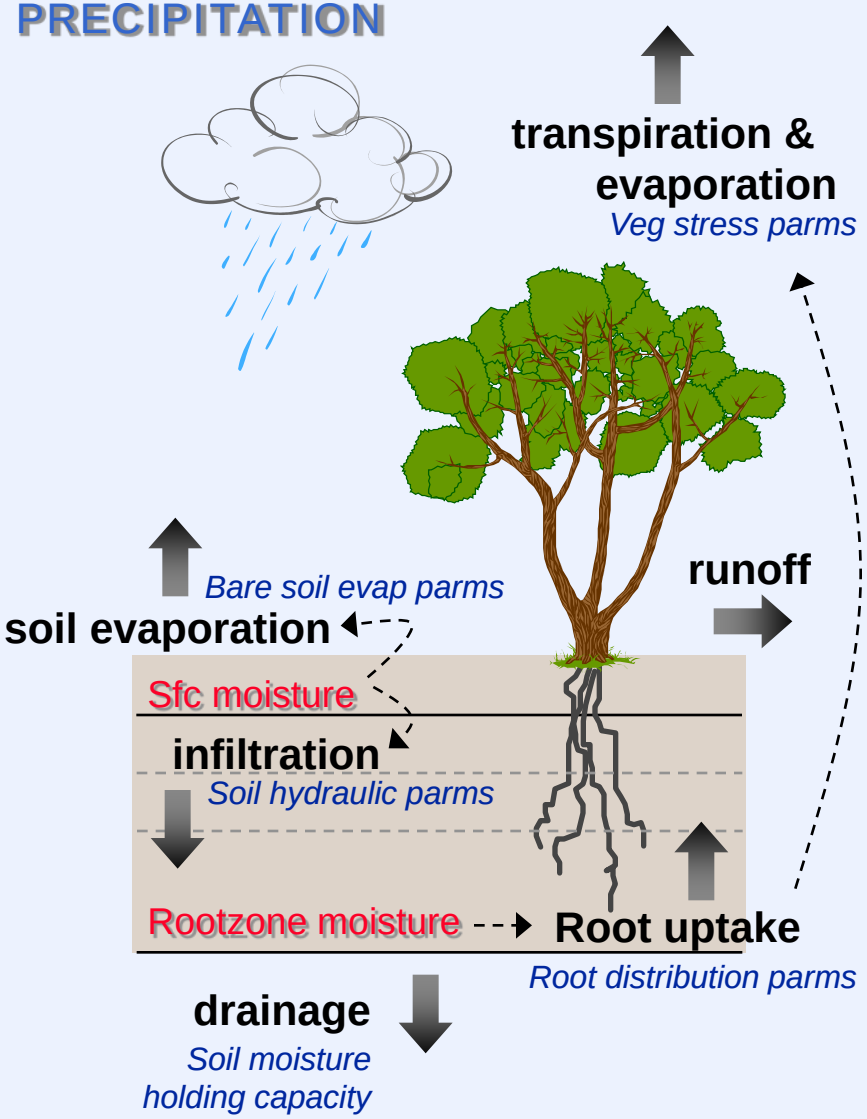
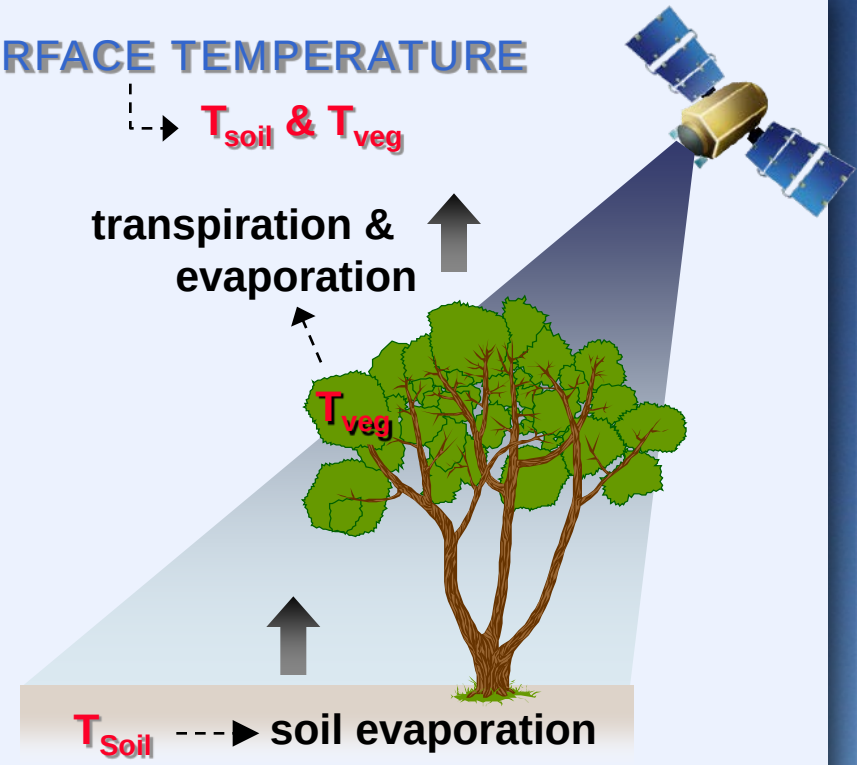
Daily ET at Landsat Scales using Multi-Sensor Data Fusion

M.C. Anderson, F. Gao, W. Kustas
USDA-ARS, Hydrology and Remote Sensing Laboratory

C. Hain, X. Zhan
NOAA - NESDIS



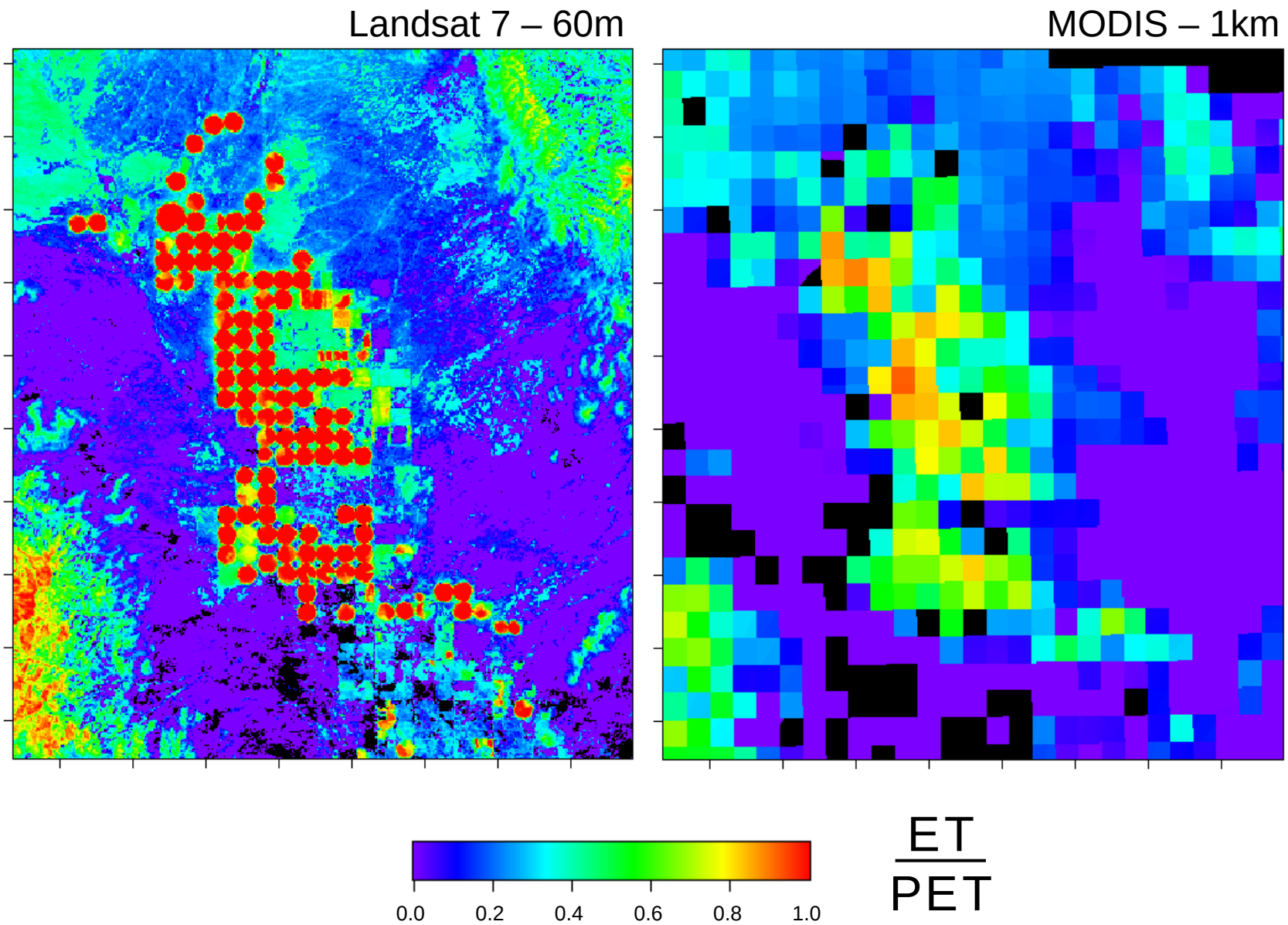


Given known radiative energy inputs, how much water loss is required to keep the soil and vegetation at the observed temperatures?

WATER BALANCE APPROACH
("forward modeling")

REMOTE SENSING APPROACH
("inverse modeling")

