



Integration of GOES, MODIS, and HypIRI Thermal Satellite Imagery for Mapping Daily ET at the Sub- field Scale

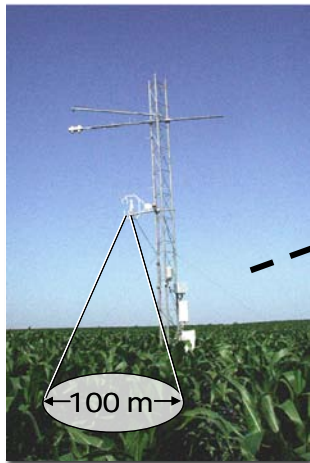
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*USDA-ARS, Hydrology and Remote Sensing
Laboratory*

C. Hain, J.R. Mecikalski
U Alabama-Huntsville, Atmospheric Science

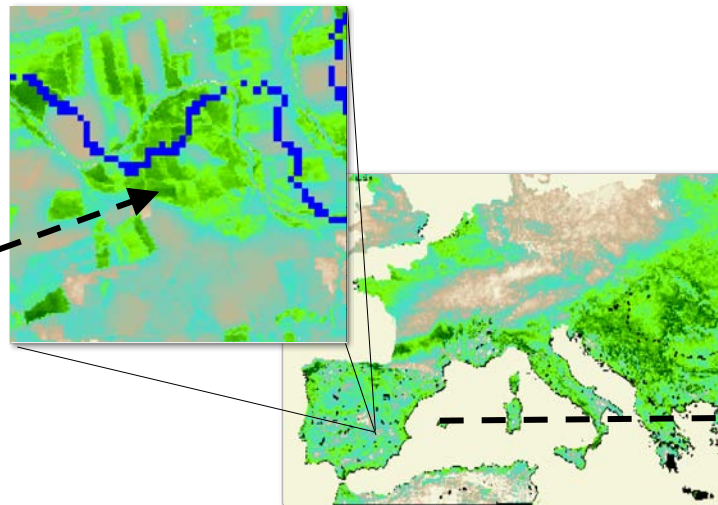
Why global remotely sensed ET?

Climate Change

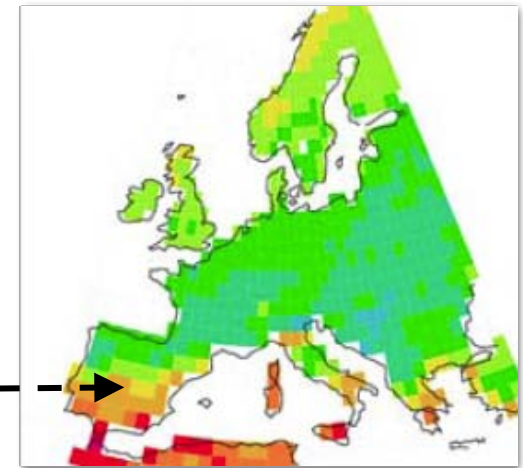
- **GEO: Essential Climate Variable**
- **Link between global energy and water cycles**
- **Adaptation to climate change**
 - *water availability, soil salinization*
- **Diagnostic check on GCMs/LSMs**
 - *bridge between observation and model grid scales*



Tower flux



Remote sensing



GCM

Why global remotely sensed ET?

ET (mm)

0

100

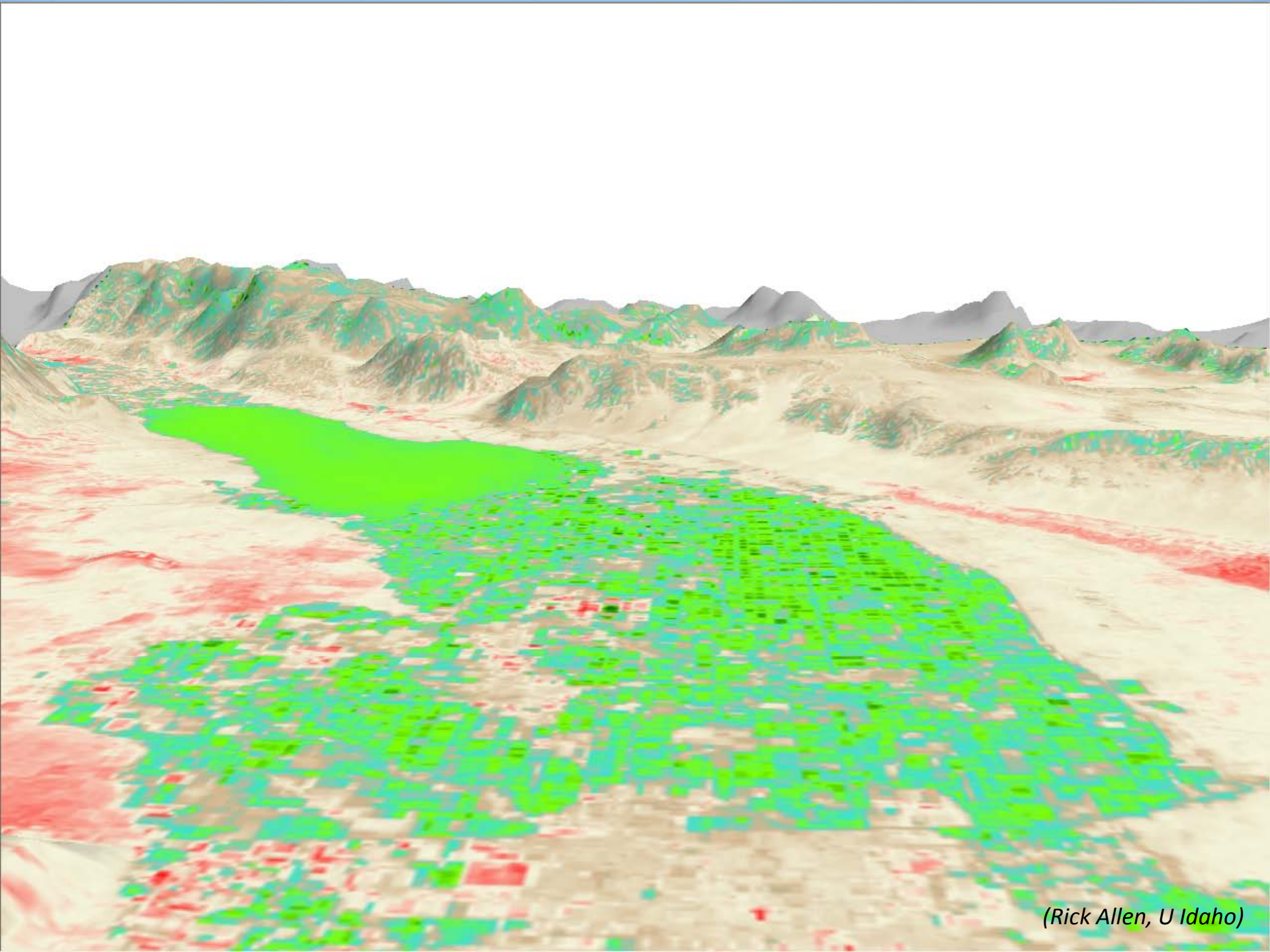
200

300

400

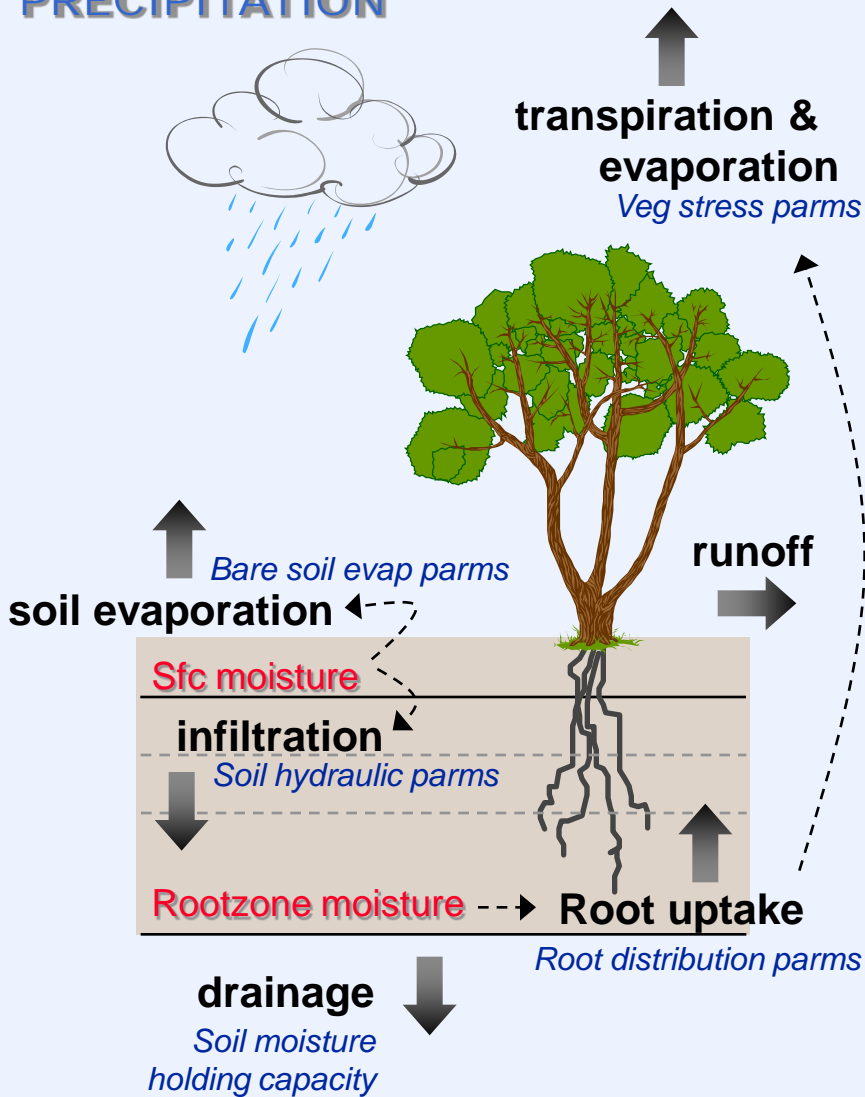
Societal Benefits

- **Water resource management**
 - *water rights compliance and trading*
- **International irrigation projects**
 - *monitoring efficiency and distribution equitability*
- **Food security**
 - *drought early warning and impact assessment*

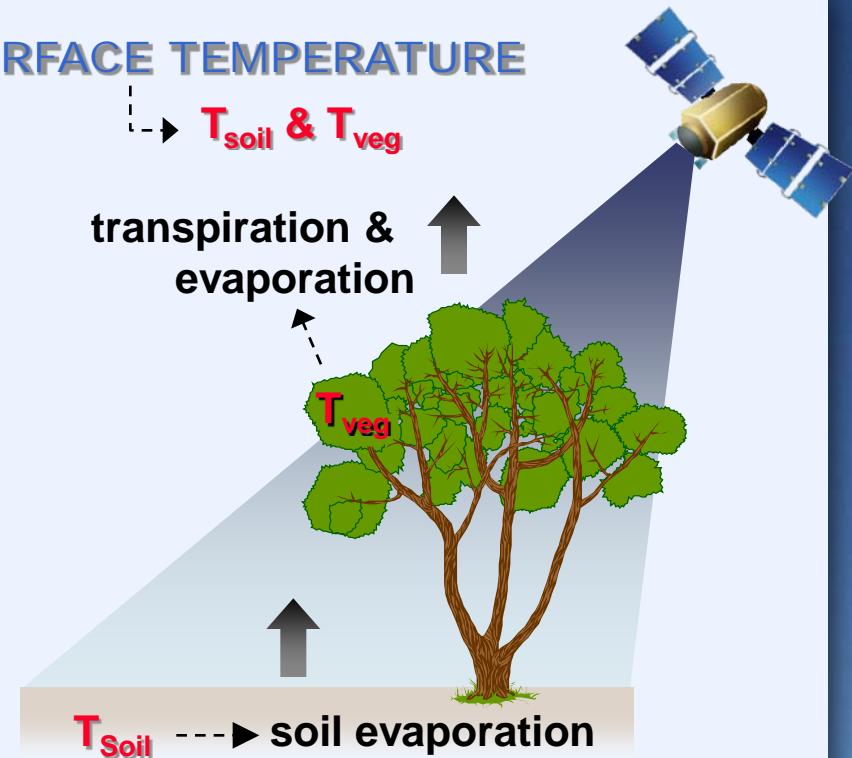


(Rick Allen, U Idaho)

PRECIPITATION



SURFACE TEMPERATURE



Given known radiative energy inputs, how much water loss is required to keep the soil and vegetation at the observed temperatures?

