created by adding the MODIS PIXEL ID field with the LUTA class description. This field was then used to dissolve (sum the area and the percent cover) the area of each LUTA class within each unique MODIS pixel.

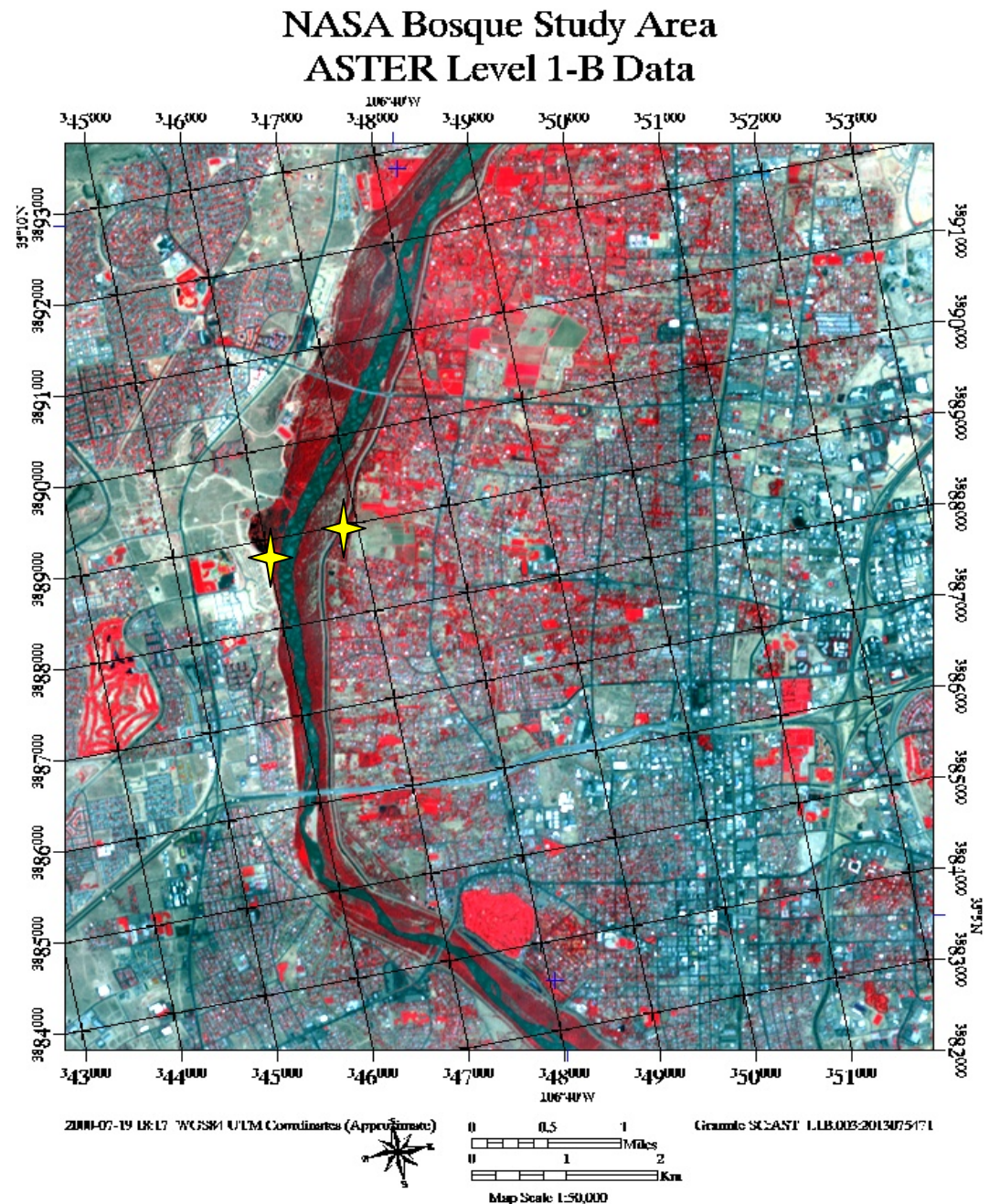
New Eddy Covariance Flux Towers ::

- ◆ Have been installed in Albuquerque to further validate the LSM runs and AWARDS ET-Toolbox for an alfalfa farm and along banks of Rio Grande

★ -- Eddy Covariance Flux Tower Sites

Collaboration between

- ❖ MRGCD
- ❖ Reclamation
- ❖ New Mexico Tech
- ❖ NASA/GSFC
- ❖ SUNY-Buffalo



* ASTER Scene Provided by Dr. Matt Becker, SUNY-Buffalo

Conclusions

- Original 0.125 Deg LDAS Runs are able to capture well regions of more homogeneous land cover and terrain conditions
- However, this resolution is not suitable for capturing the highly heterogeneous land cover surrounding the Middle Rio Grande River Basin
- New methods of downscaling LIS LSMs and to utilize the high resolution and diverse land cover classifications of the area have been introduced
- Different satellite-derived land cover maps were shown to have major impacts on the accumulative estimates of ET and energy balance terms
- The latest MODIS products tend to not capture all land cover features well in New Mexico, but they are more updated maps and are more compatible with a larger range of land surface products suitable for LSMs and high resolution

Future Work

- The new MODIS-LUTA runs will be completed and validated with the two eddy covariance (EC) flux towers in Albuquerque
- In addition, other EC flux tower measurements in the region and for more forested (“bosque”) sites will be used as well for further validation of AWARDS ET Toolbox and the LIS LSM output
- Incorporation of the local network of NM meteorological station data will be incorporated to enhanced LDAS forcing products

Thank You!