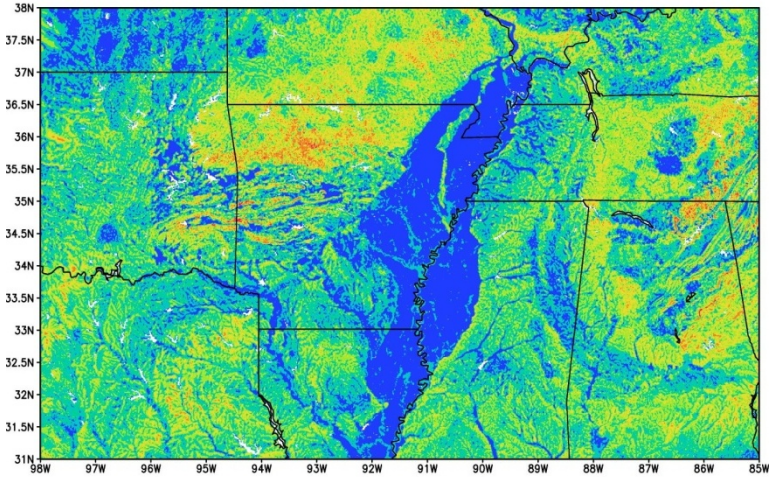
Sensitivity to irrigation

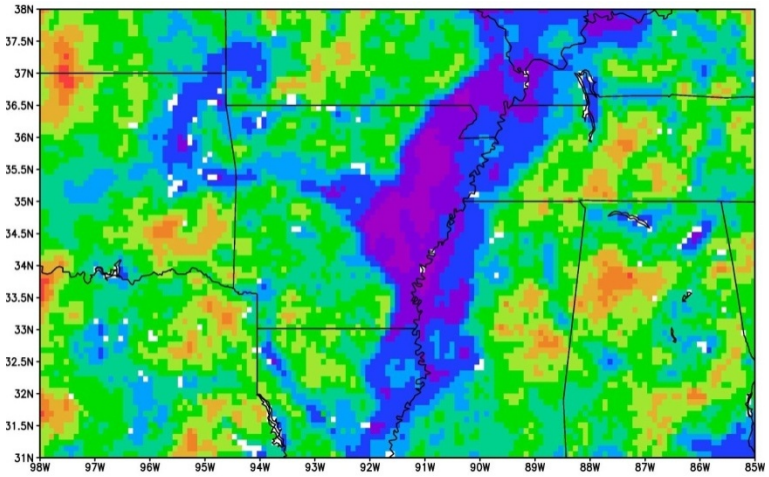


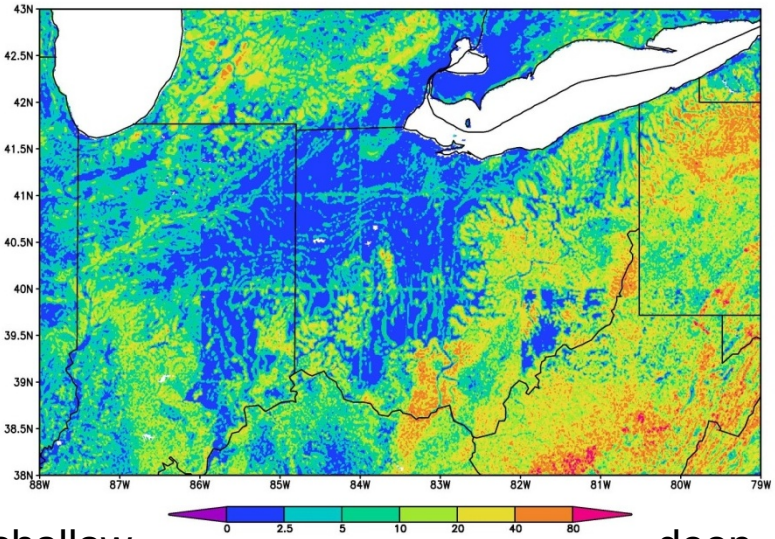
Sensitivity to shallow water tables

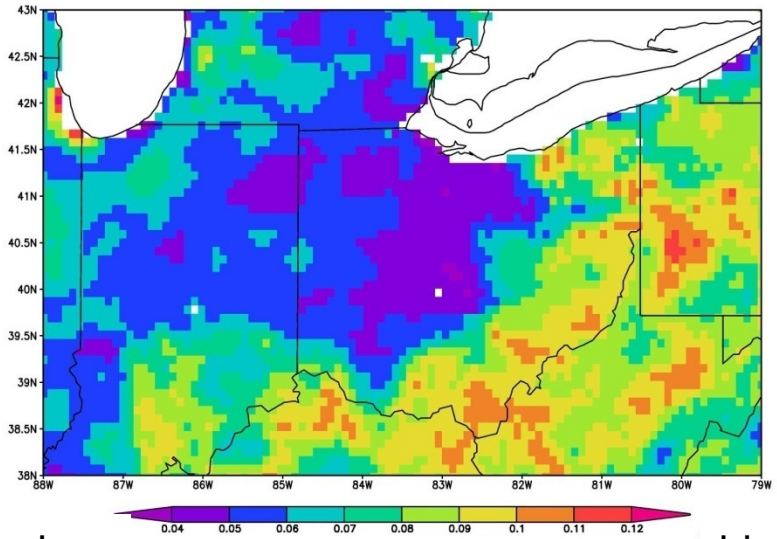
Simulated climatological water table*

Temporal variability in ET/PET









shallow deep low high

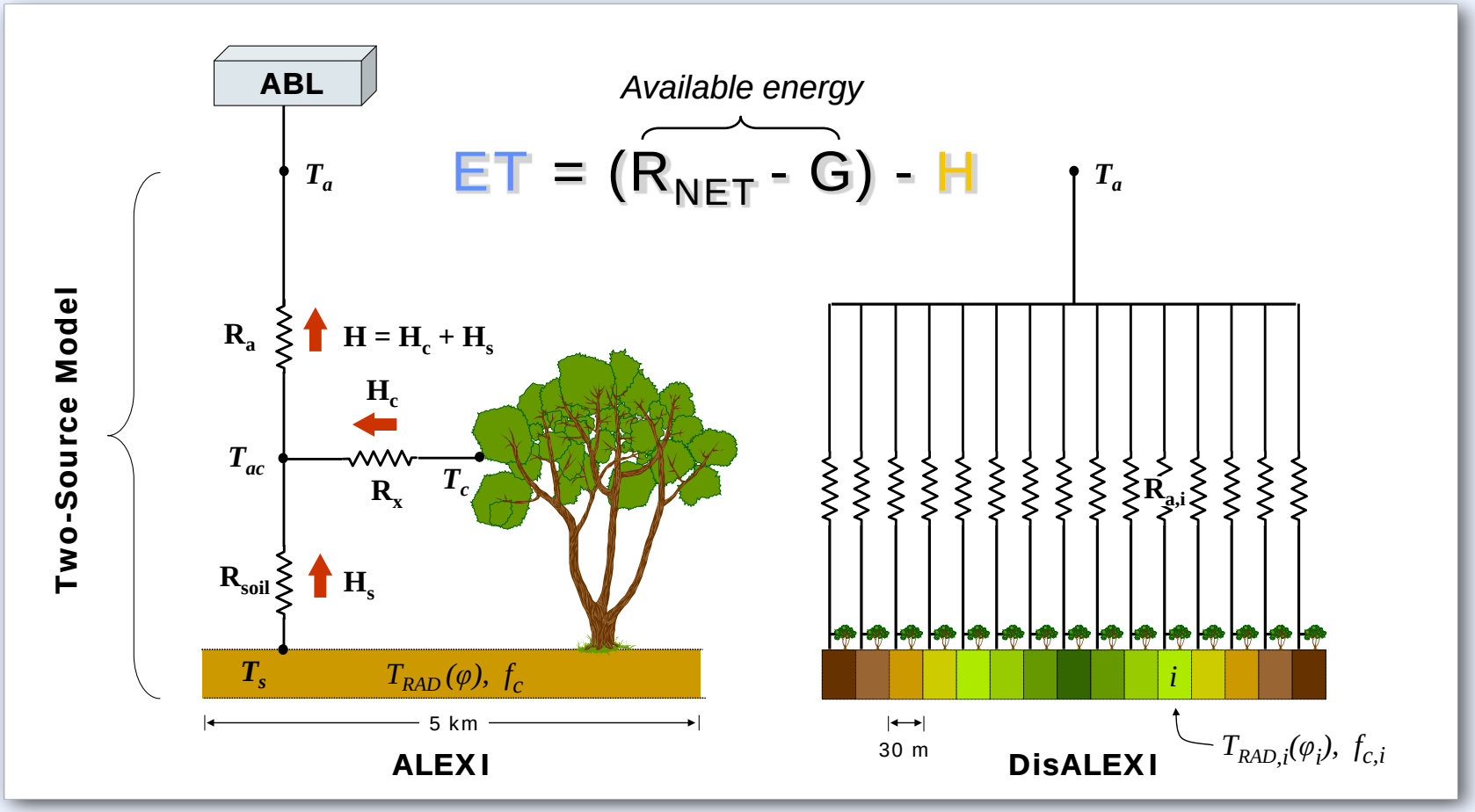
* Miquez-Macho et al, BAMS, 90, 663-672

Satellite Thermal Imaging Systems

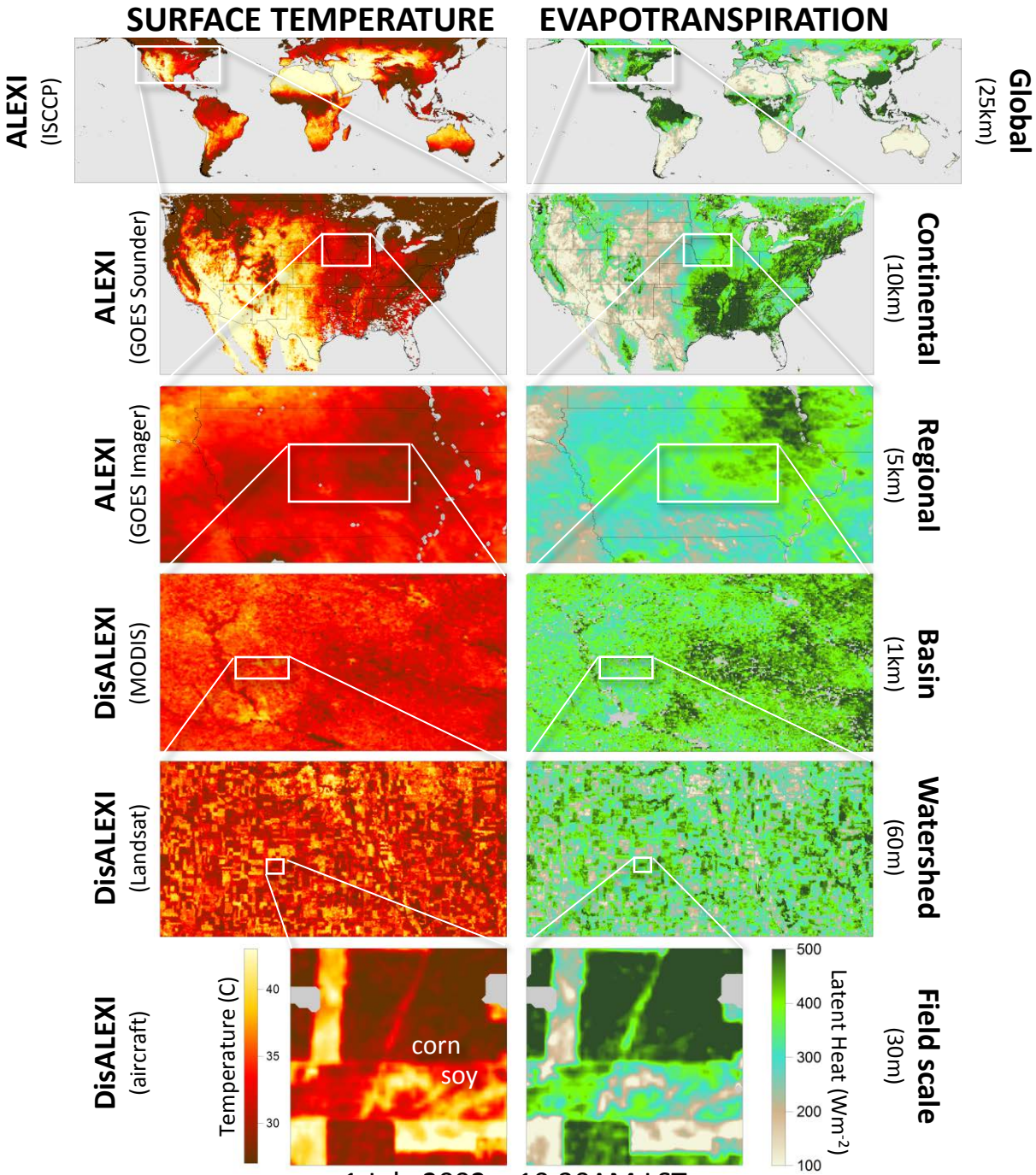
Pixel Scale	Spatial Resolution	Temporal Resolution	Current Sources	Future Sources
Coarse	5-20 km	15 min	AIRS GOES MSG	CrIS GOES MSG
Moderate	1 km	2-4 times daily	MODIS AVHRR ATSR	VIIRS AVHRR ATSR
Fine	90–120 m	Once every 8-16 days	ASTER Landsat	LDCM HyspIRI?

Table from S. Hook

Atmosphere-Land Exchange Inverse (ALEXI)

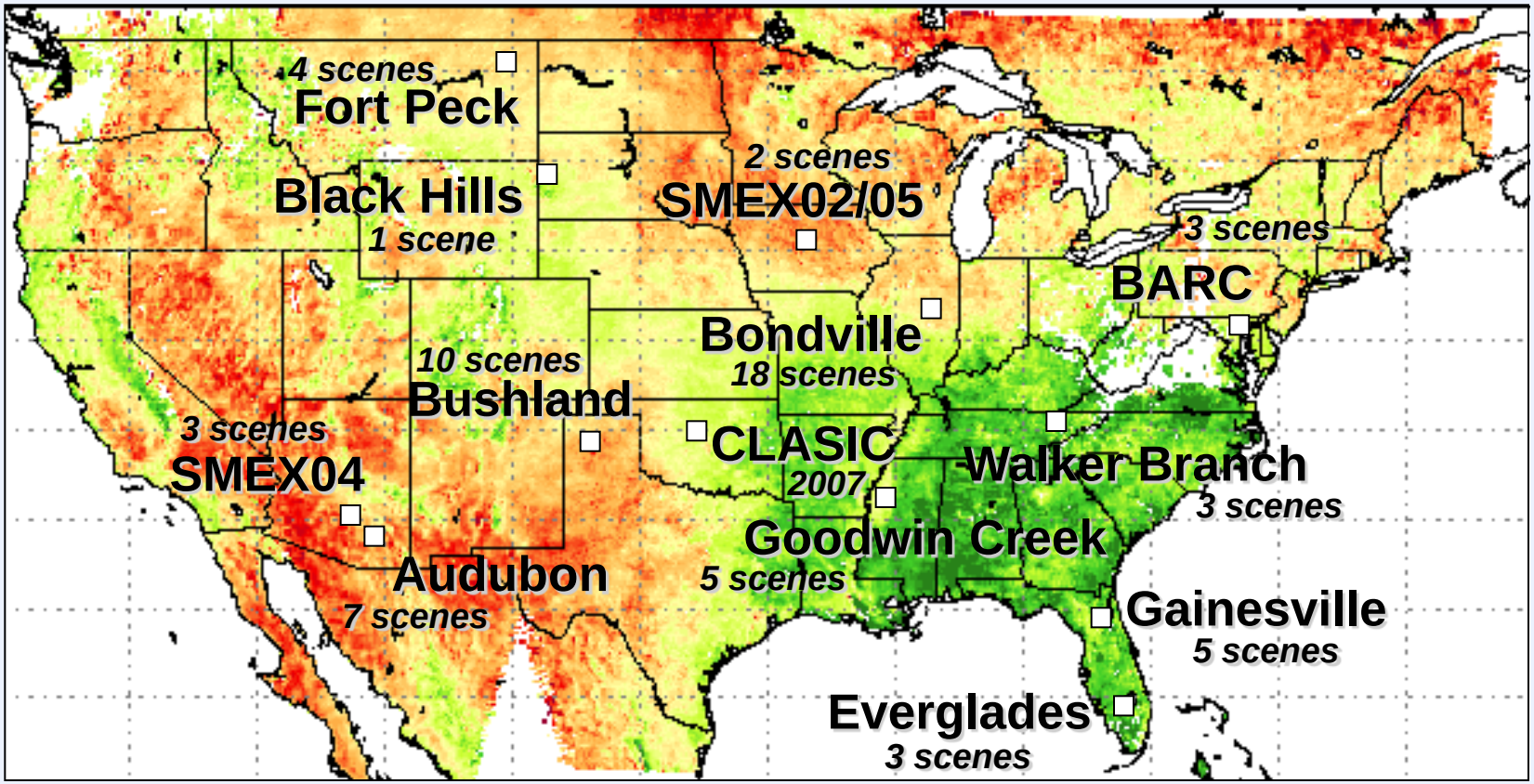


	Regional scale	Landscape scale
Surface temp:	ΔT_{RAD} - GOES	T_{RAD} - TM, MODIS, HyspIRI
Air temp:	T_a - ABL model	T_a - ALEXI



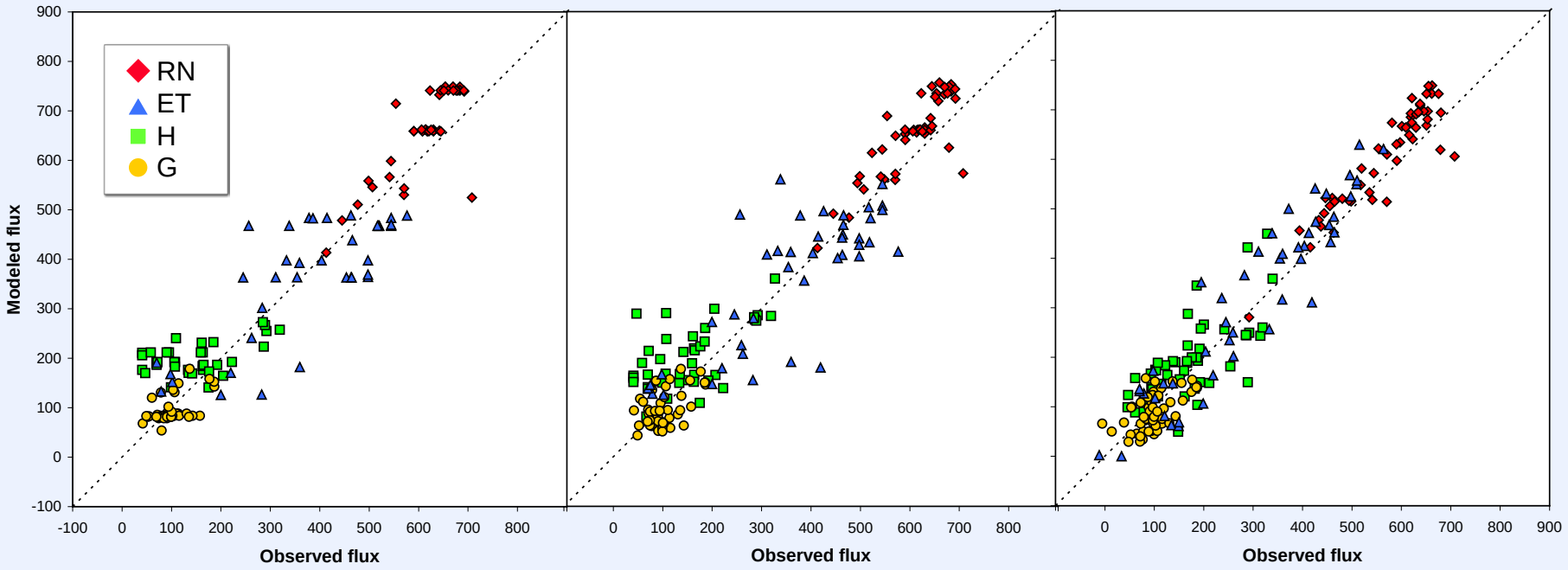
1 July 2002 – 10:30AM LST

ALEXI validation sites

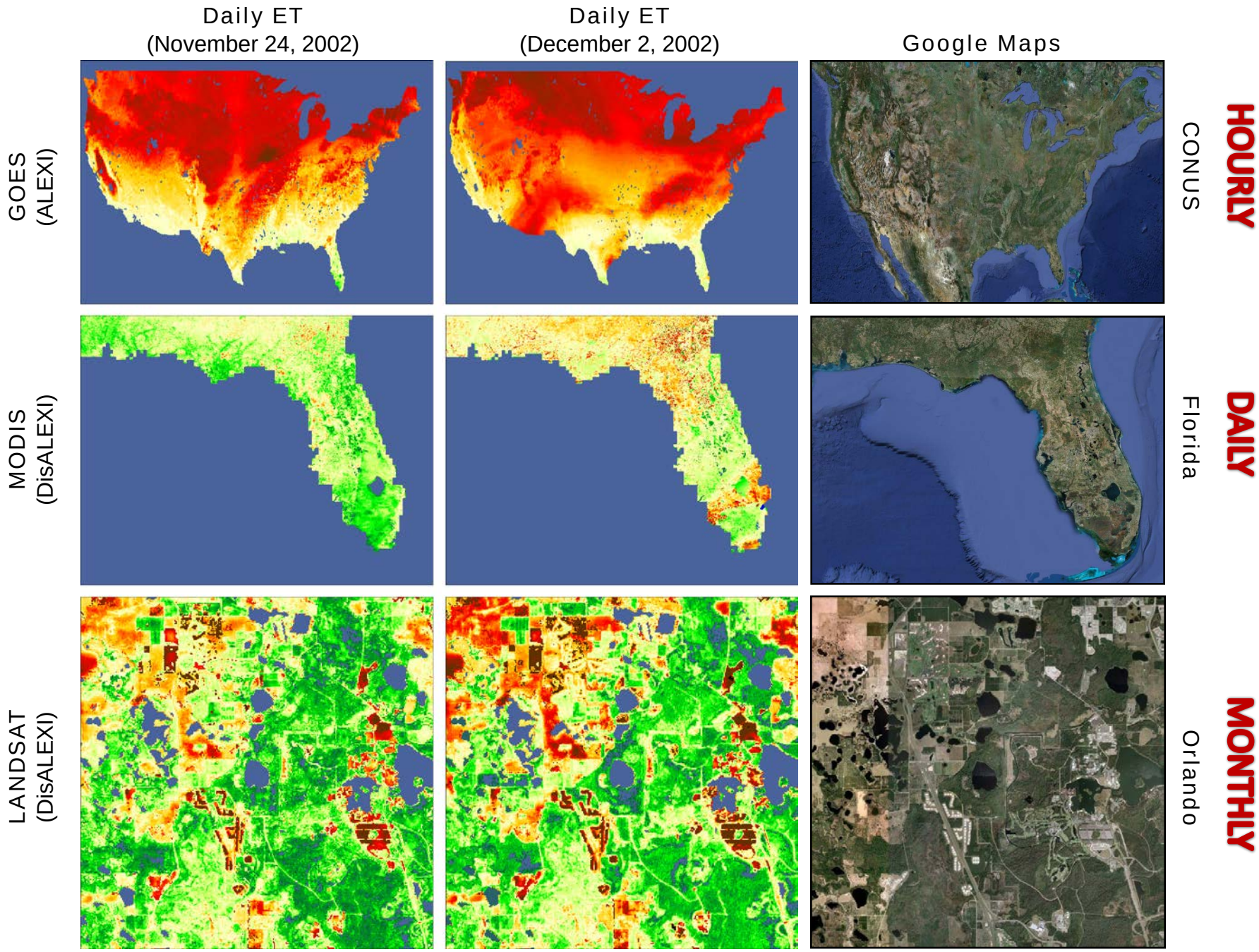


Effect of TIR resolution on validation

GOES (10 km) MODIS (1 km) Landsat (~100 m)