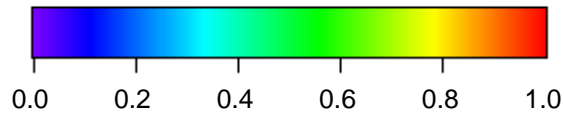
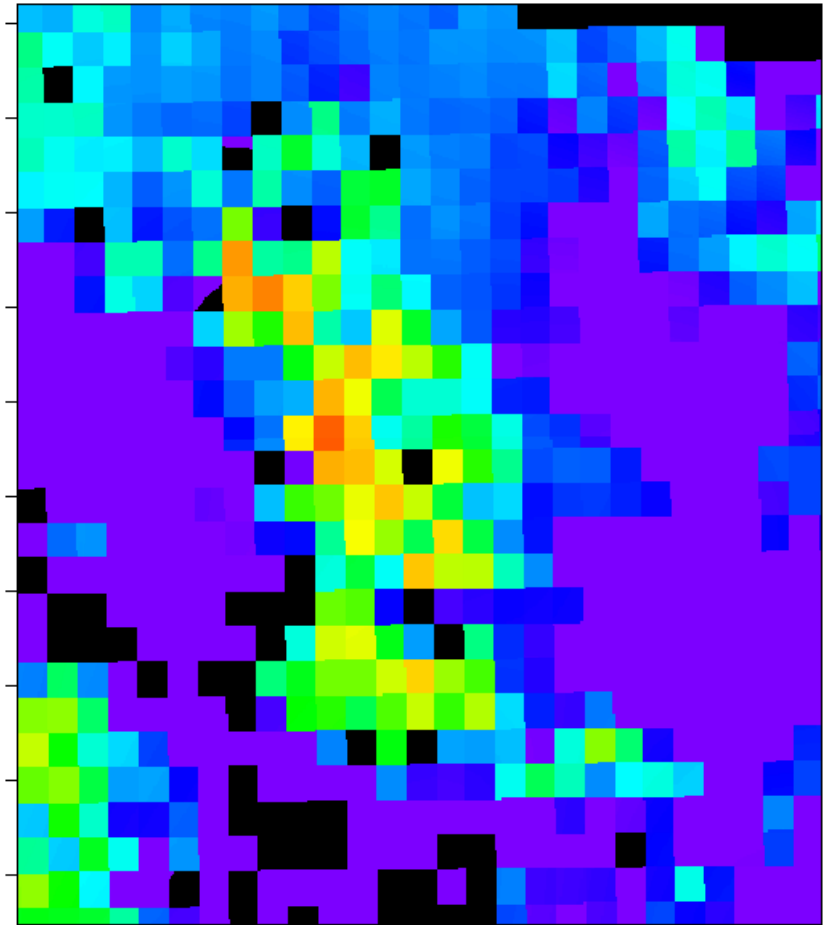
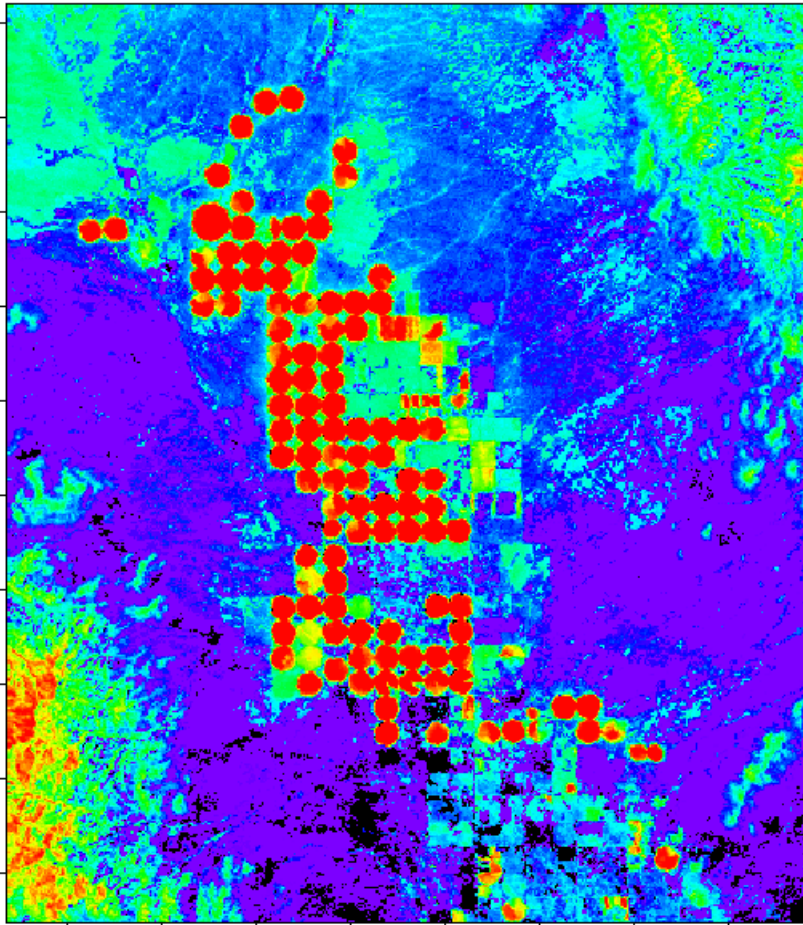
WATER BALANCE APPROACH
("forward modeling")

REMOTE SENSING APPROACH
("inverse modeling")

Sensitivity to irrigation

Landsat 7 – 60m

MODIS – 1km



$$\frac{ET}{PET}$$

Satellite Thermal Imaging Systems

| Pixel Scale | Spatial Resolution | Temporal Resolution | Current Sources | Future Sources |
|-------------|--------------------|----------------------|------------------------|------------------------|
| Coarse | 5-20 km | 15 min | AIRS GOES MSG | CrIS GOES MSG |
| Moderate | 1 km | ~Daily | MODIS AVHRR ATSR | VIIRS AVHRR ATSR |
| Fine | 60–120 m | Once every 8-16 days | ASTER Landsat | LDCM HyspIRI |

Table from S. Hook

A satellite-style map of North America, showing the United States, Canada, and Mexico. The map is overlaid with a grid of green lines. The text is centered over the United States.

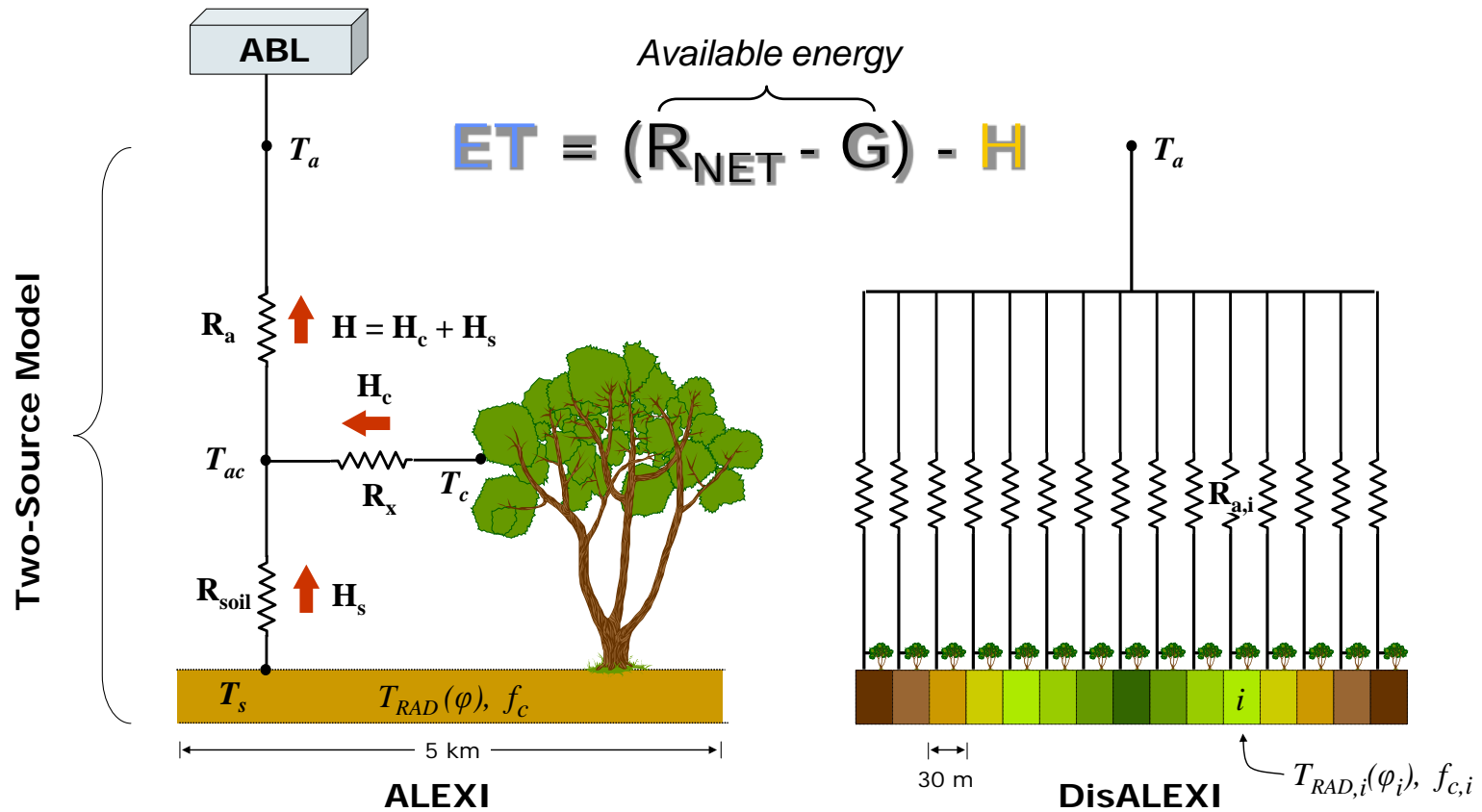
APPLICATIONS

... evapotranspiration

**ALEXI - Atmosphere-Land
Exchange Inverse Model**

(Anderson et al, JGR, 2007)

Atmosphere-Land Exchange Inverse (ALEXI)



Regional scale

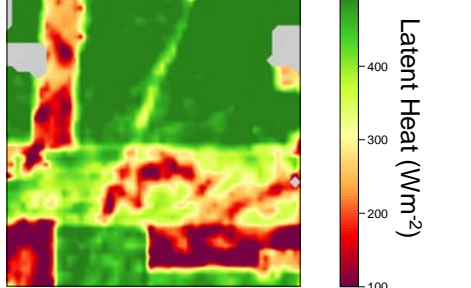
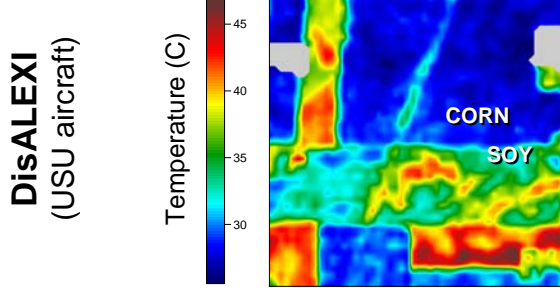
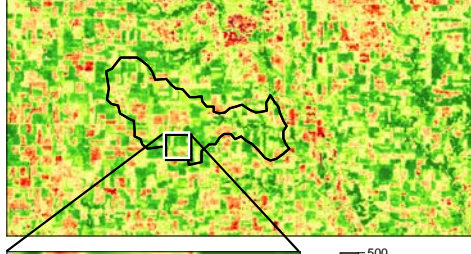
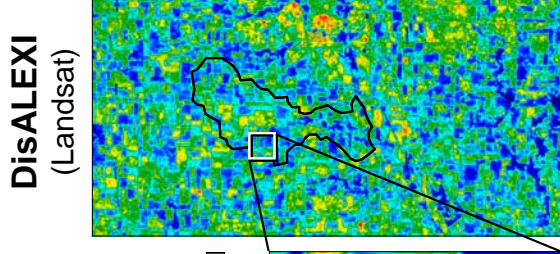
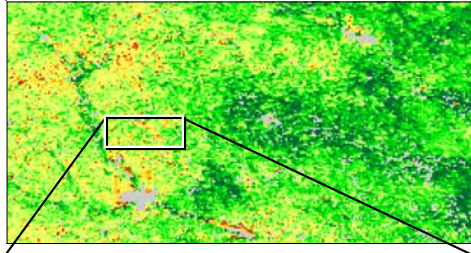
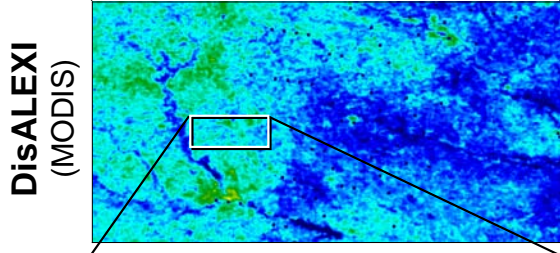
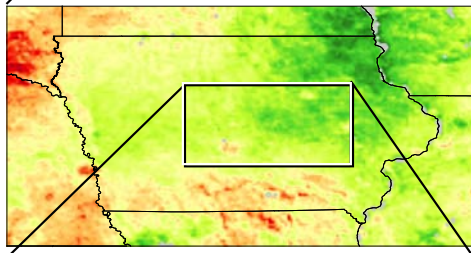
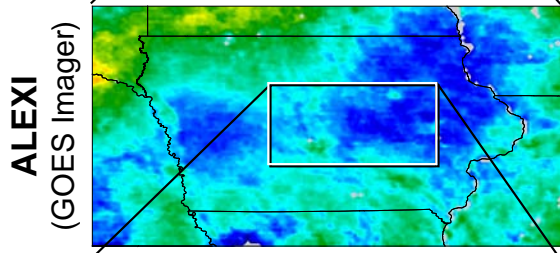
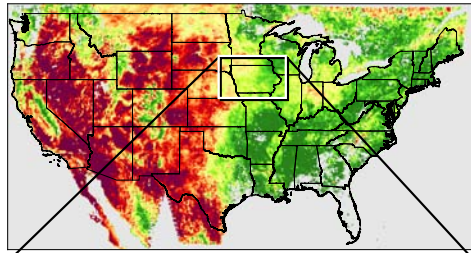
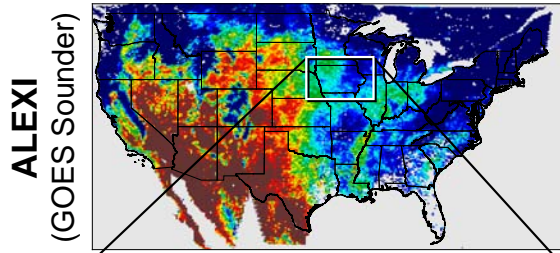
Surface temp: ΔT_{RAD} - GOES
 Air temp: T_a - ABL model

Landscape scale

T_{RAD} - TM, MODIS, HypsIRI
 T_a - ALEXI

SURFACE TEMPERATURE

EVAPOTRANSPIRATION



Continental
(10km)

Regional
(5km)

Watershed
(1km)

Catchment
(60m)

Field scale
(30m)

1 July 2002 – 10:30AM CST

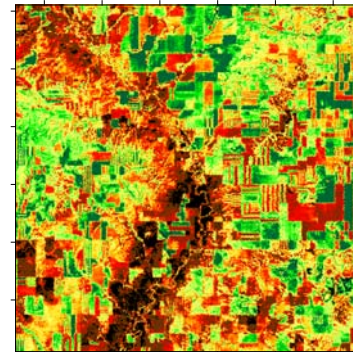
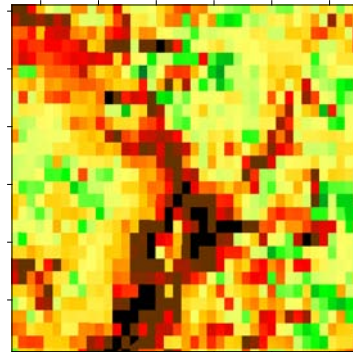
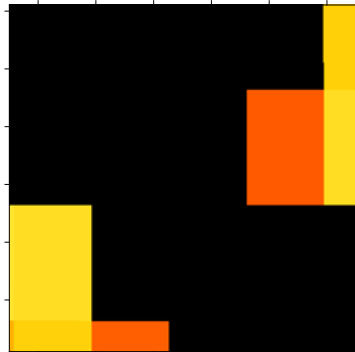
FORT PECK, MONTANA

GOES (10km)

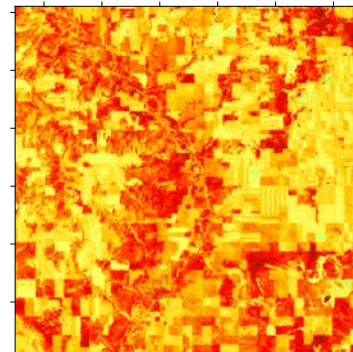
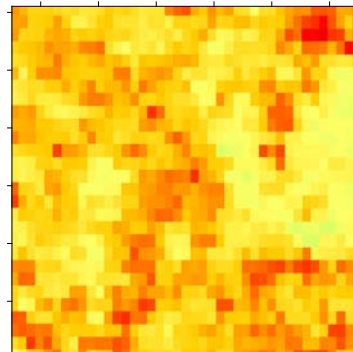
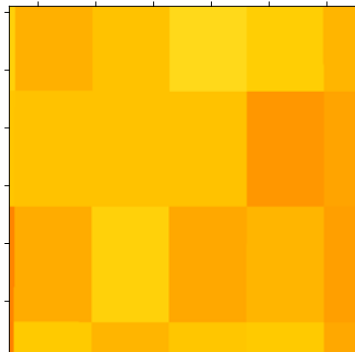
MODIS (1km)

Landsat (~100m)

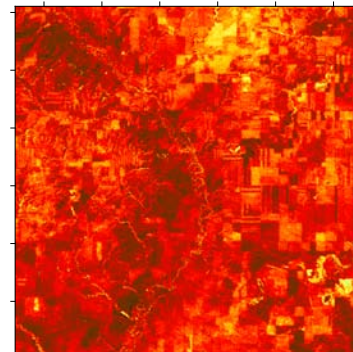
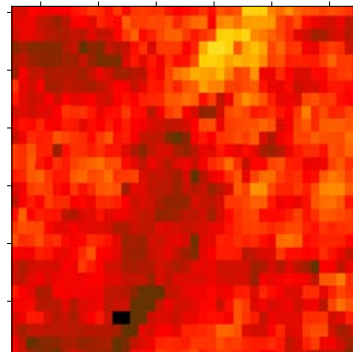
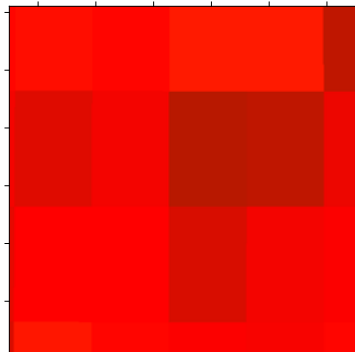
30 Jun 2002



18 Aug 2002



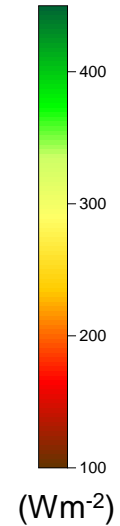
2 Sep 2002



(hourly)

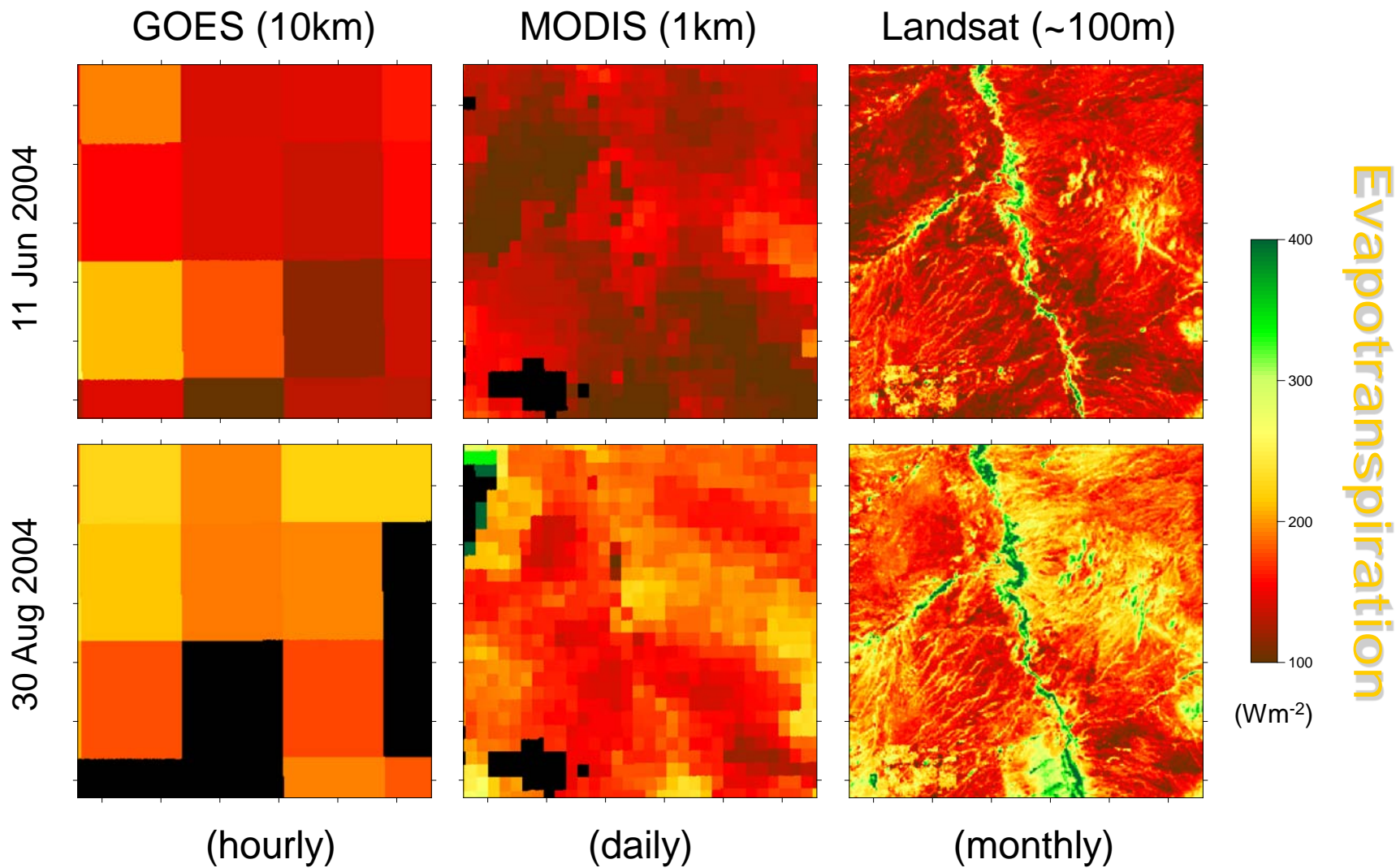
(daily)