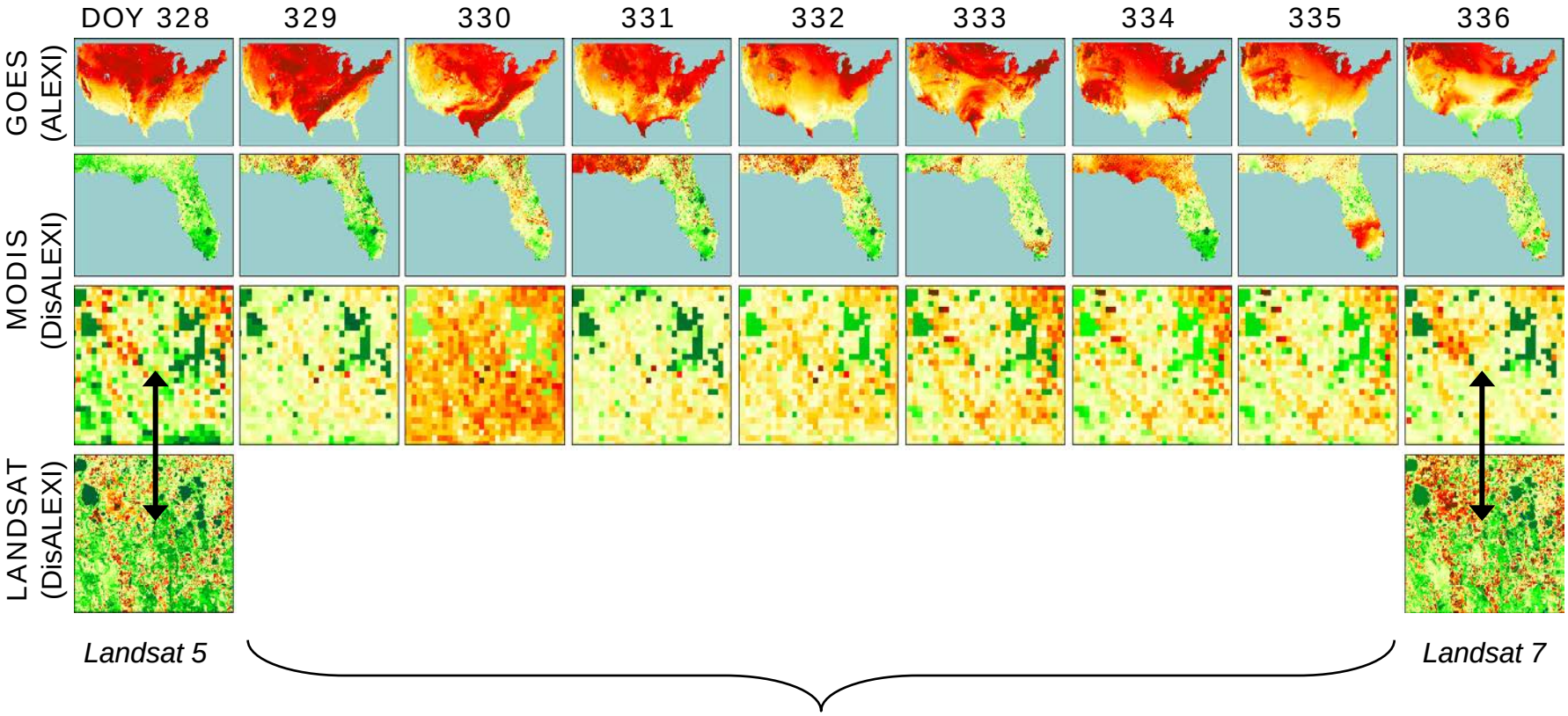


MAD: 75 Wm^{-2} (25%) **MAD: 63 Wm^{-2} (20%)** **MAD: 47 Wm^{-2} (15%)**


Daily ET
(November 24, 2002)
Daily ET
(December 2, 2002)
Google Maps
GOES
(ALEXI)
MODIS
(DisALEXI)
LANDSAT
(DisALEXI)
HOURLY
CONUS
DAILY
Florida
MONTHLY
Orlando

GOES/MODIS/Landsat FUSION

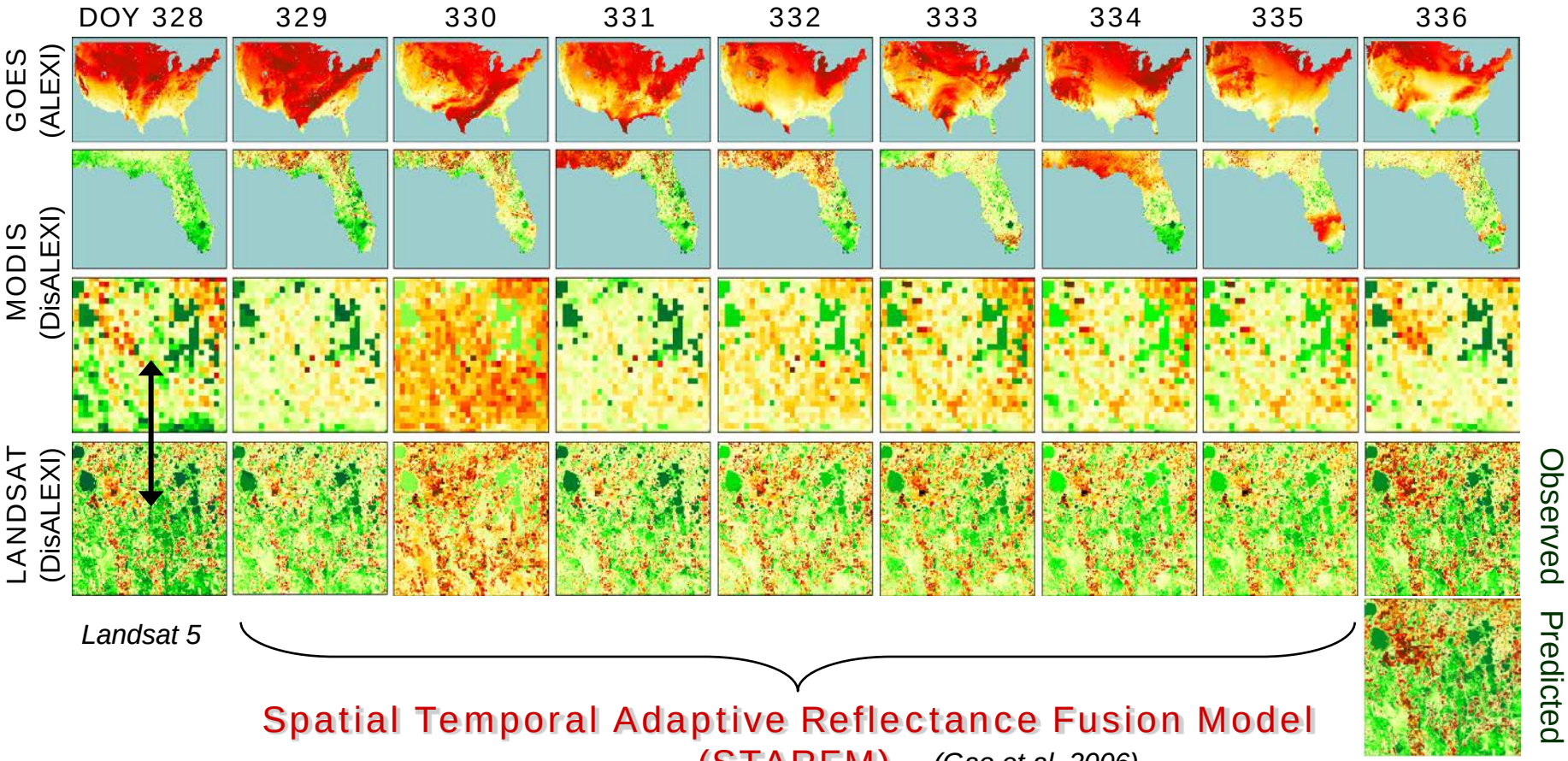
Daily Evapotranspiration – Orlando, FL, 2002



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

GOES/MODIS/Landsat FUSION

Daily Evapotranspiration – Orlando, FL, 2002



Landsat 5

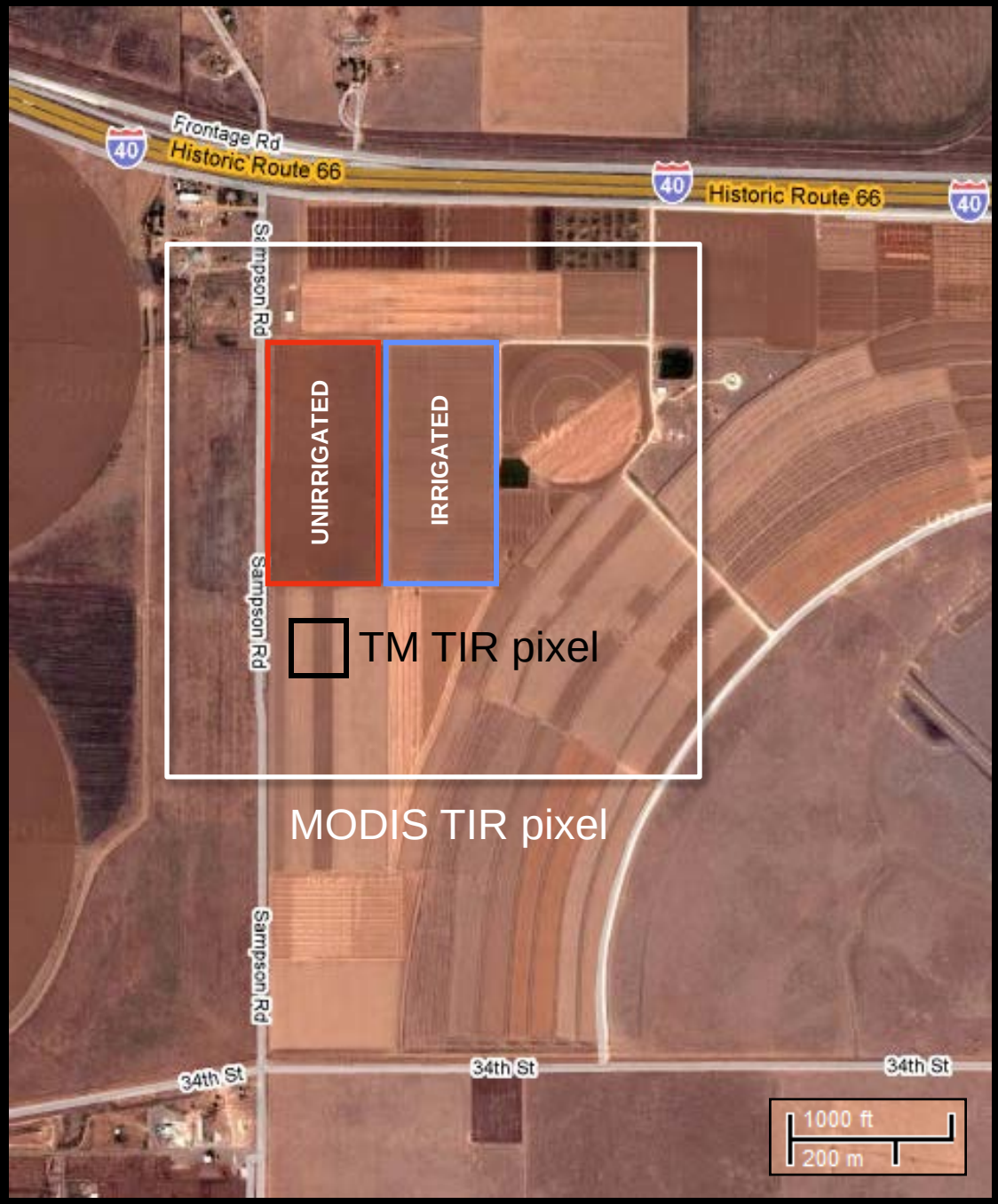
Spatial Temporal Adaptive Reflectance Fusion Model (STARFM) *(Gao et al, 2006)*

R^2: 0.83
(9% error)

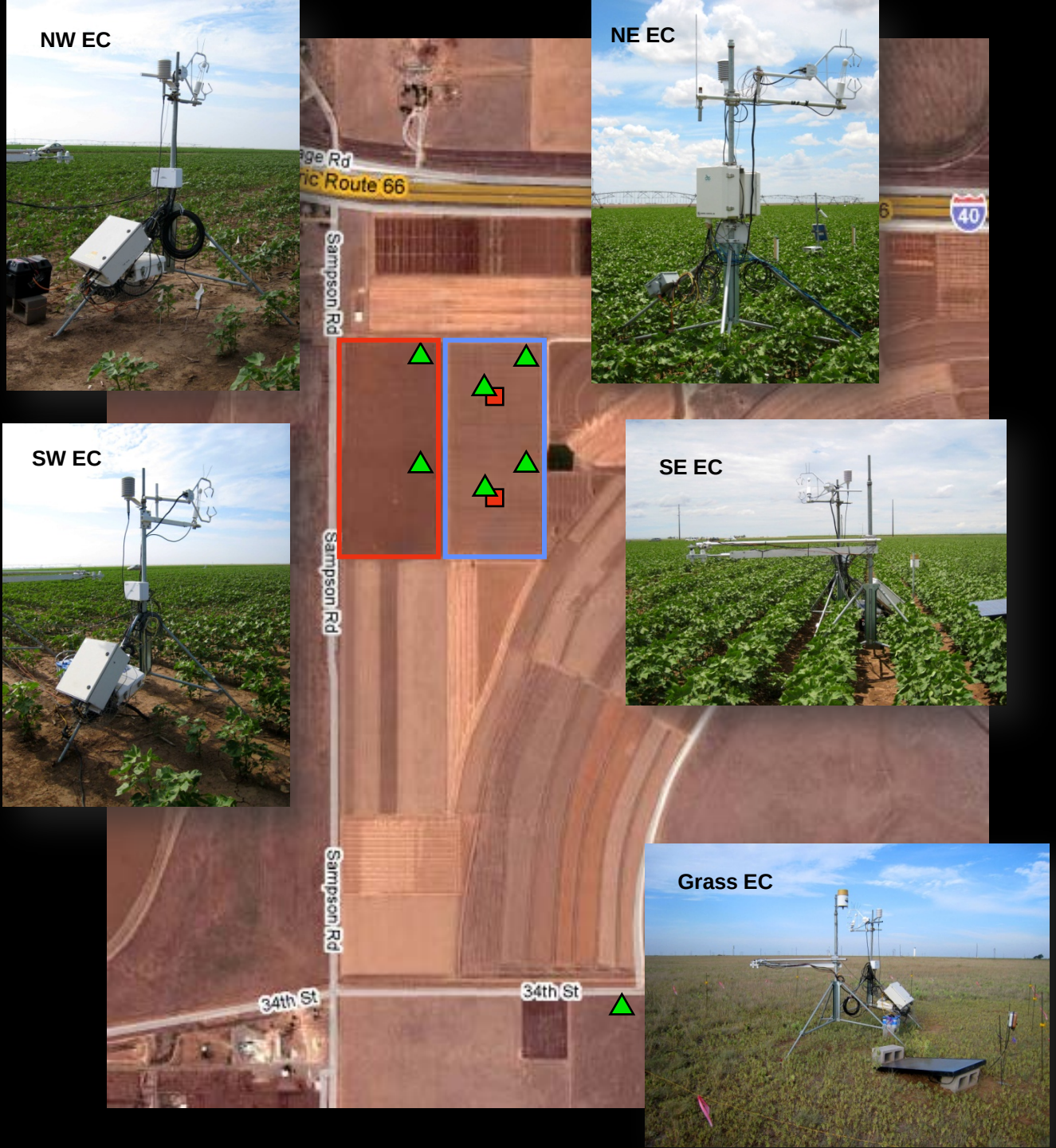
BEAREX 08

Bushland Evapotranspiration and Agricultural Remote Sensing EXperiment

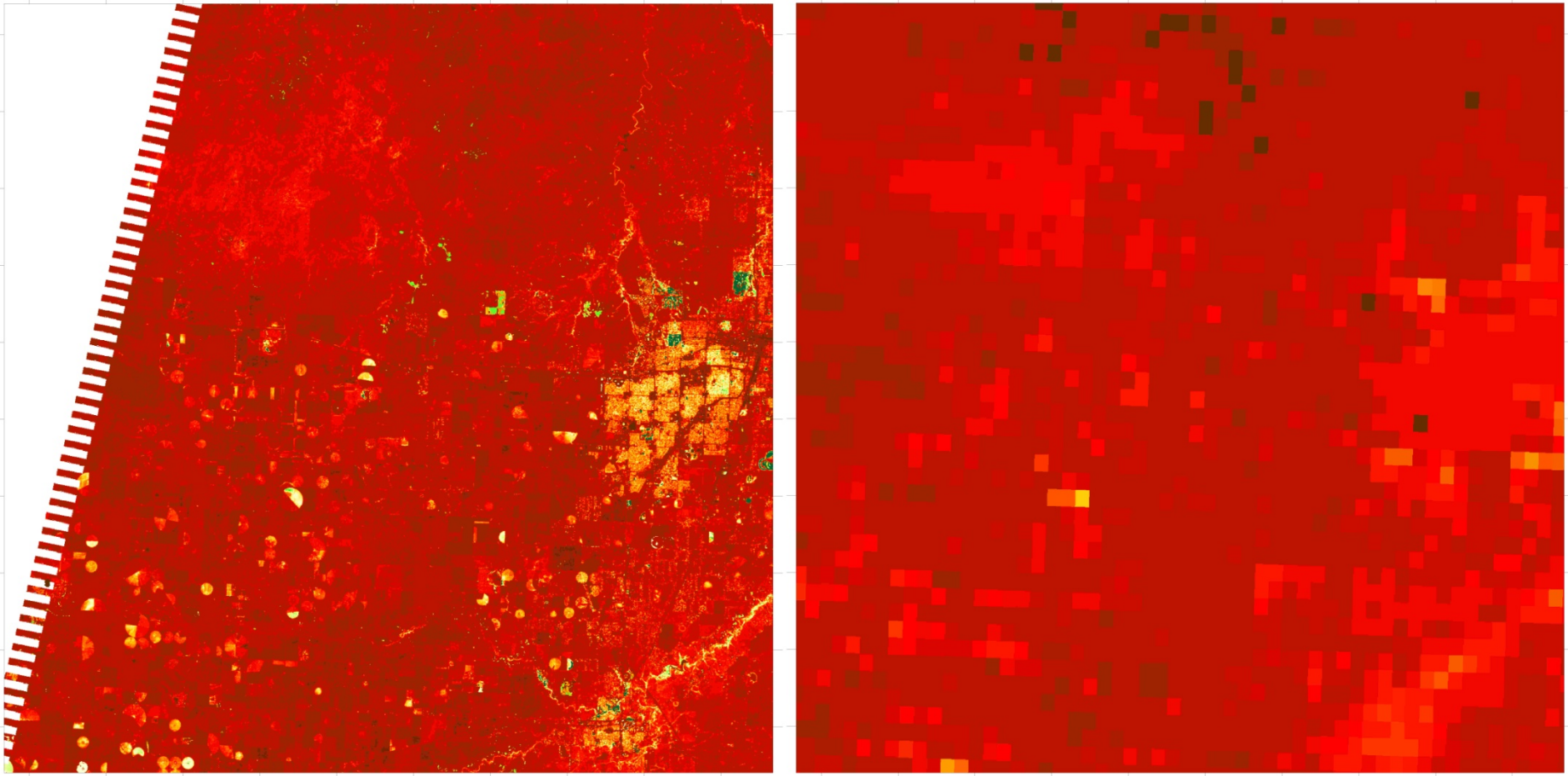
USDA-ARS Conservation & Production Lab
Bushland, TX