(monthly)



Evapotranspiration

SAN PEDRO RIVER, ARIZONA

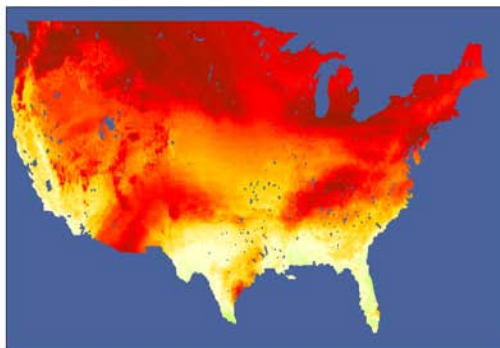
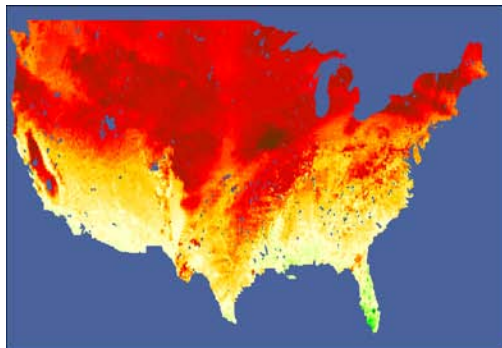


Daily ET
(November 24, 2002)

Daily ET
(December 2, 2002)

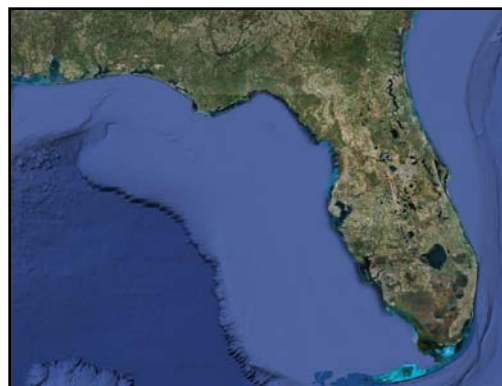
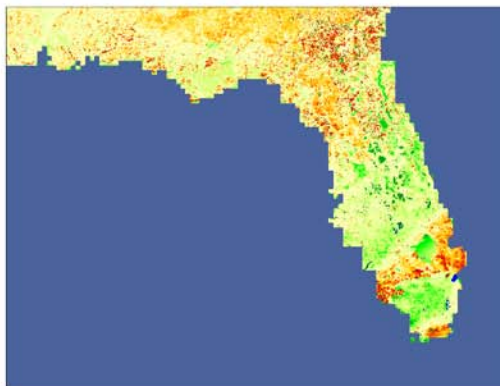
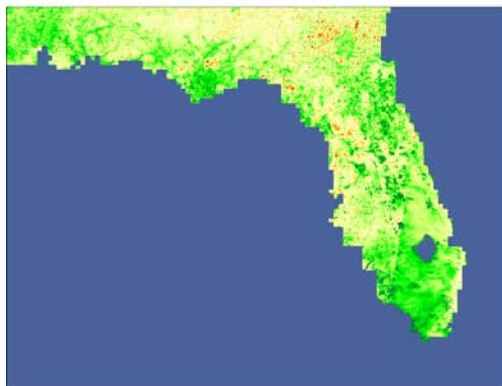
Google Maps

GOES
(ALEXI)



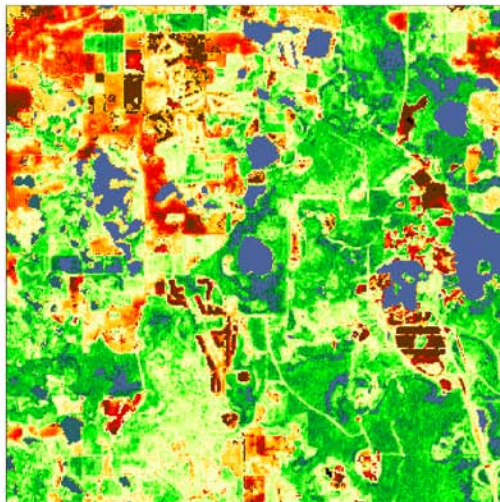
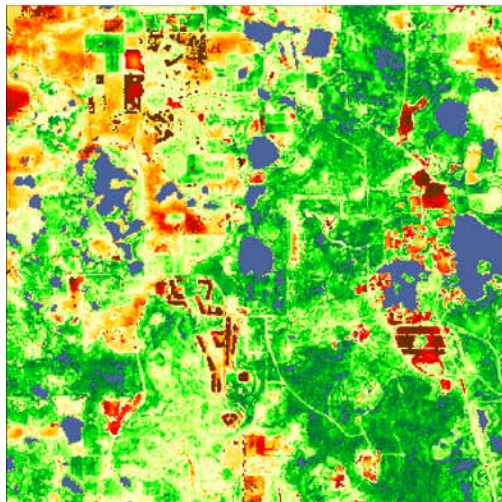
CONUS

MODIS
(DisALEXI)



Florida

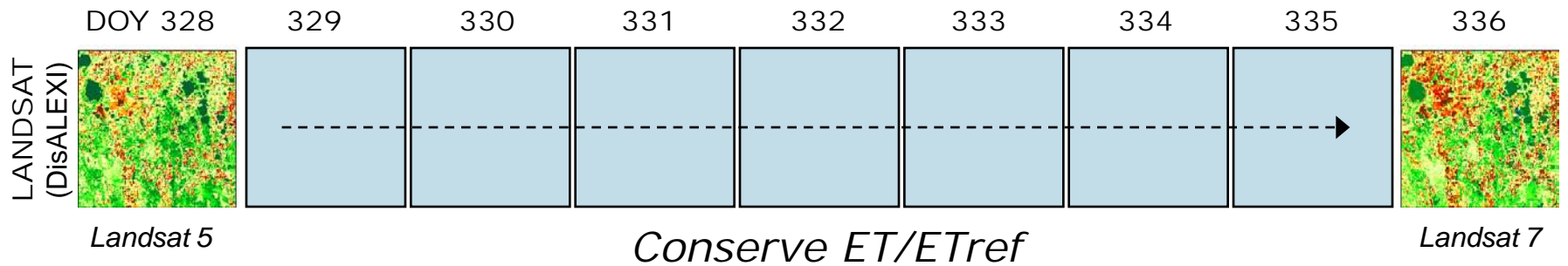
LANDSAT
(DisALEXI)



Orlando

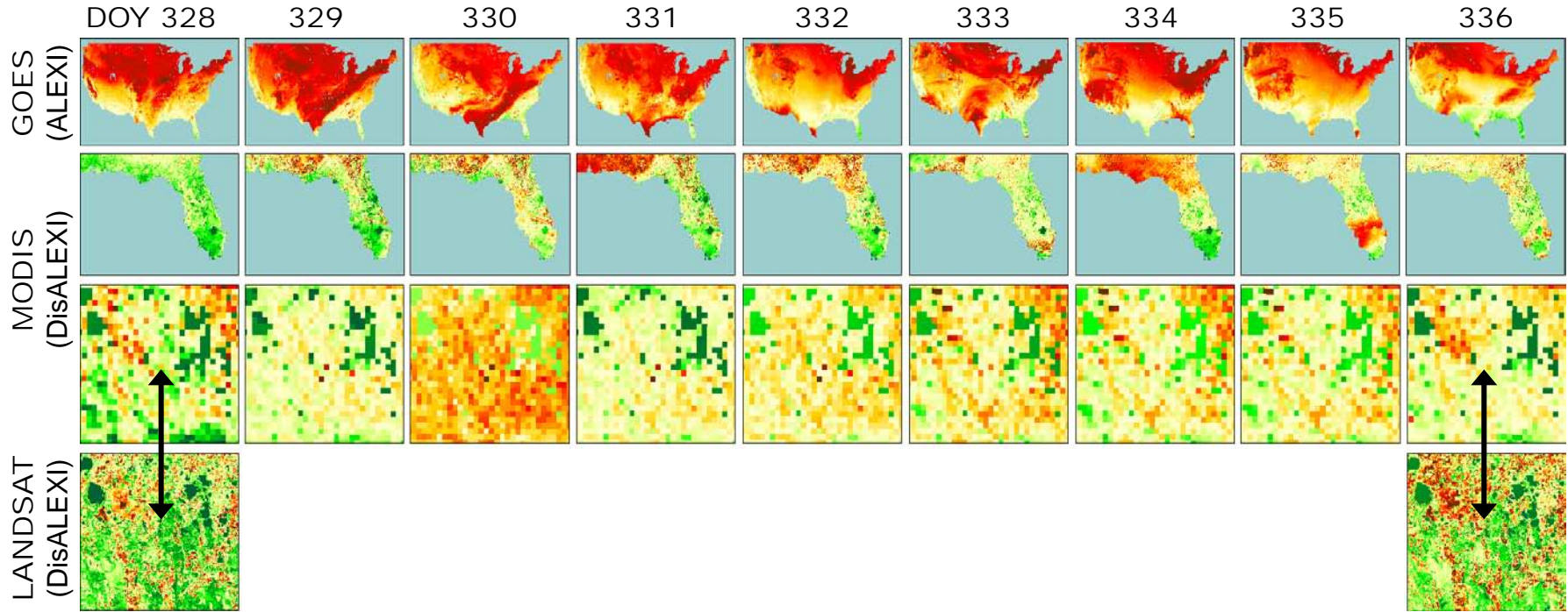
HIGH-RESOLUTION INTERPOLATION

Daily Evapotranspiration – Orlando, FL, 2002



GOES/MODIS/Landsat FUSION

Daily Evapotranspiration – Orlando, FL, 2002



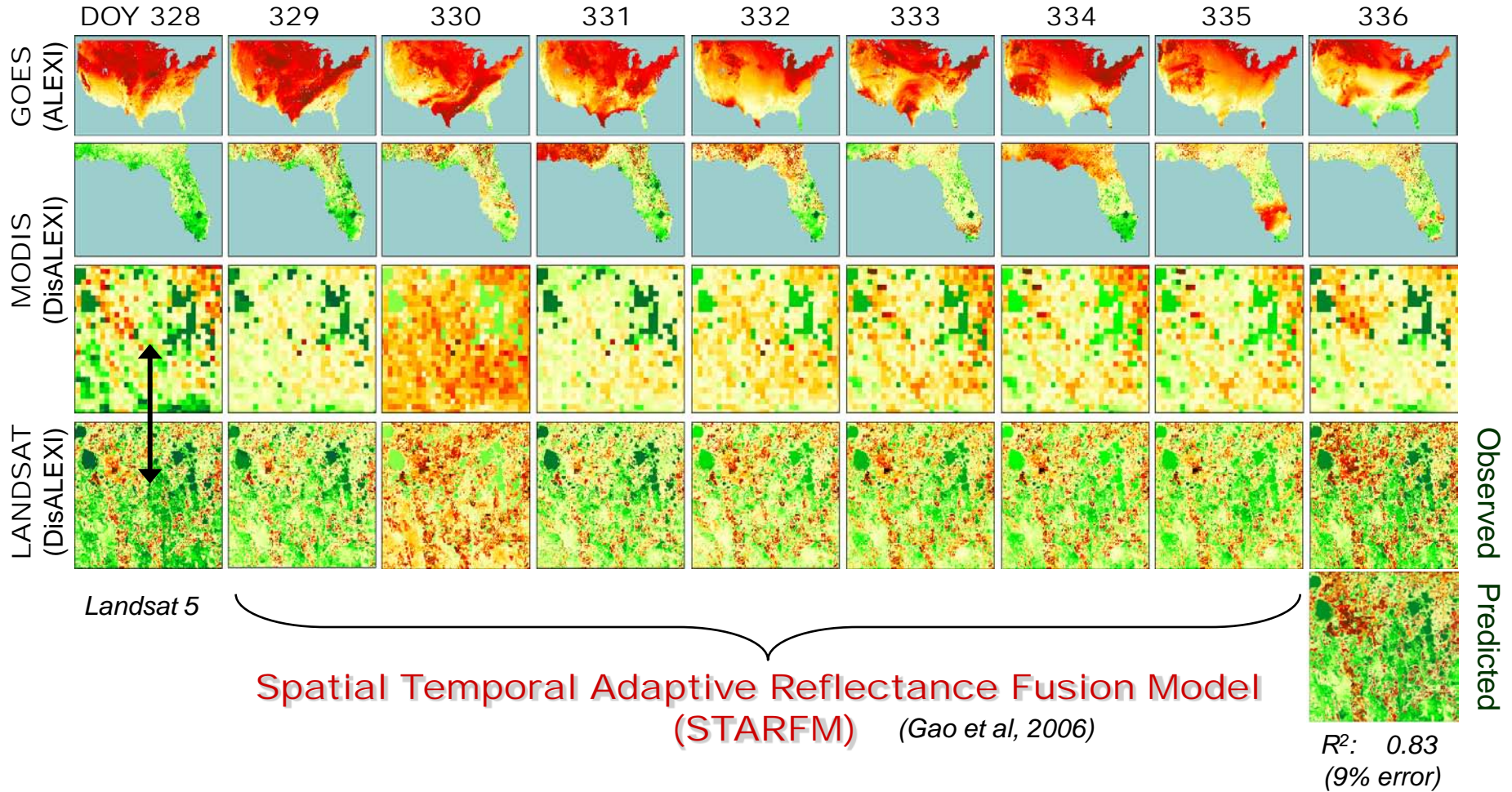
Landsat 5

Landsat 7

**Spatial Temporal Adaptive Reflectance Fusion Model
(STARFM)** (Gao et al, 2006)

GOES/MODIS/Landsat FUSION

Daily Evapotranspiration – Orlando, FL, 2002



A satellite-style map of North America, showing the United States, Canada, and Mexico. The map is overlaid with a grid of green lines representing state or provincial boundaries. The text is centered on the map. The background is a blue sky with some clouds.