Frontage Rd
Historic Route 66
40
Historic Route 66
40
40
Sampson Rd
UNIRRIGATED
IRRIGATED
Sampson Rd
TM TIR pixel
MODIS TIR pixel
Sampson Rd
34th St
34th St
34th St
1000 ft
200 m

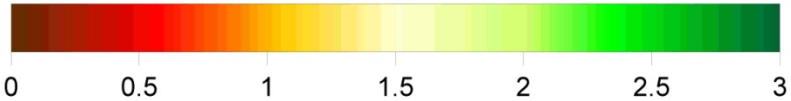
NW
NE
SW
SE
Route 66
Sampson Rd
Sampson Rd
Sampson Rd
34th St
34th St
34th St
1000 ft
200 m


NW EC
NE EC
SW EC
SE EC
Grass EC
Sampson Rd
Sampson Rd
Sampson Rd
34th St
34th St
40

DOY 155 (June 3)

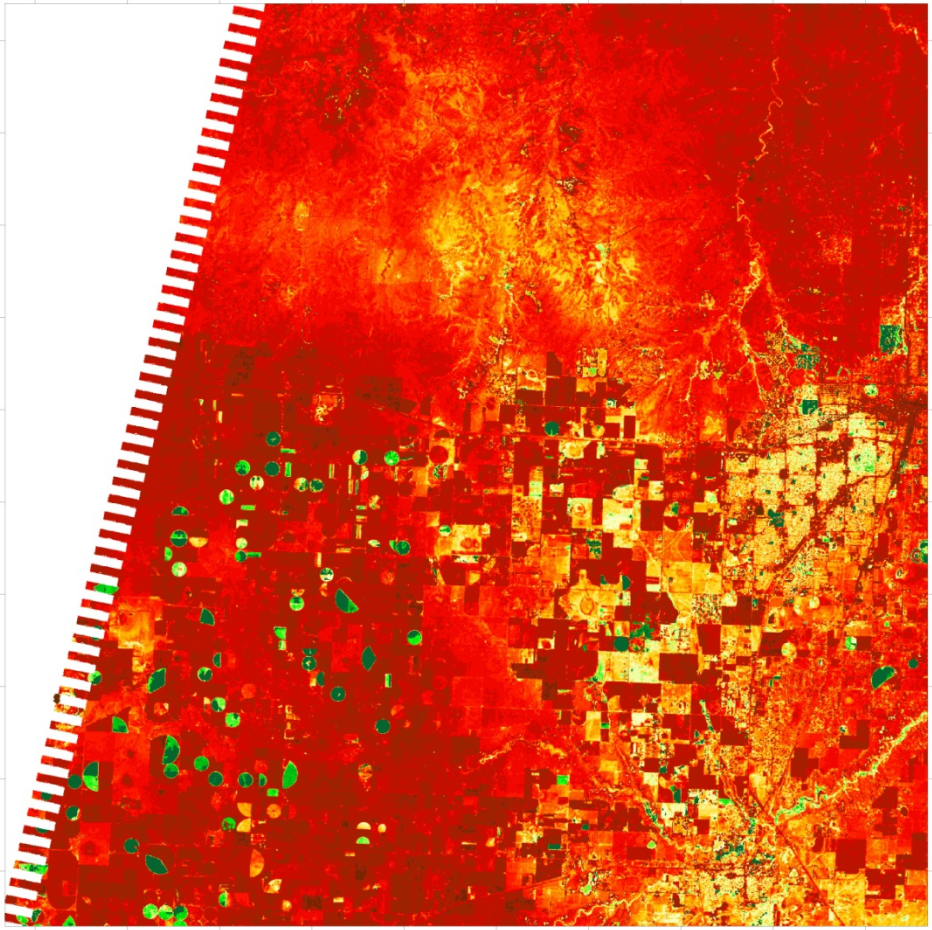


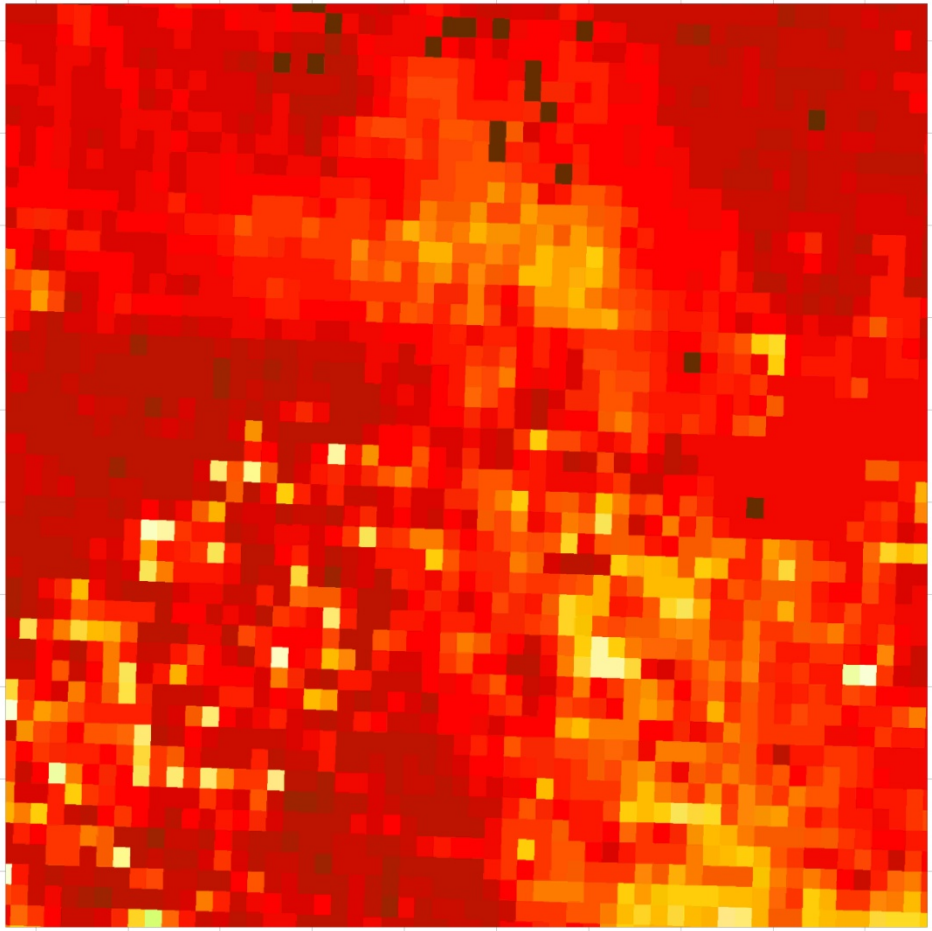
LANDSAT **MODIS**



Leaf Area Index

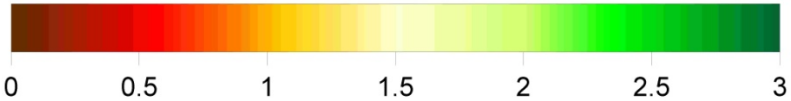
DOY 187 (July 5)





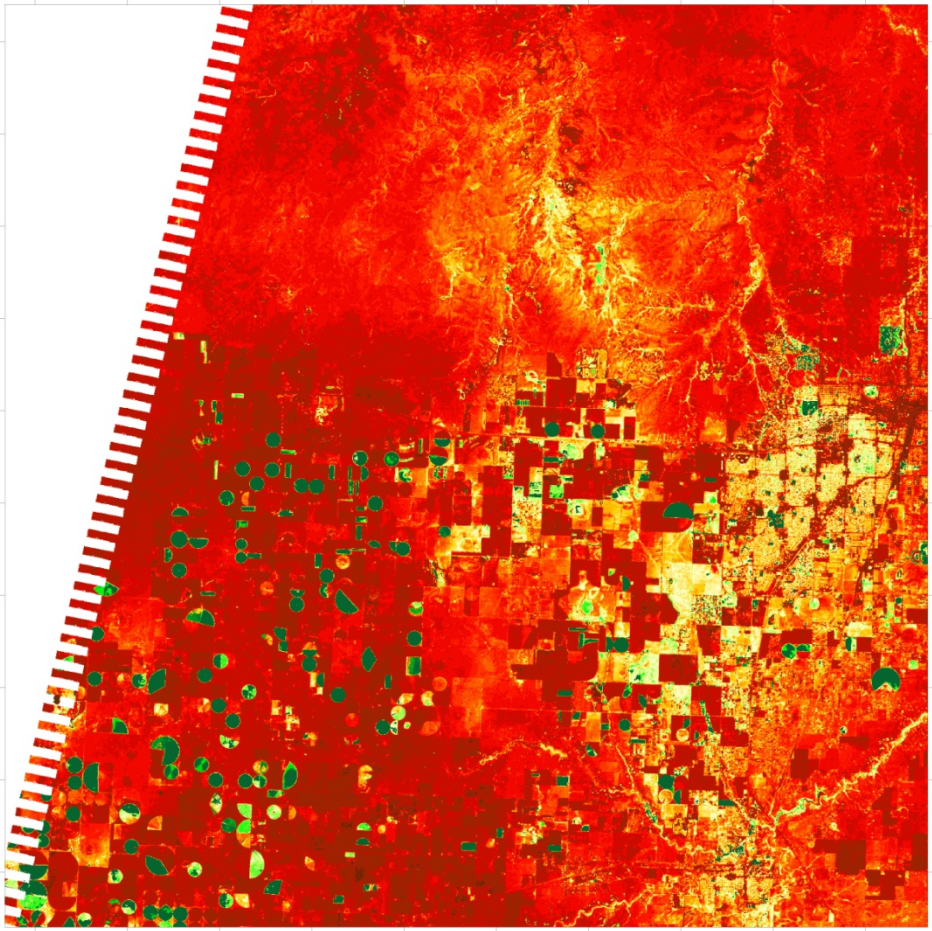
LANDSAT

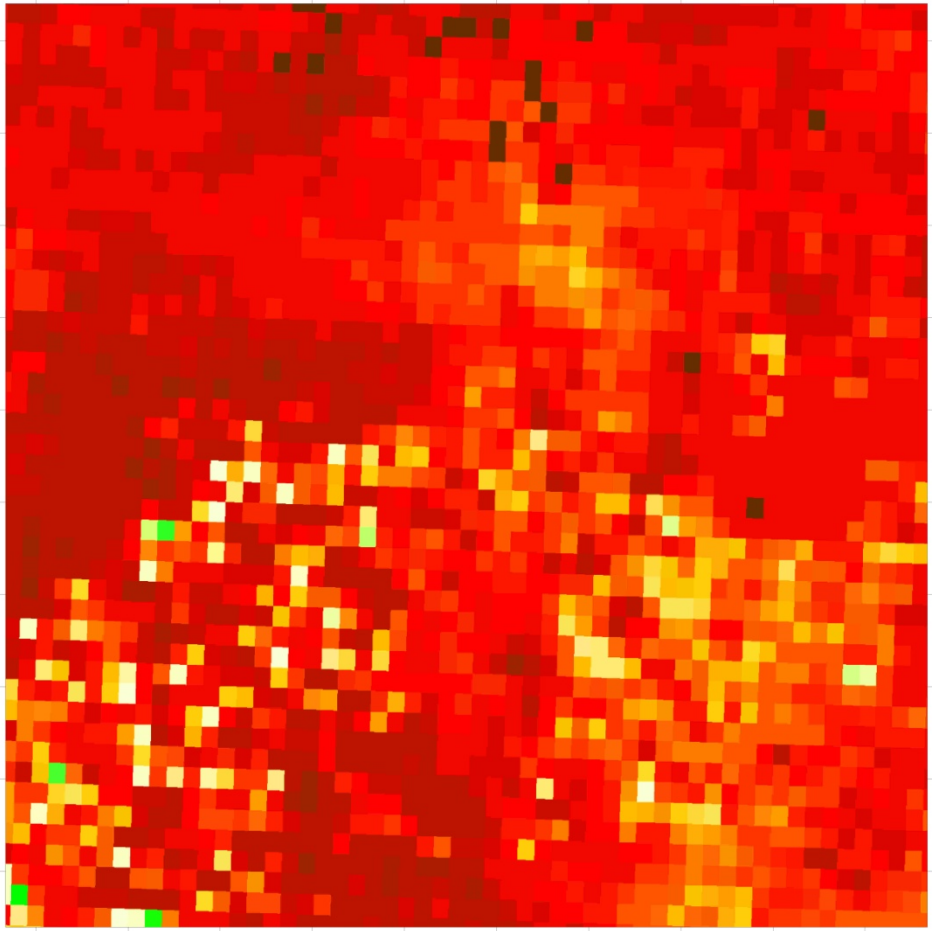
MODIS



Leaf Area Index

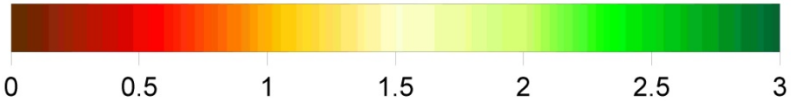
DOY 203 (July 21)