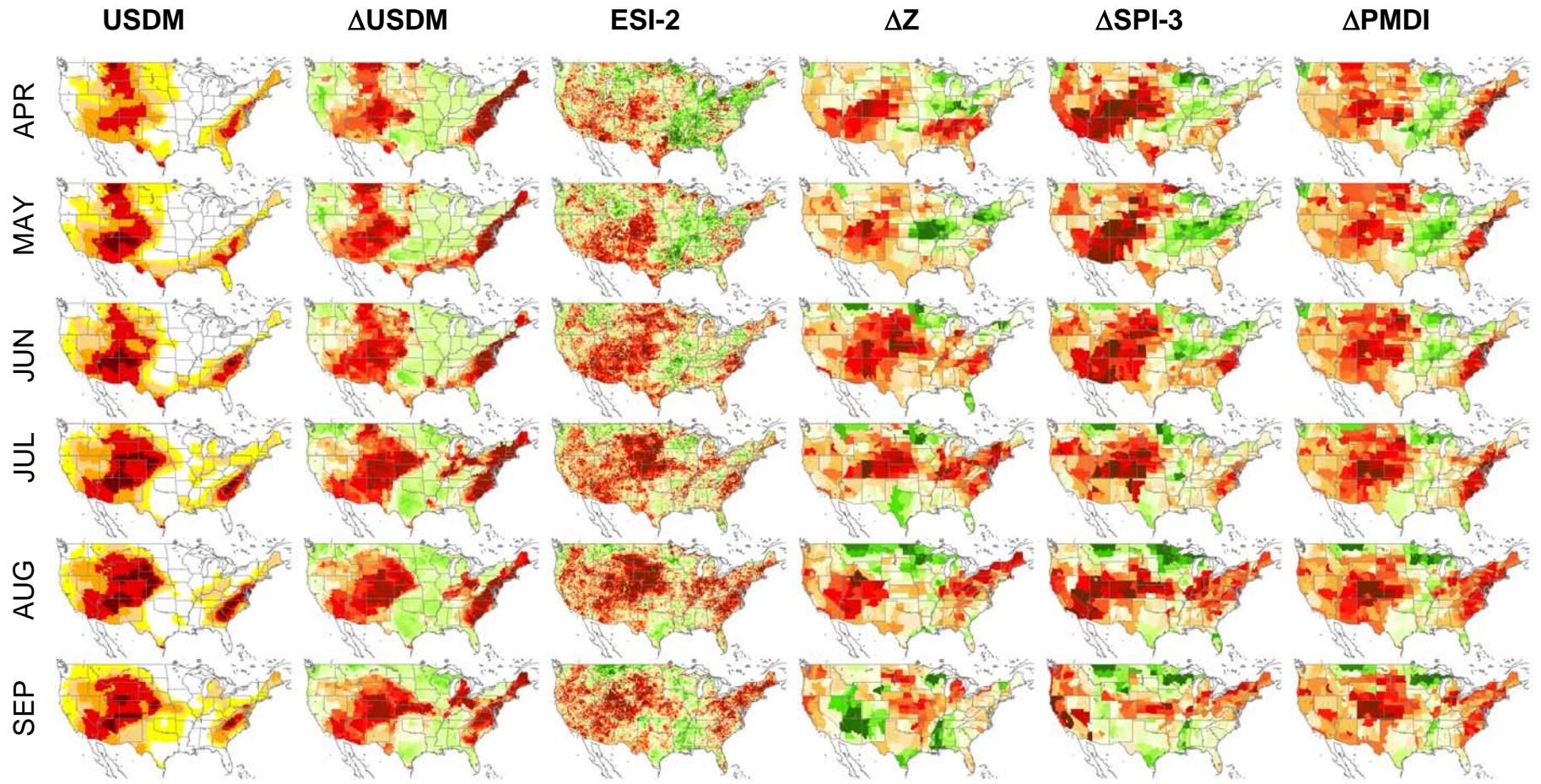
APPLICATIONS

... monitoring drought

Anomalies in $\frac{AET}{PET}$

Evaporative Stress Index

MONTHLY ANOMALIES

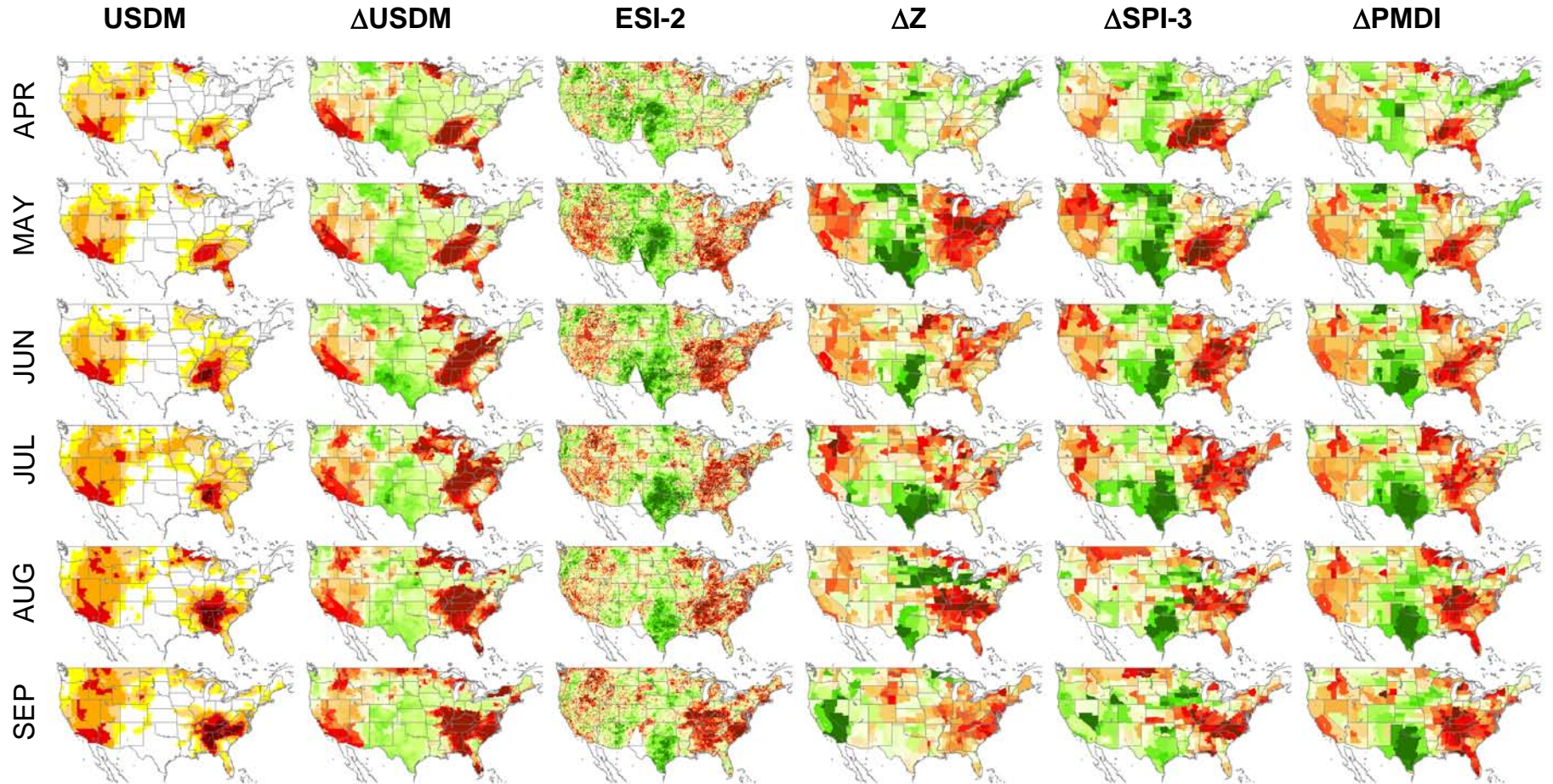


D0 D1 D2 D3 D4


Drier Wetter
-2 -1 0 1 2

2002

MONTHLY ANOMALIES



D0 D1 D2 D3 D4

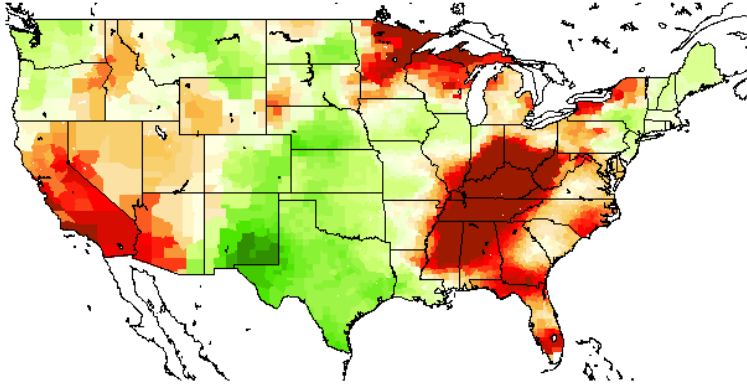
Drier  Wetter

-2 -1 0 1 2

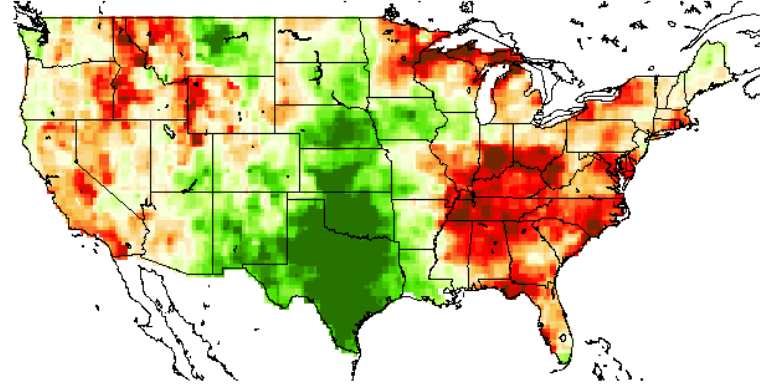
2007

2007 SEASONAL ANOMALIES

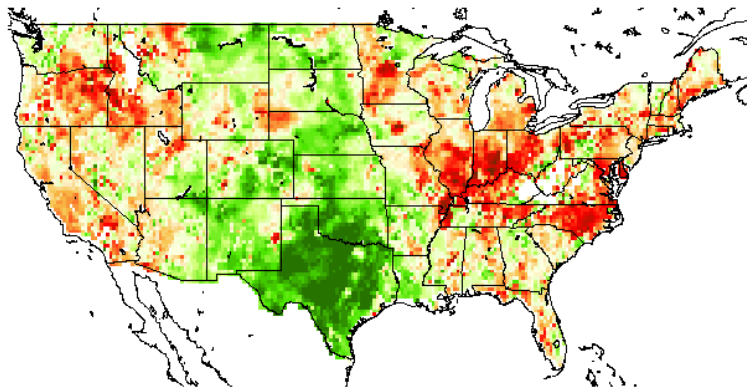
USDM



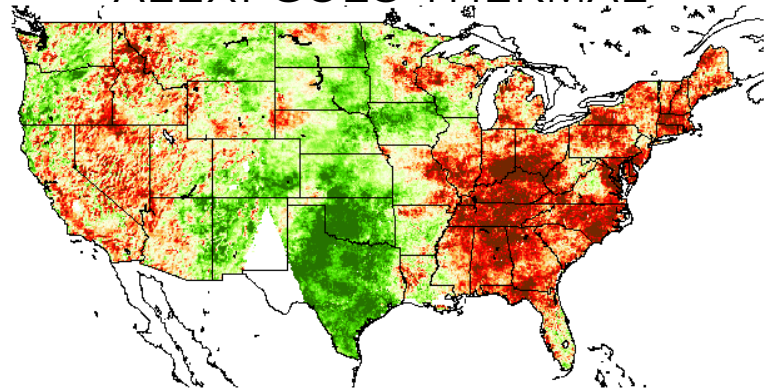
LIS - NOAH



USDA AMSR-E MICROWAVE



ALEXI GOES THERMAL



- samples 5cm layer
- 50km pixels (AMSR)
- ~2-day coverage
- light vegetation cover

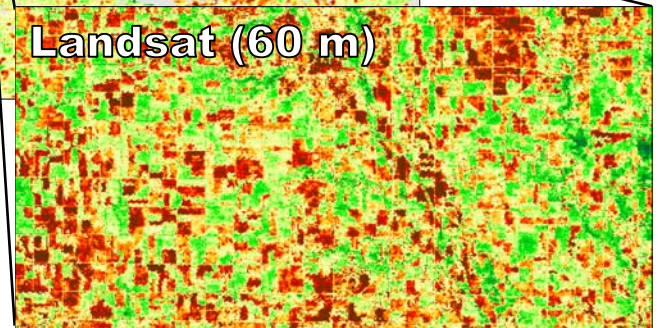
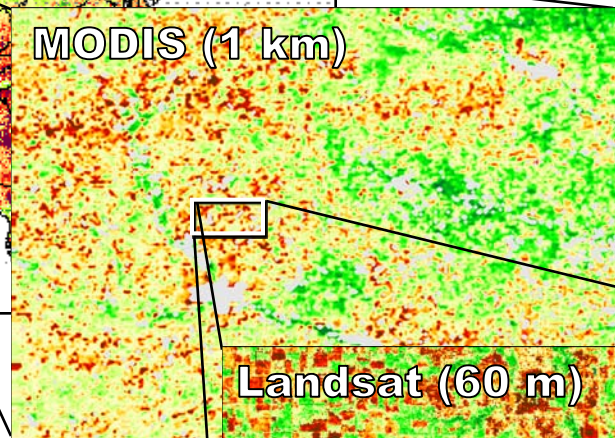
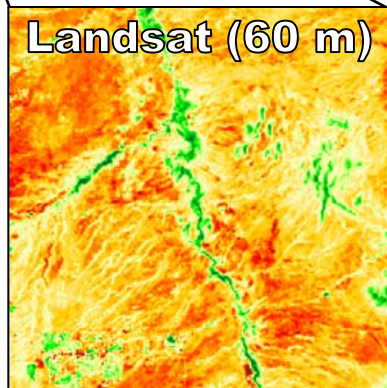
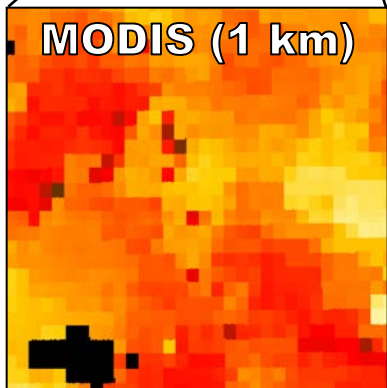
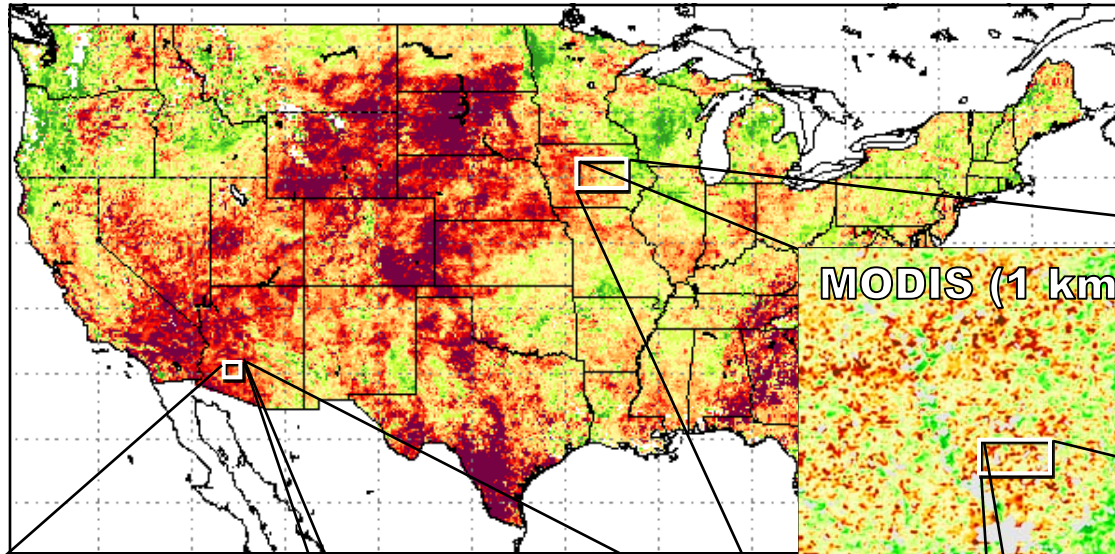
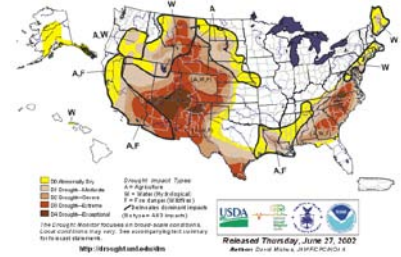
- samples ~1-2m layer
- 60m - 5km pixels (L7, GOES)
- ~15-day coverage (90%)
- low to high vegetation cover

Multi-scale Drought Monitoring

GOES Evaporative Stress Index

JUNE 2002

U.S. Drought Monitor June 25, 2002

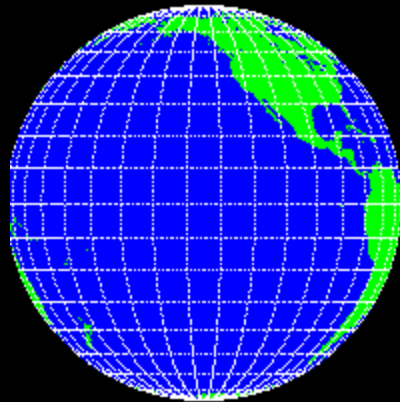


A satellite-style map of North America, showing the United States, Mexico, and parts of Canada. A green grid is overlaid on the landmass, representing a domain for global applications. The text is centered over the United States.

GLOBAL APPLICATIONS

*... Improve ALEXI domain
coverage and resolution*

Geostationary Satellite Coverage



GOES W 135°W
NOAA (US)



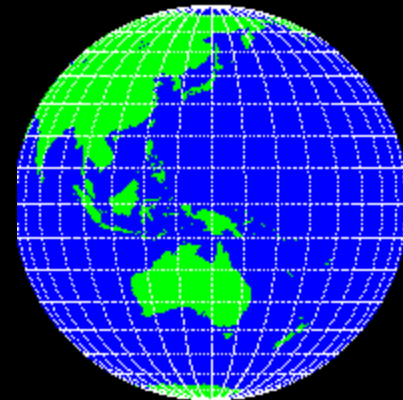
GOES E 75°W
NOAA (US)



Meteosat 0°
Eumetsat (EU)



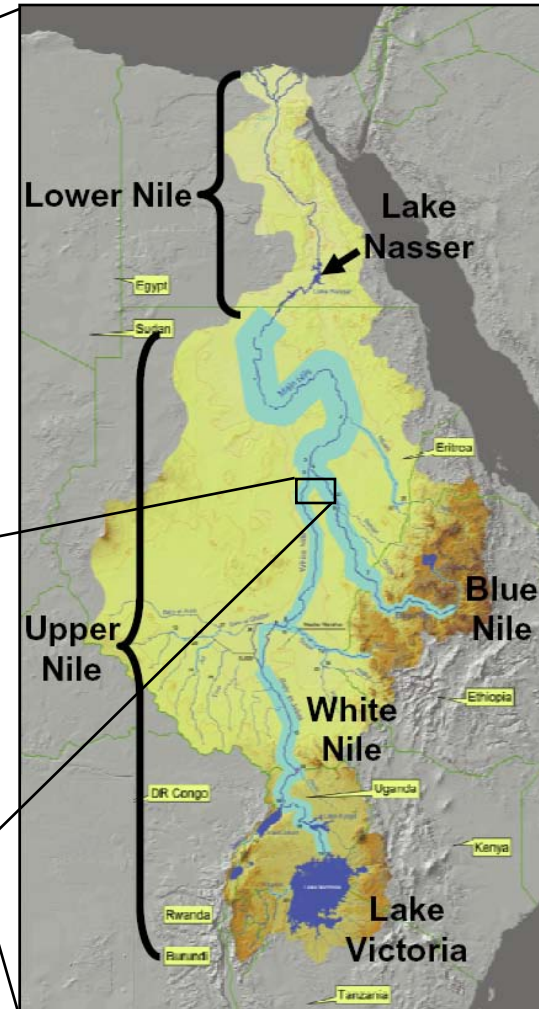
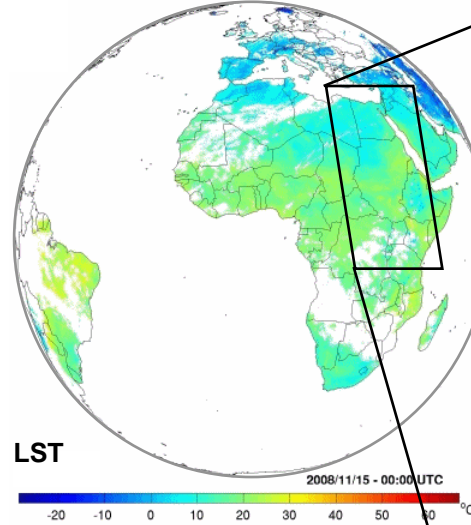
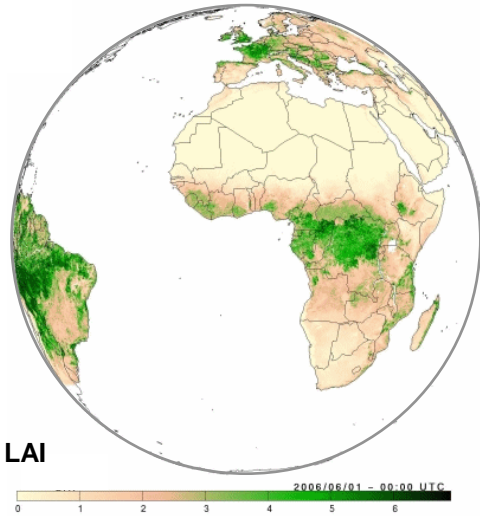
Meteosat 63°E
Eumetsat (EU)



GMS 140°E
JAXA (Japan)

Nile Basin Initiative Decision Support

METEOSAT COVERAGE

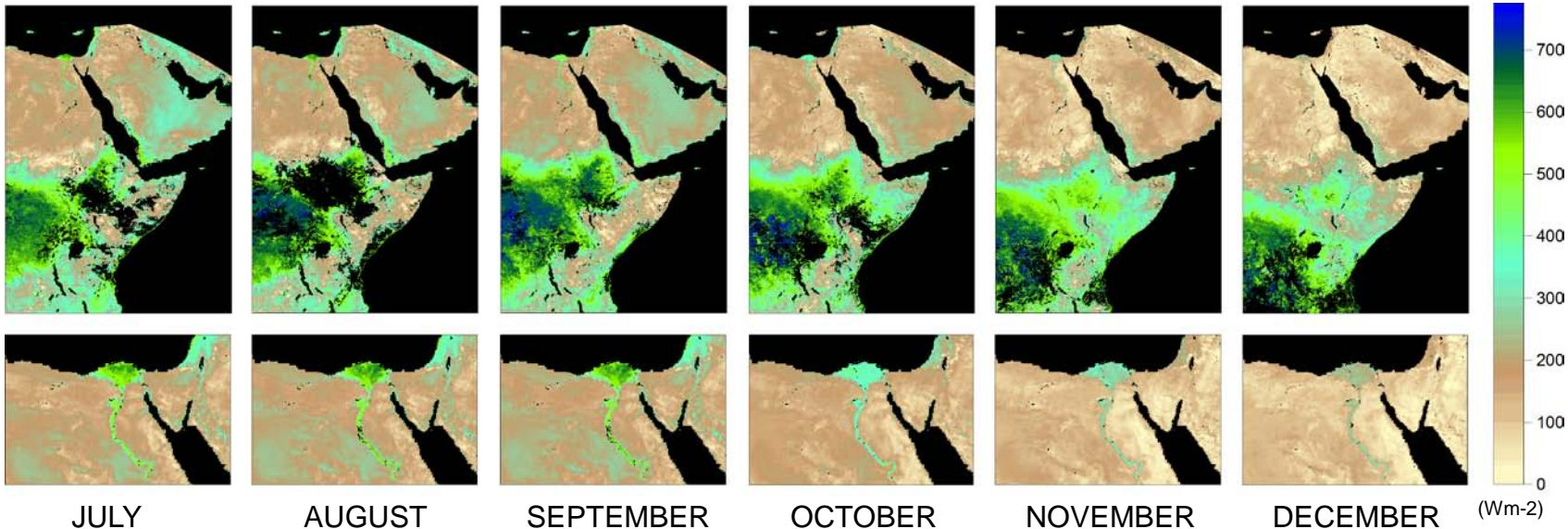


L7-ETM+ 1/12/02 USGS Image Gallery

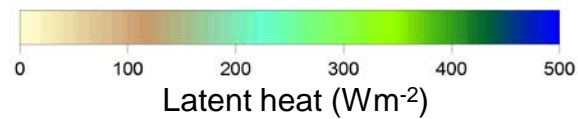
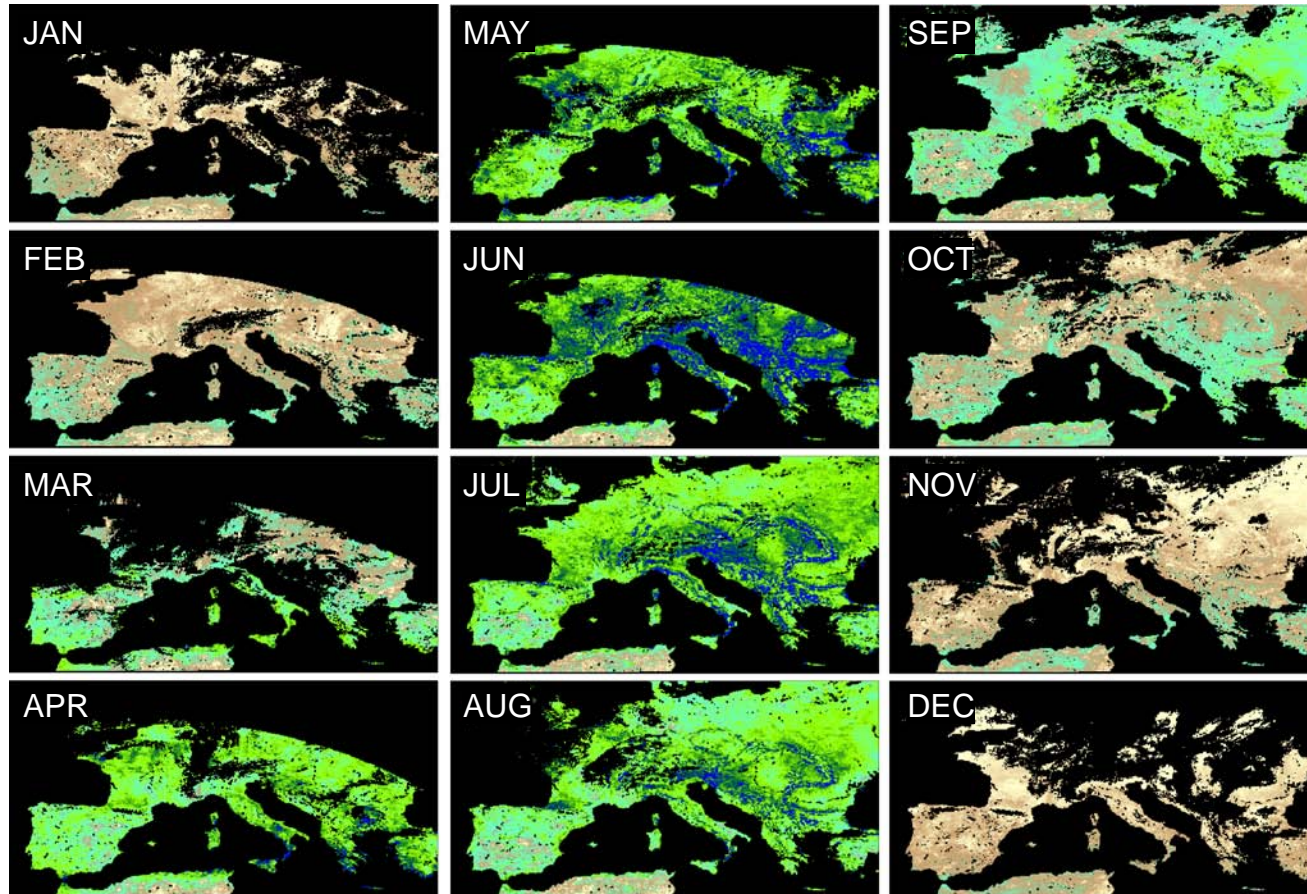
Midday Latent Heat Flux

2008

Meteosat
(ALEXI)



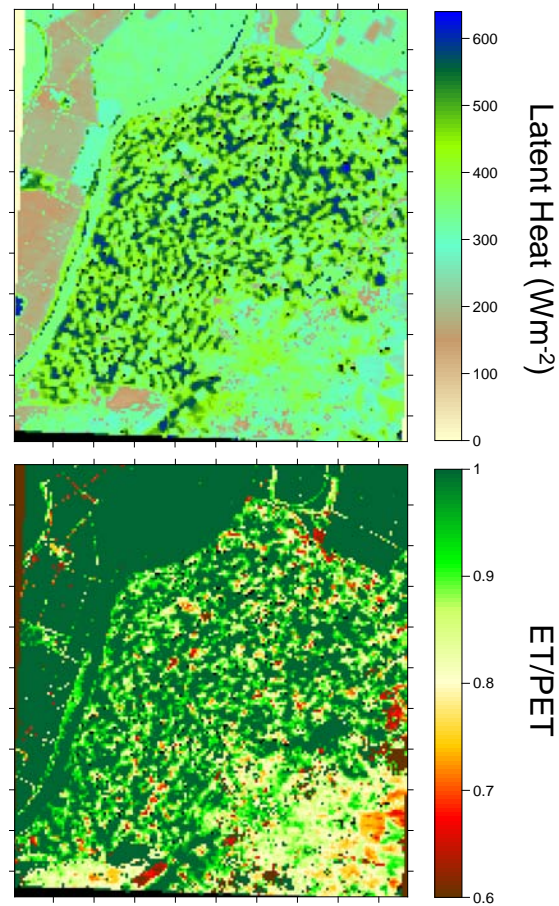
ALEXI – Europe (Meteosat 10km)



Spain (Irrigation District)



LEBRIJA, SPAIN May 15 2005



Landsat 5 (120m)