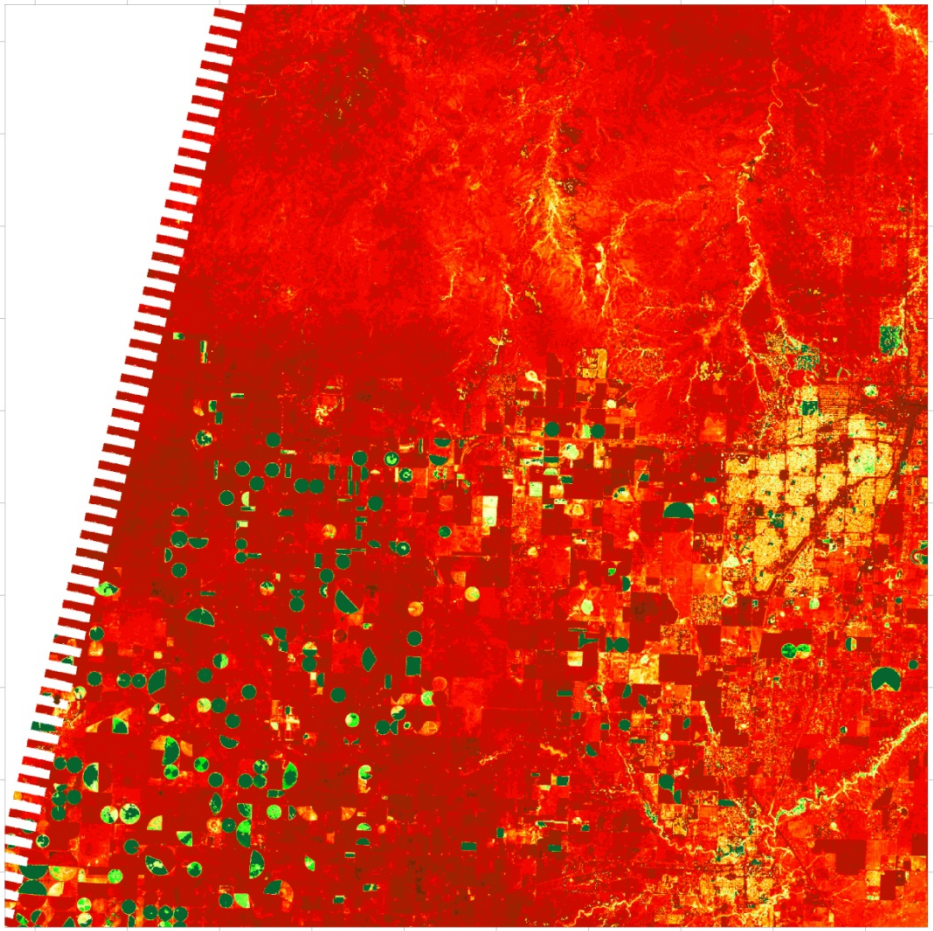
LANDSAT

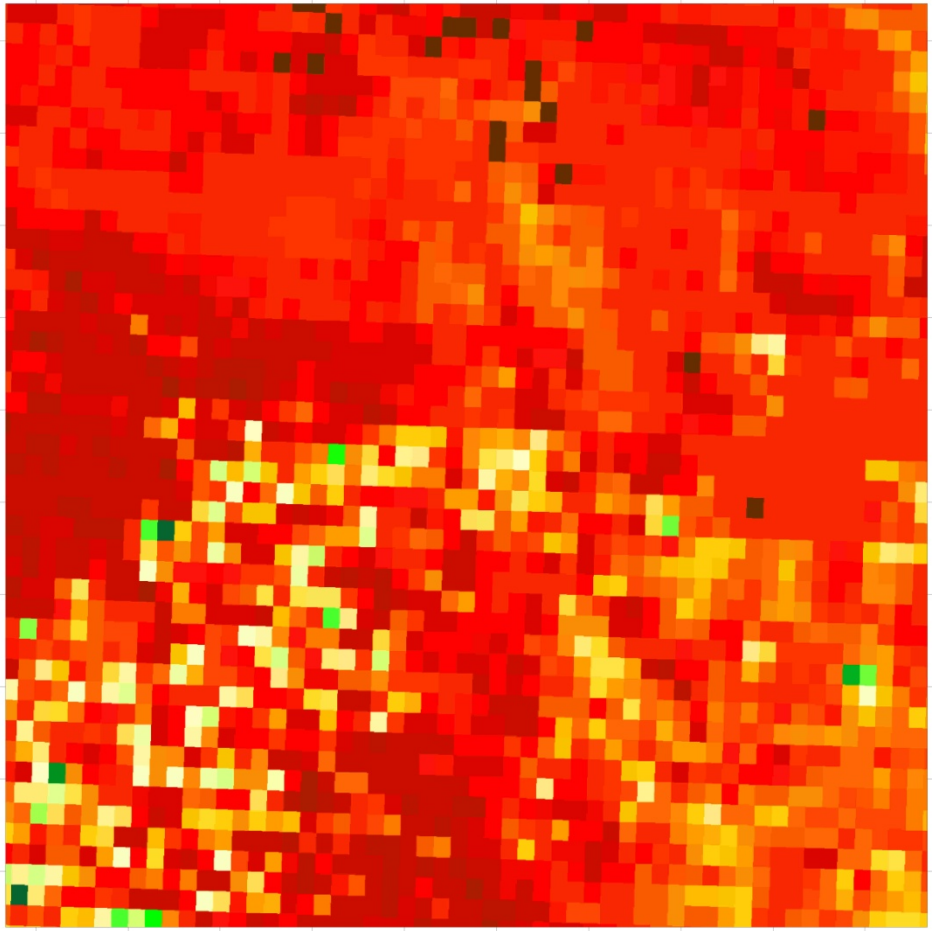
MODIS



Leaf Area Index

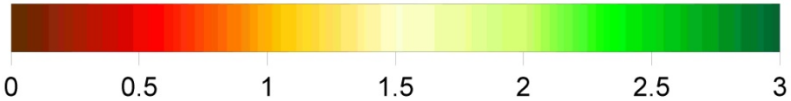
DOY 219 (August 6)





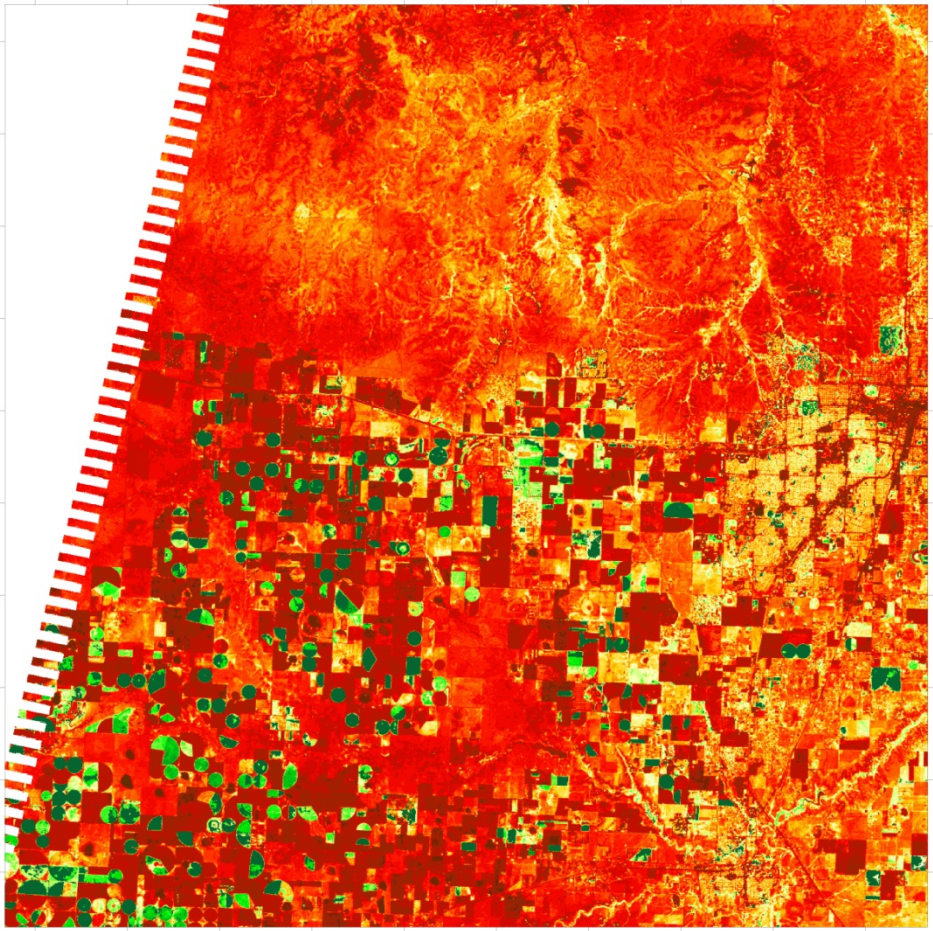
LANDSAT

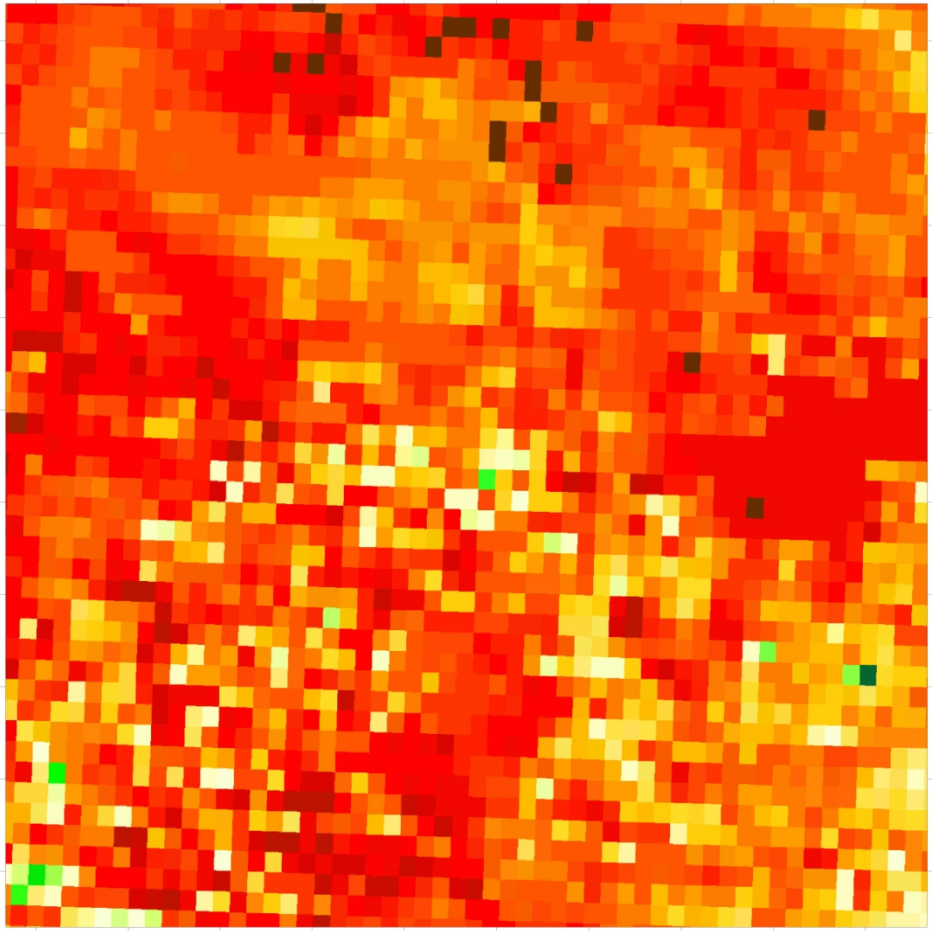
MODIS



Leaf Area Index

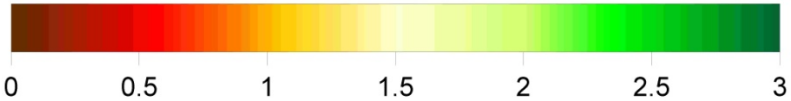
DOY 235 (August 22)





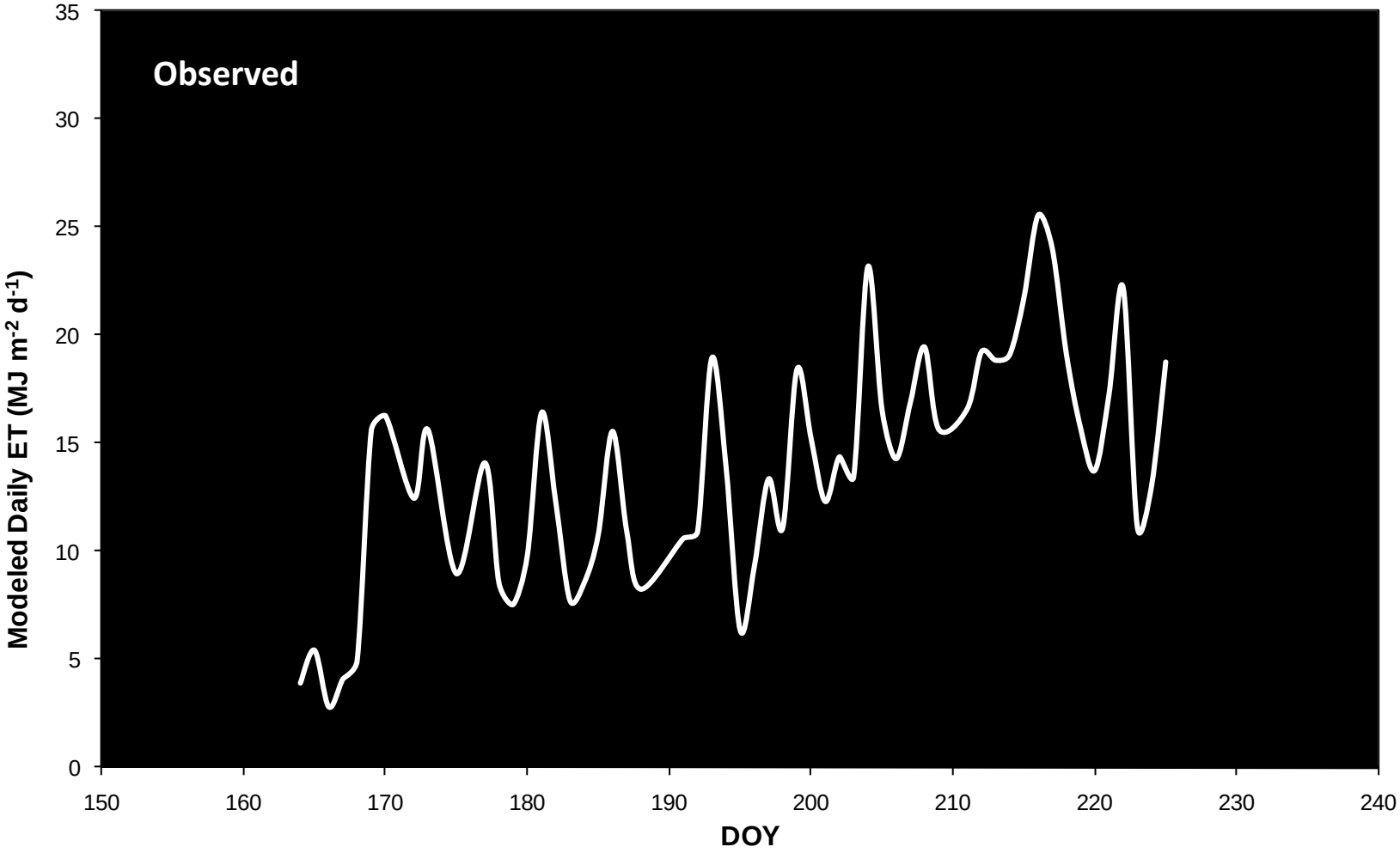
LANDSAT

MODIS

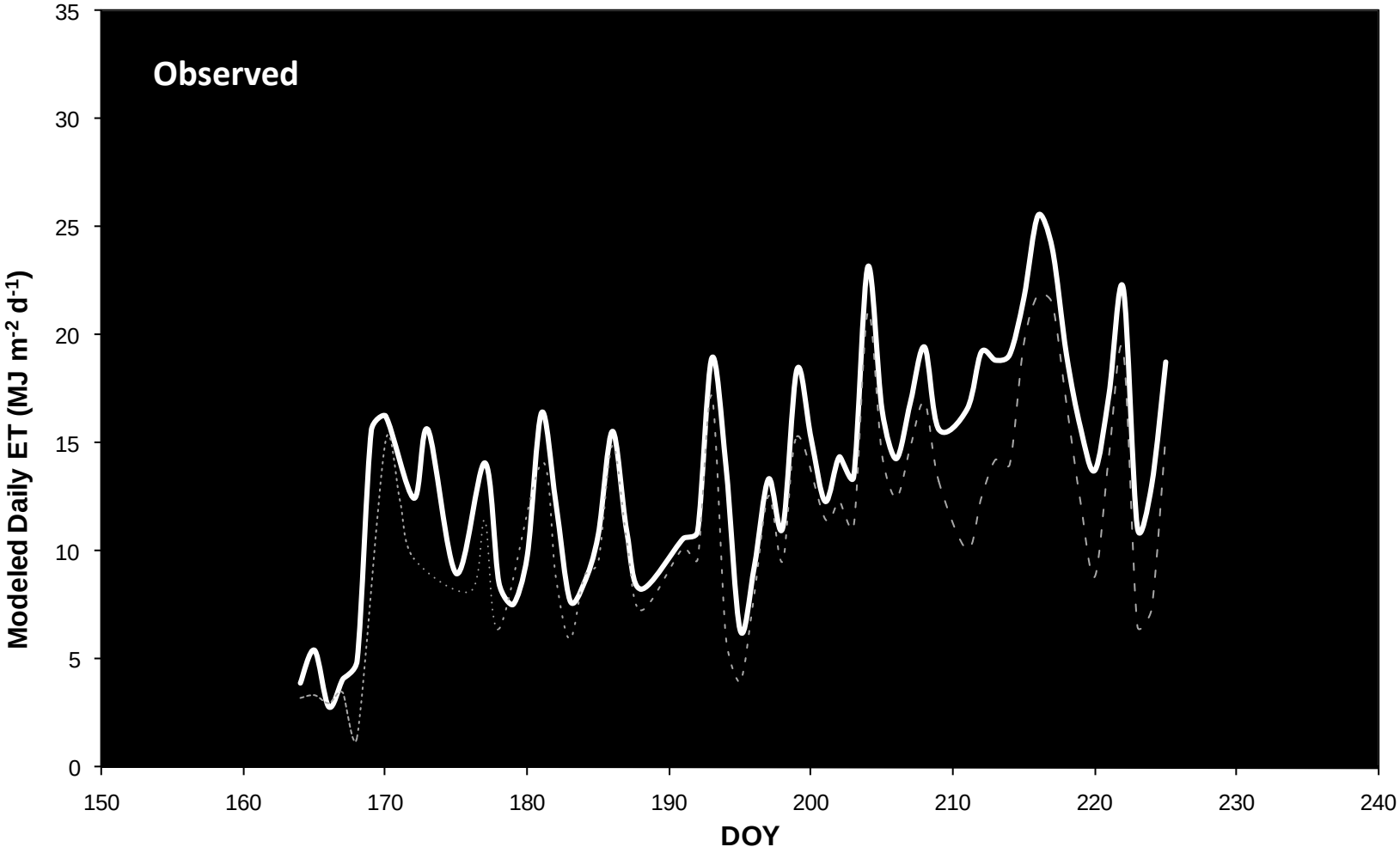


Leaf Area Index

IRRIGATED COTTON



IRRIGATED COTTON



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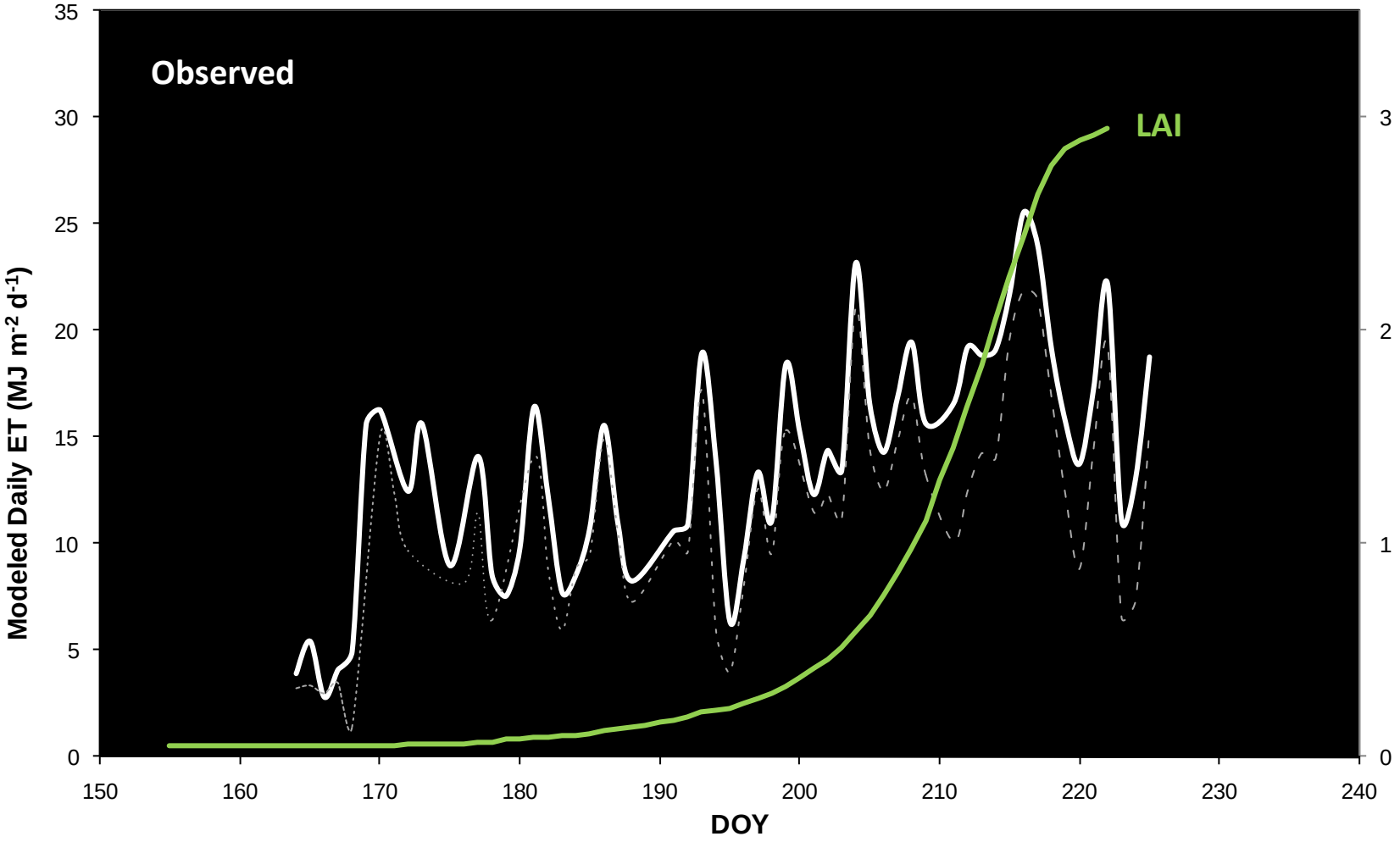

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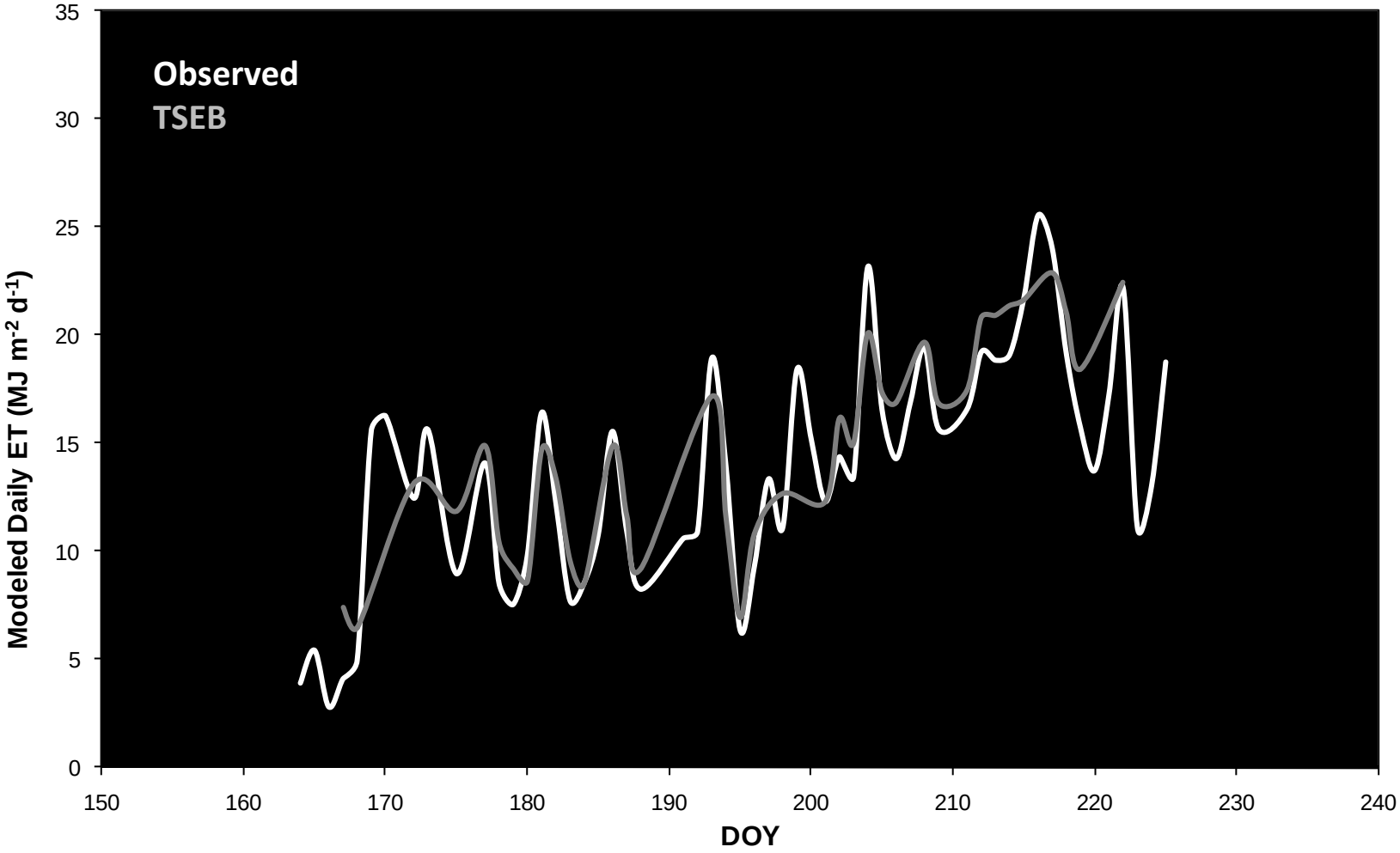

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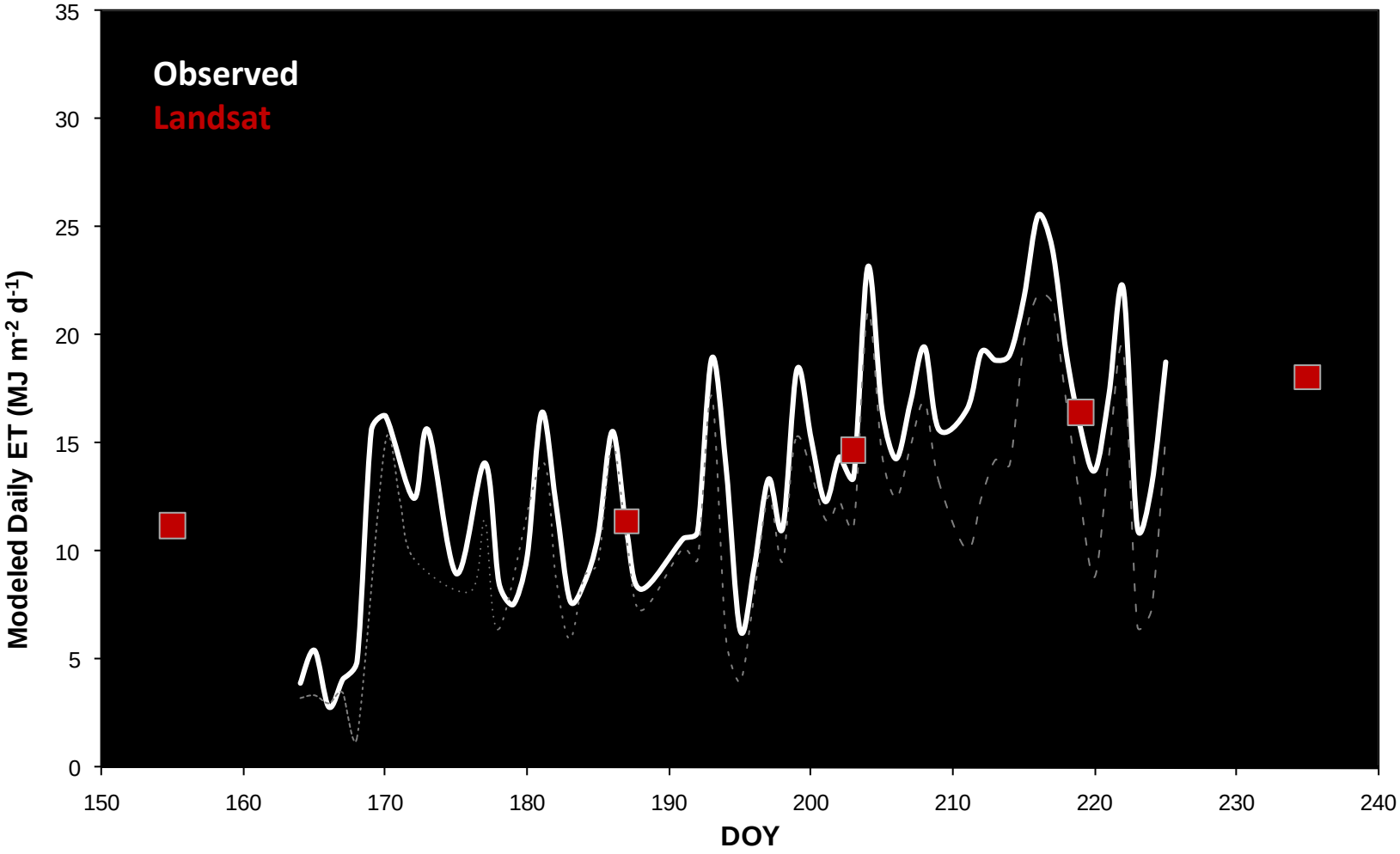

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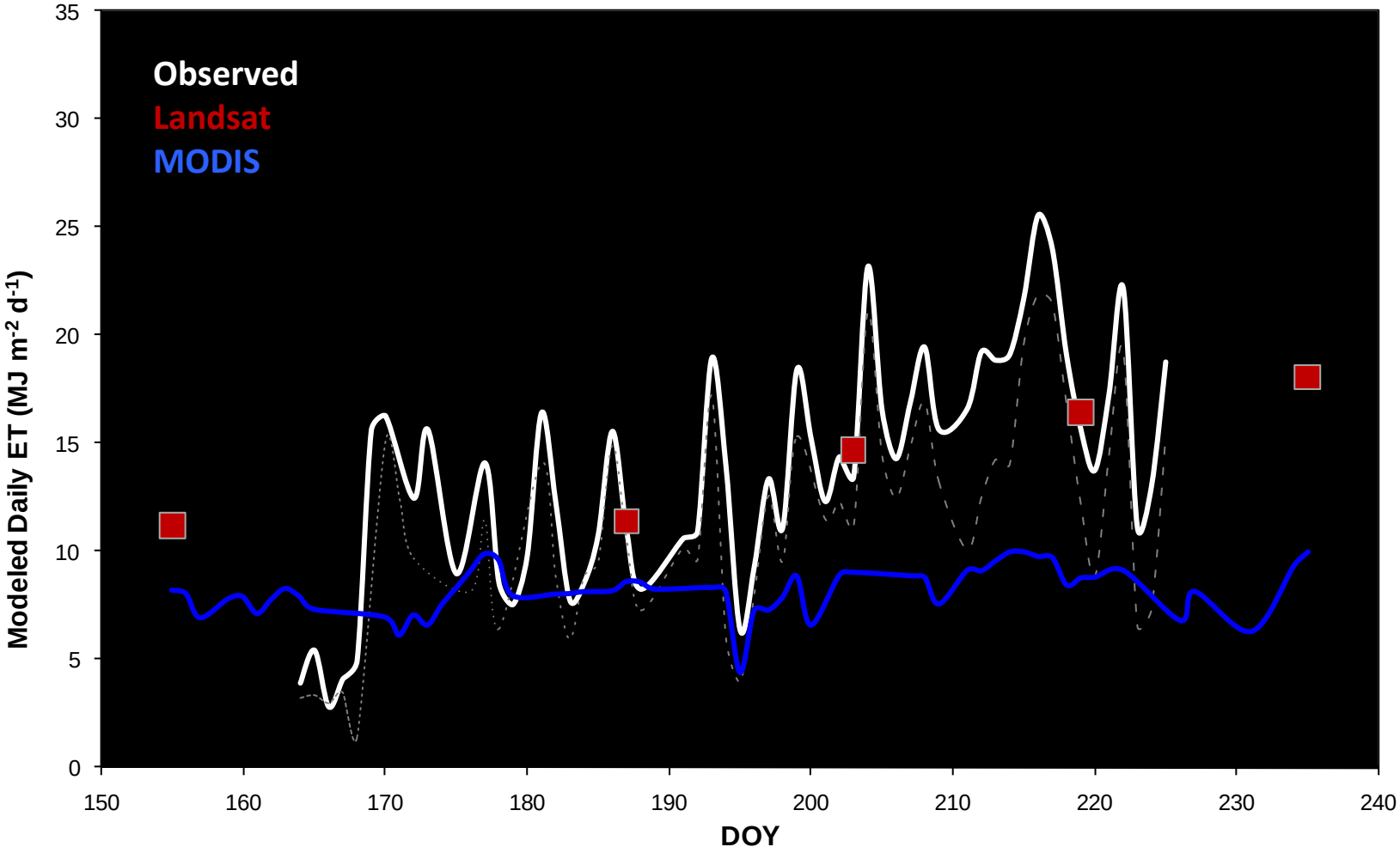

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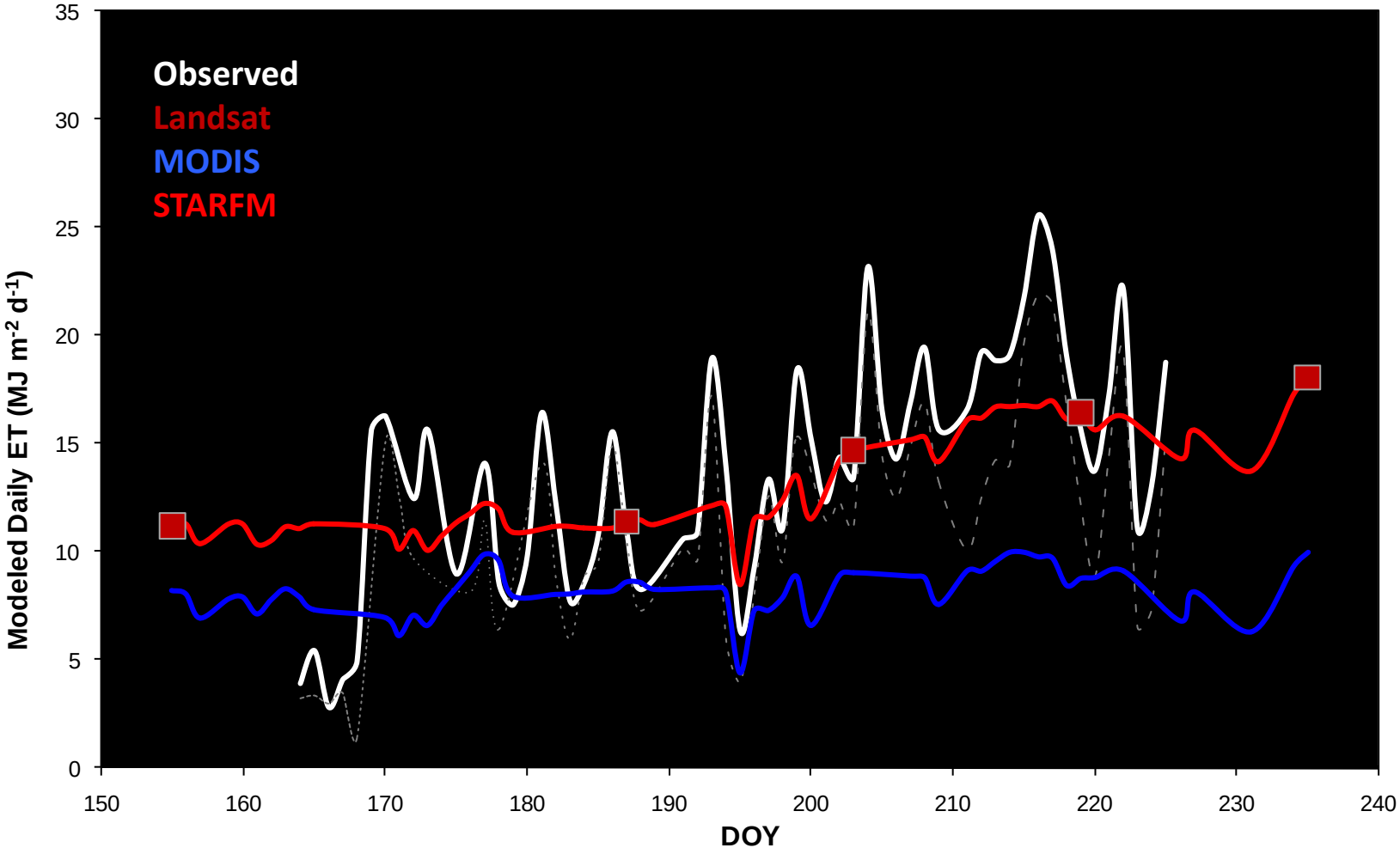