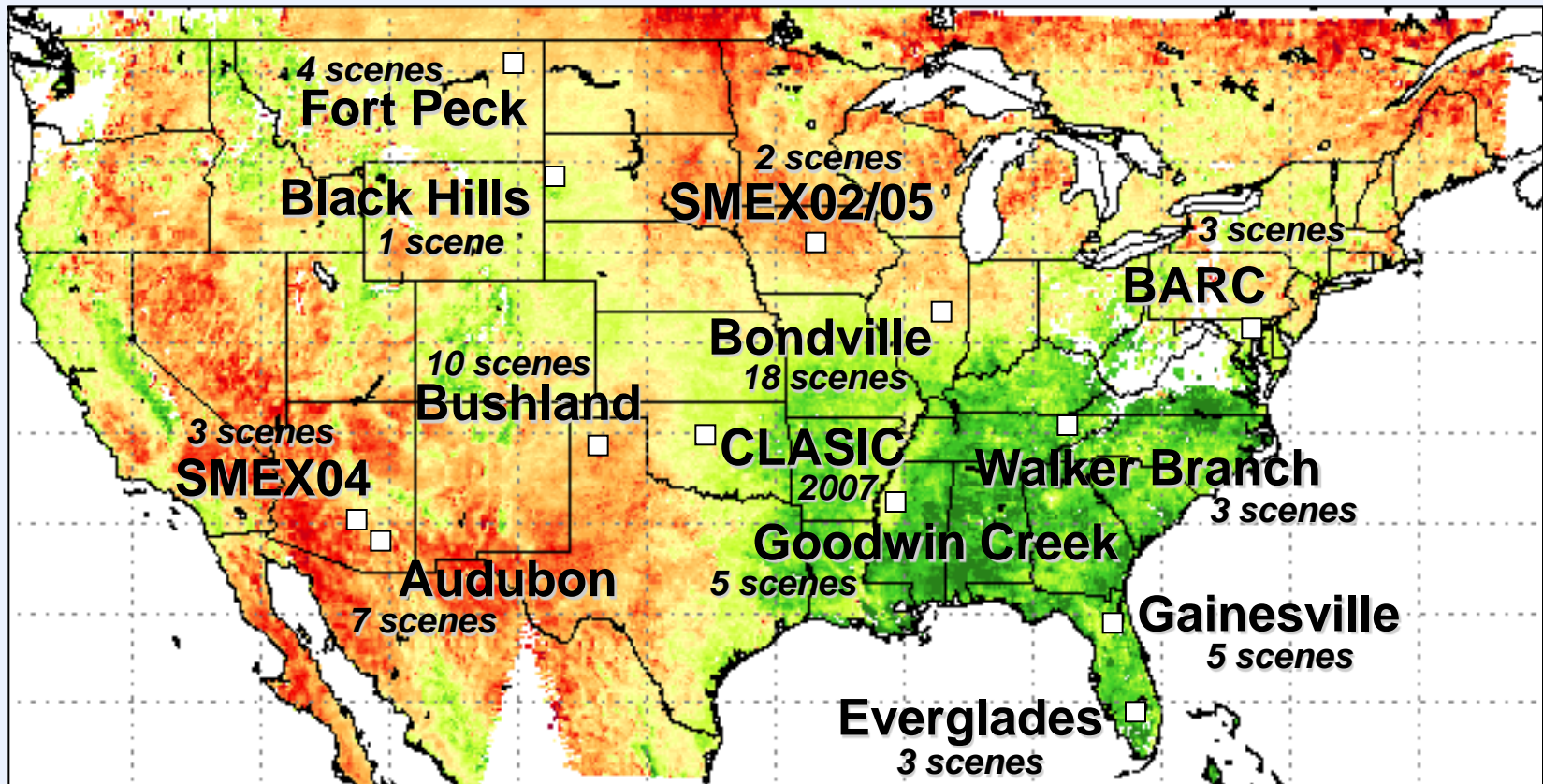
CONCLUSIONS

- HypsIRI is uniquely suited for global water use applications:
 - ... *wall-to-wall coverage*
 - ... *5-day revisit (TIR)*
 - ... *sub-field scale resolution (60m)*
 - ... *hyperspectral stress signals*

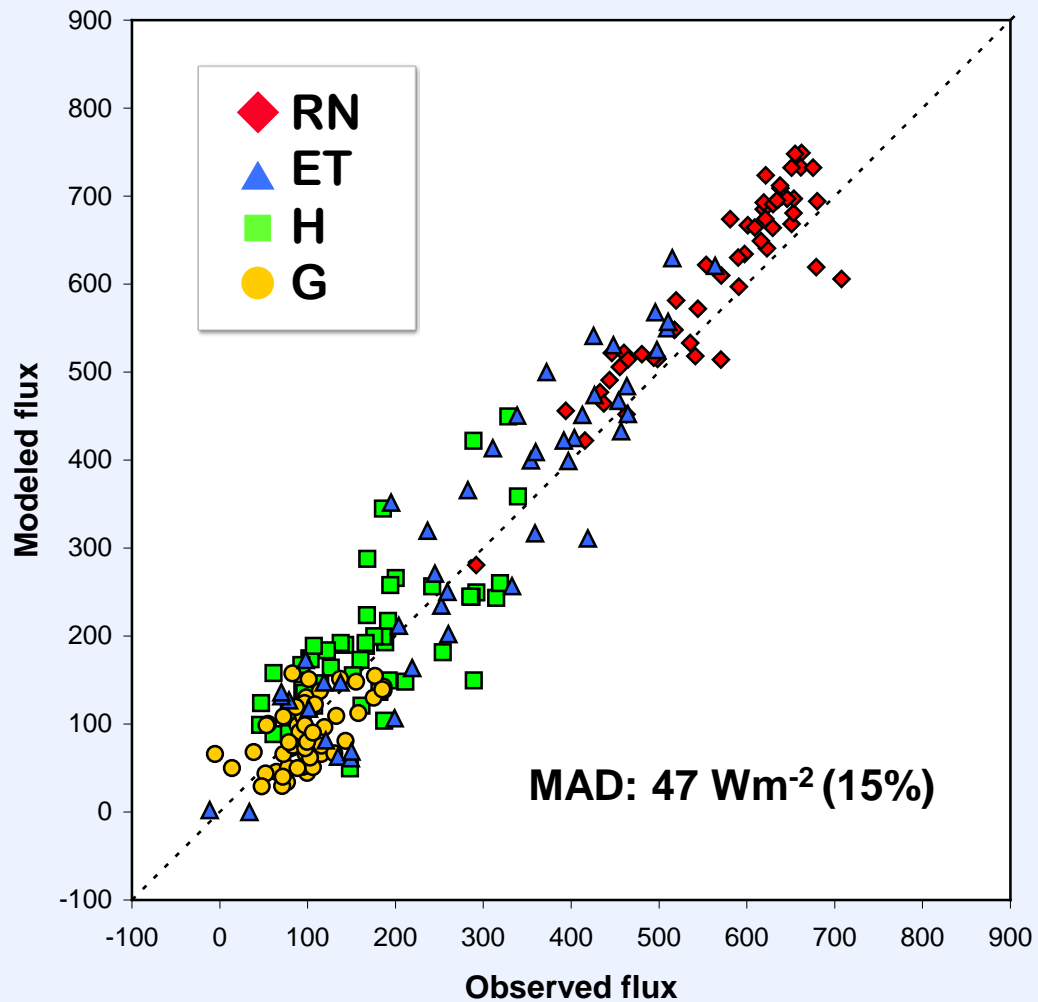
HYSPIRI ADDS SIGNIFICANT VALUE TO OPERATIONAL TIR IMAGING SYSTEMS

Martha.Anderson@ars.usda.gov

ALEXI validation sites

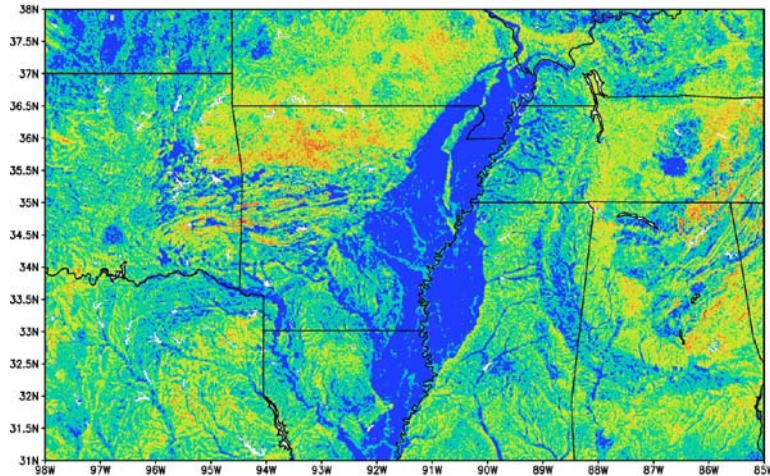


Clear-sky fluxes using Landsat TIR (~100m)

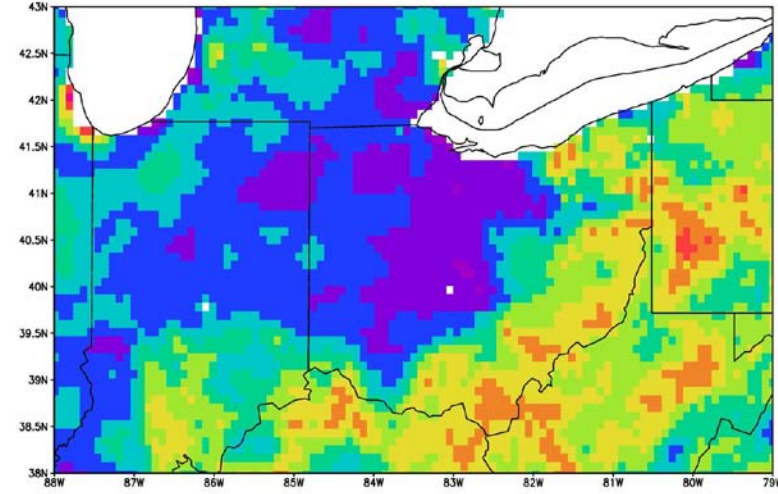
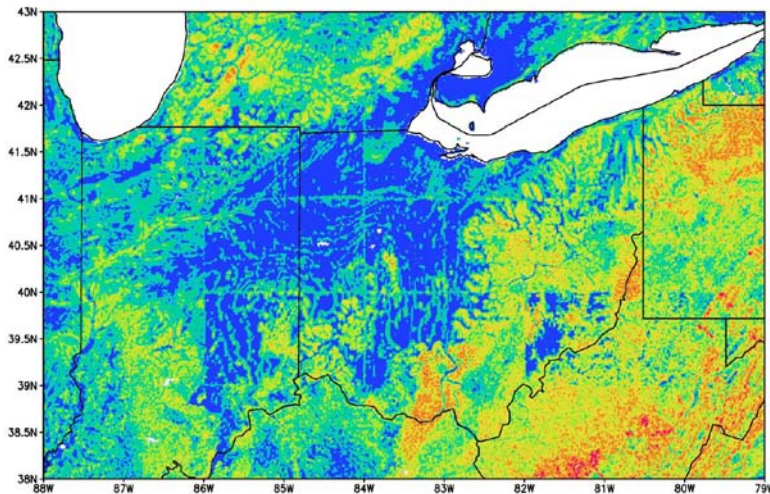
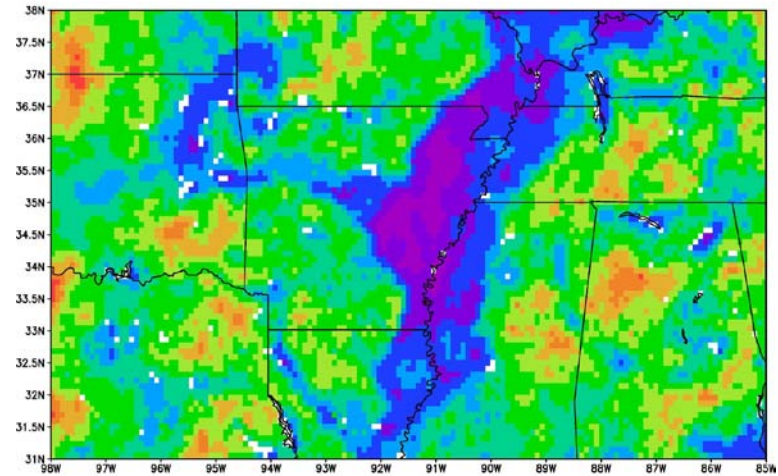


Sensitivity to shallow water tables

Simulated climatological water table*



Temporal variability in ET/PET



shallow  deep

low  high

* Miguez-Macho et al, BAMS, 90, 663-672