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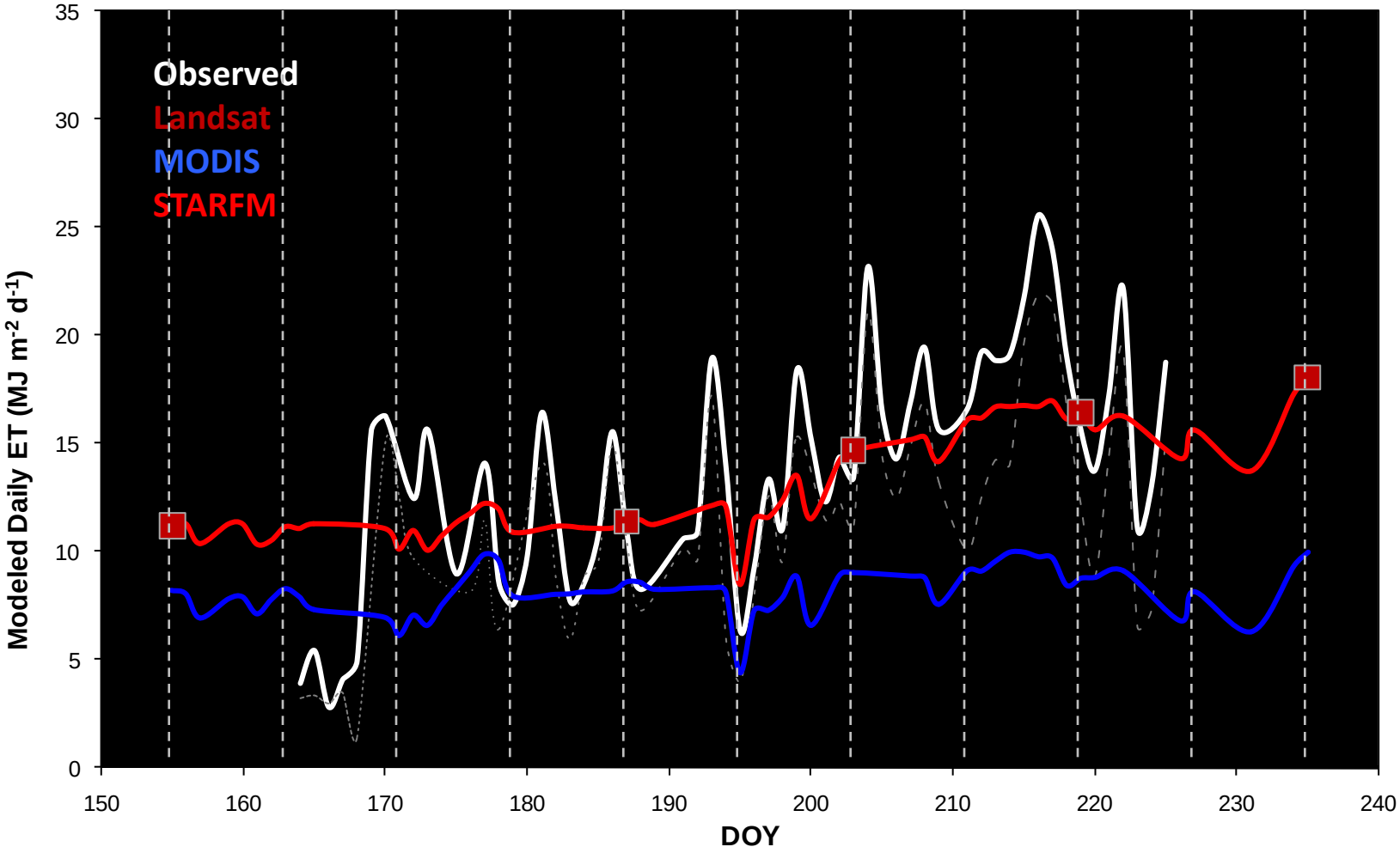

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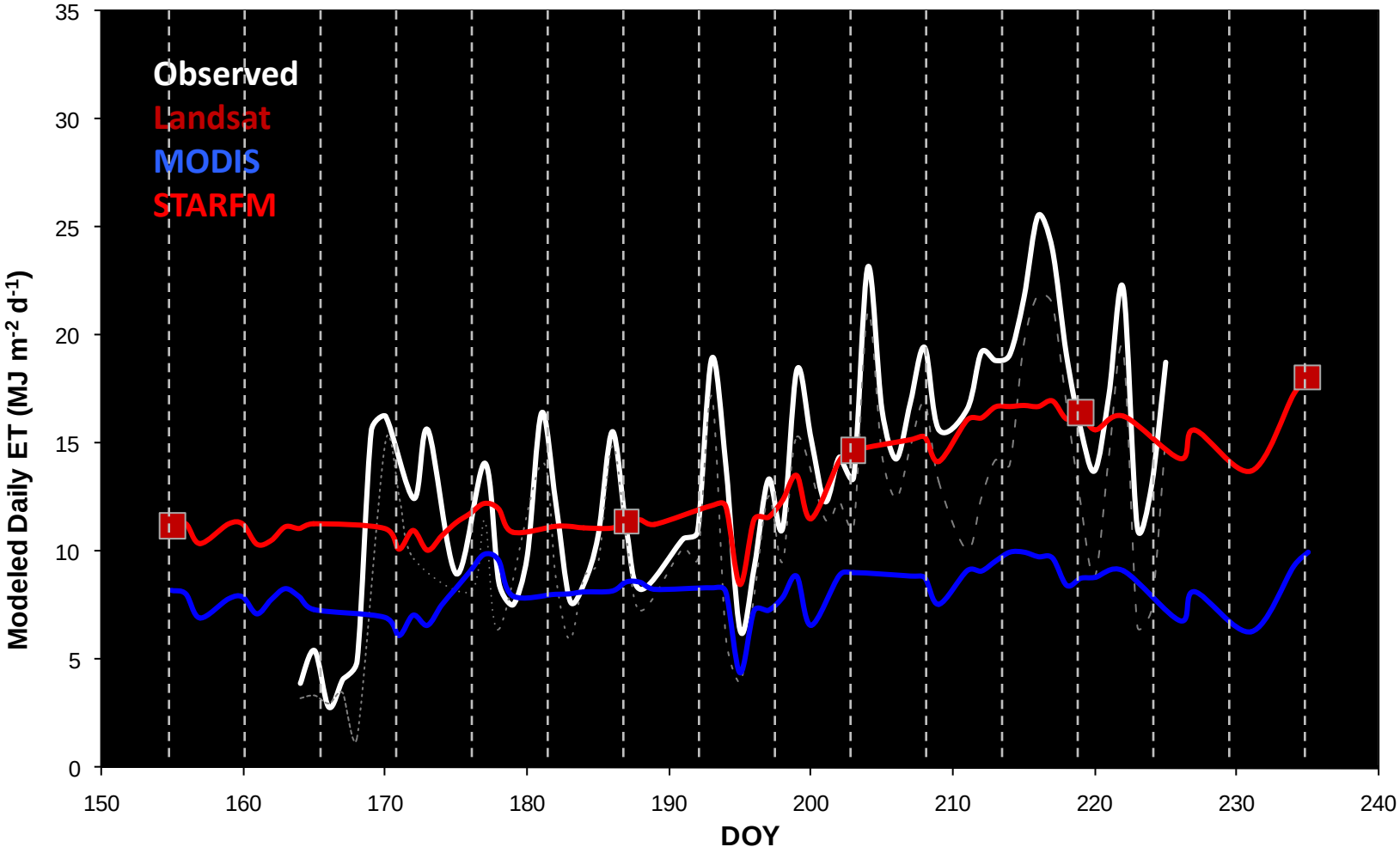
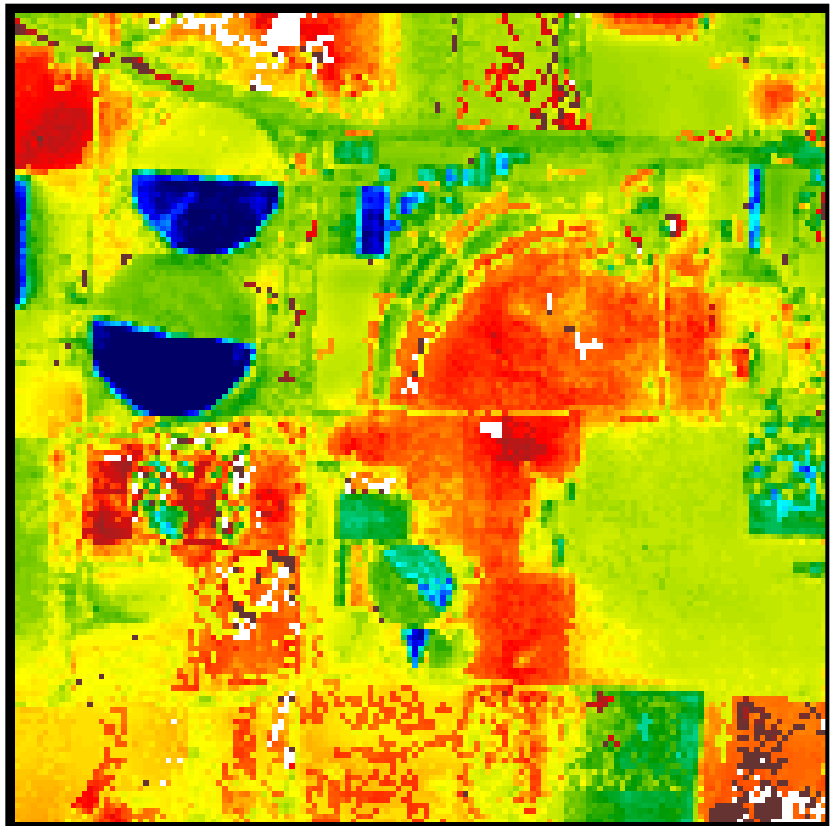
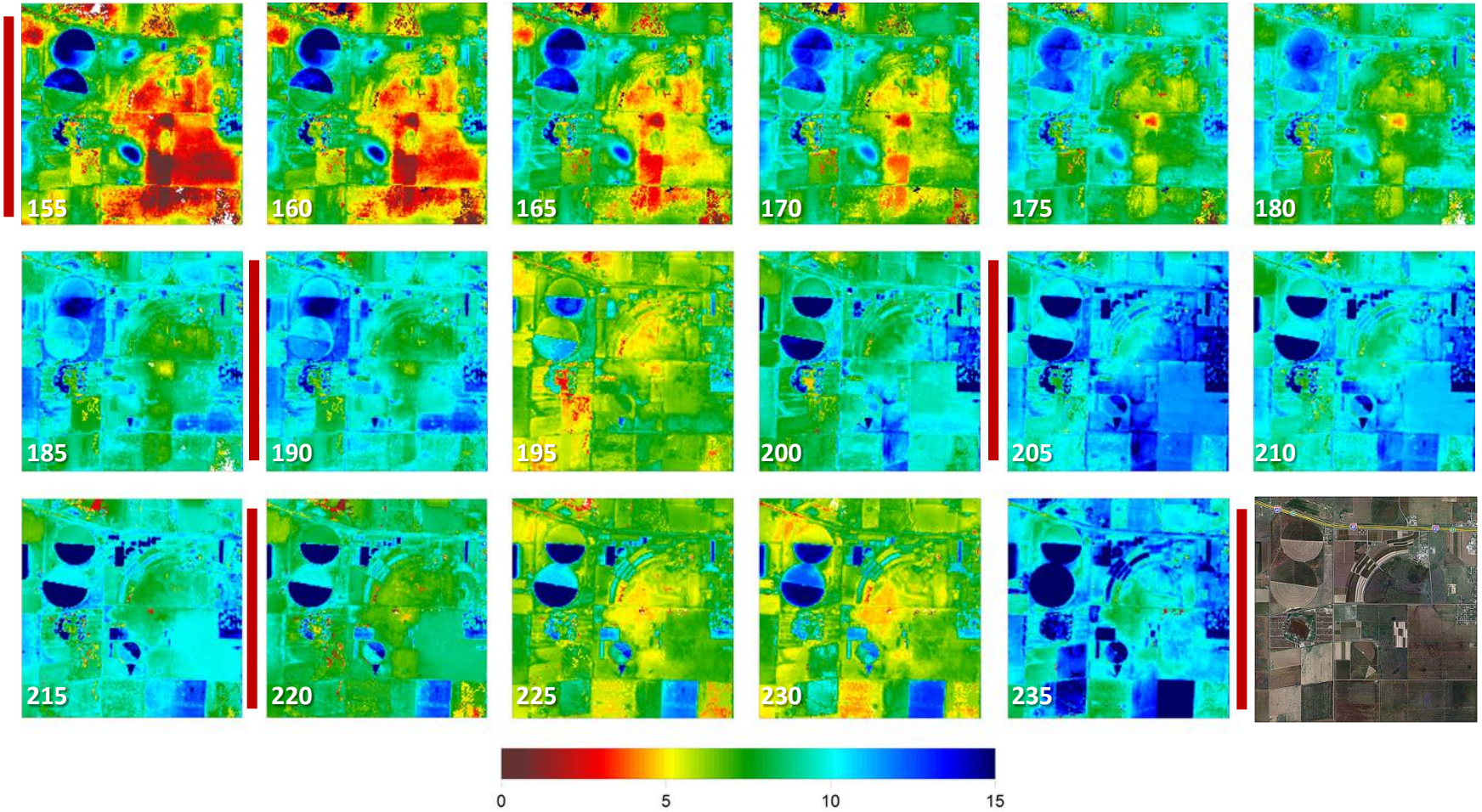


40
40
40
57



DAILY TIME-SERIES

(5-DAY INTERVALS)



Daily ET (MJ m^{-2} d^{-1})

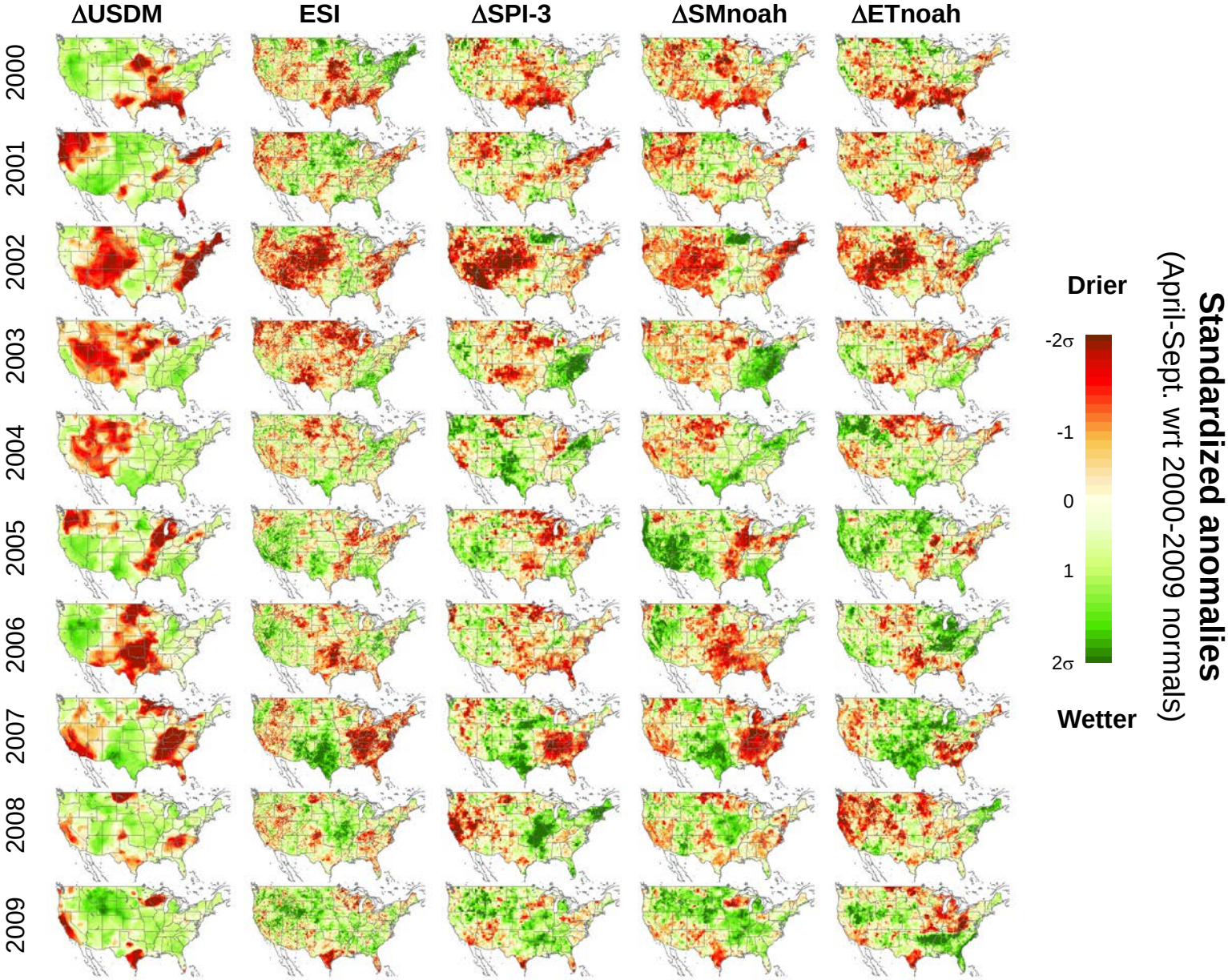
ONGOING/FUTURE WORK

... monitoring drought

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

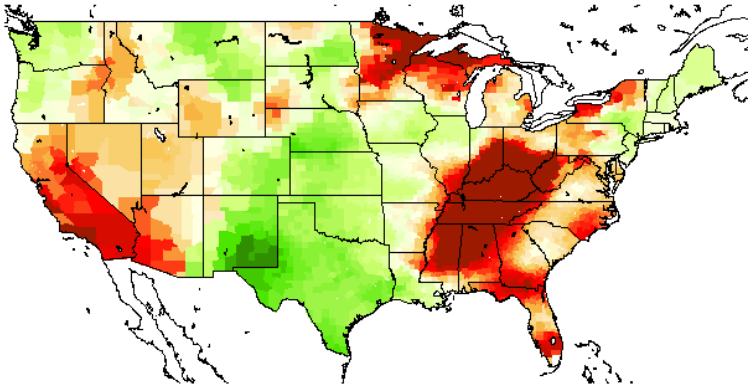
Evaporative Stress Index

SEASONAL ANOMALIES

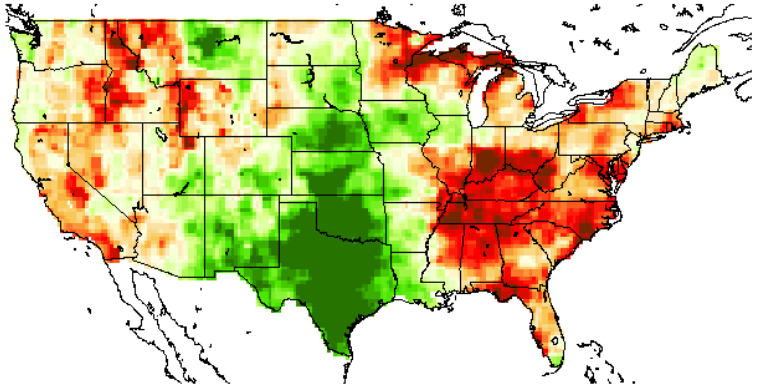


2007 SEASONAL ANOMALIES

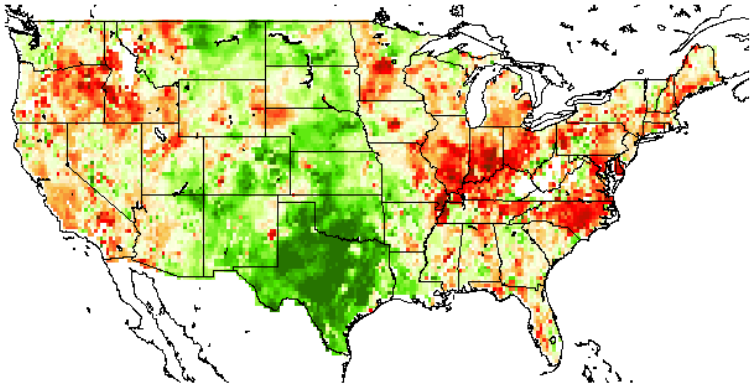
USDM



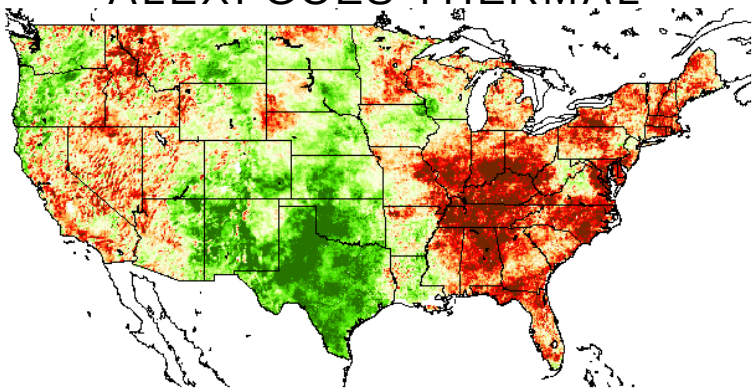
LIS - NOAH



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

Evaporative Stress Index (ESI): 2000 - Present - Mozilla Firefox

File Edit View History Bookmarks Tools Help

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Evaporative Stress Index (ESI): 2000 - Present

Product: ESI **Composite:** 1 month

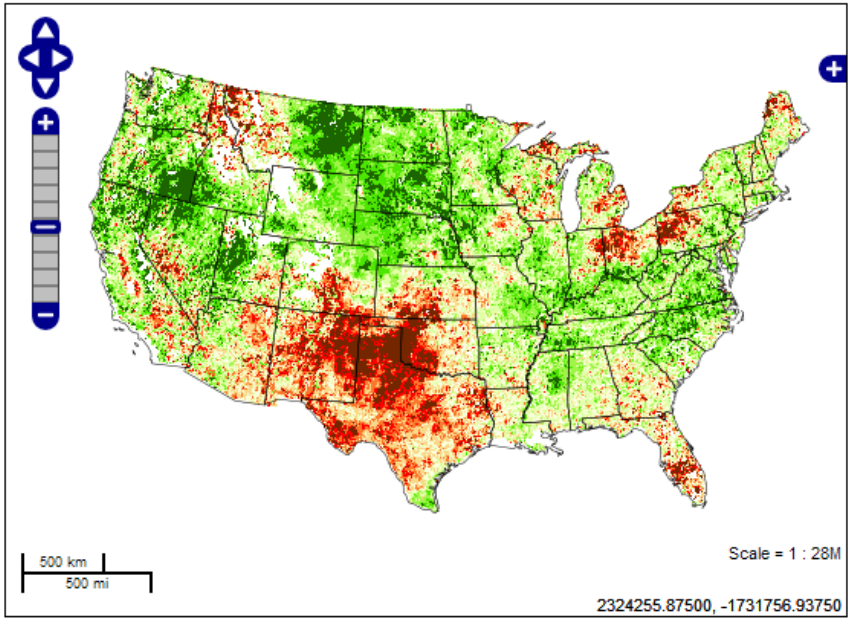
Year: ← 2011 **Day of year:** ← Day 196

LINK ☑

Product: DM **Composite:** 0 months

Year: ← 2011 **Day of year:** ← Day 196 →

2011/us_esi_01mn_2011196al.tif



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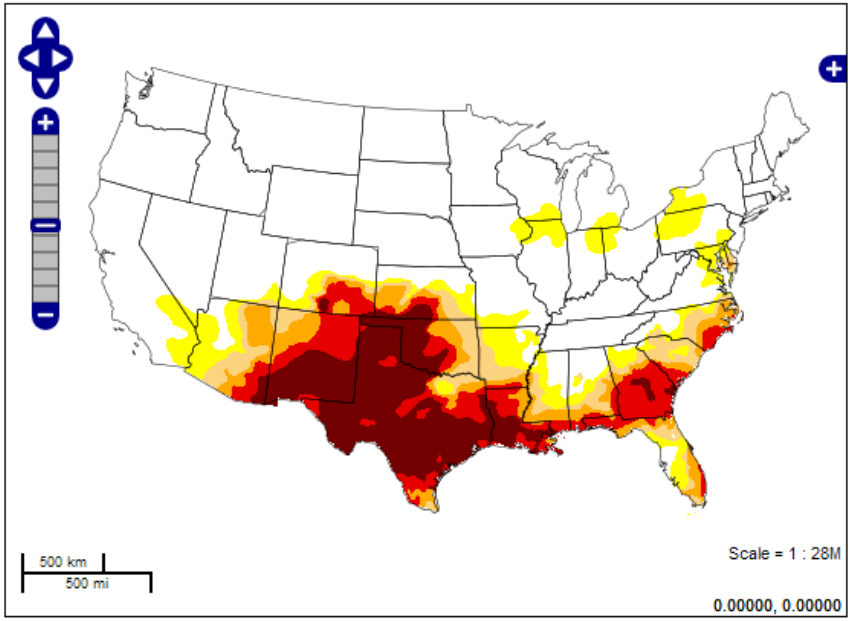


D0 D1 D2 D3 D4

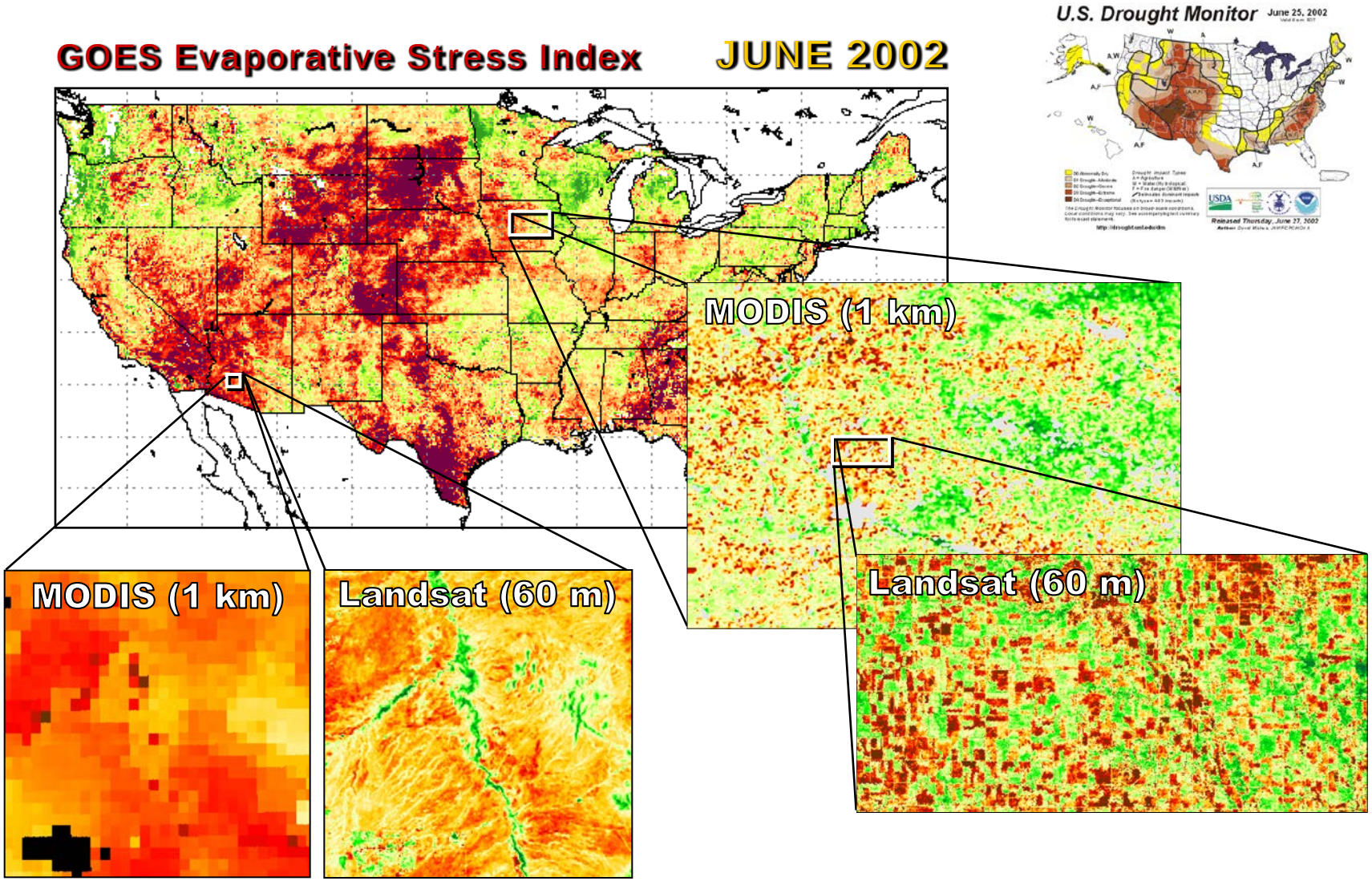
Download Displayed Data:
Albers Conic Equal-Area projection: geotiff :: zipped GRID
Latitude/Longitude coordinates: geotiff :: zipped GRID

Download Displayed Data:
Albers Conic Equal-Area projection: geotiff :: zipped GRID
Latitude/Longitude coordinates: geotiff :: zipped GRID

Access to all data via FTP

To download multiple files, point an FTP client to hrsl.arsusda.gov and use the same user ID / password.

Multi-scale Drought Monitoring

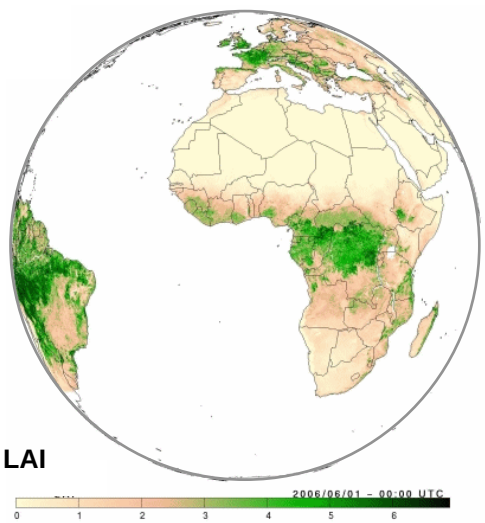


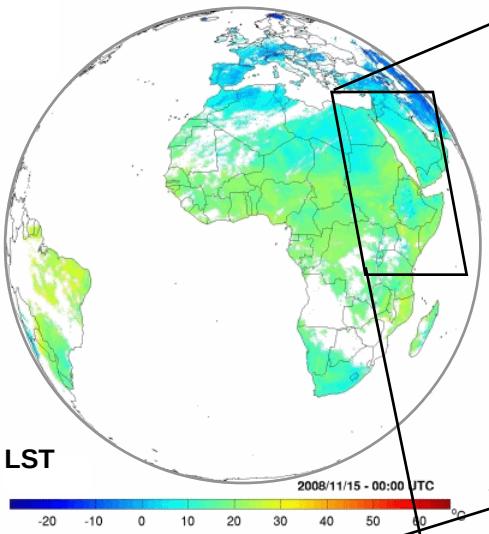
NEW DOMAINS

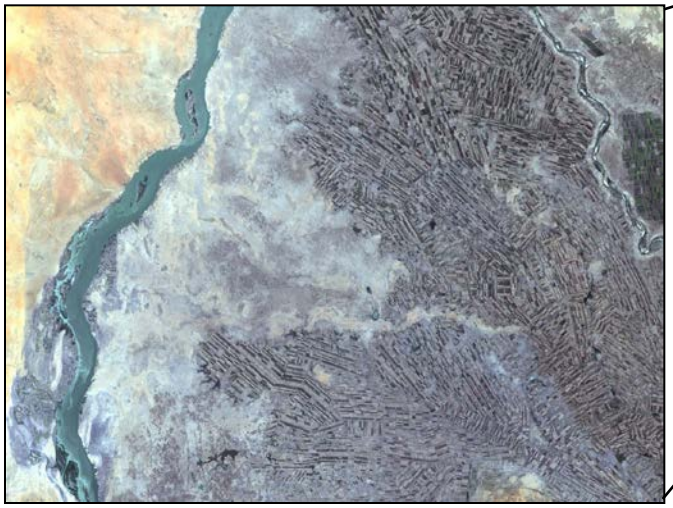
... Africa and Mideast

Northeast Africa

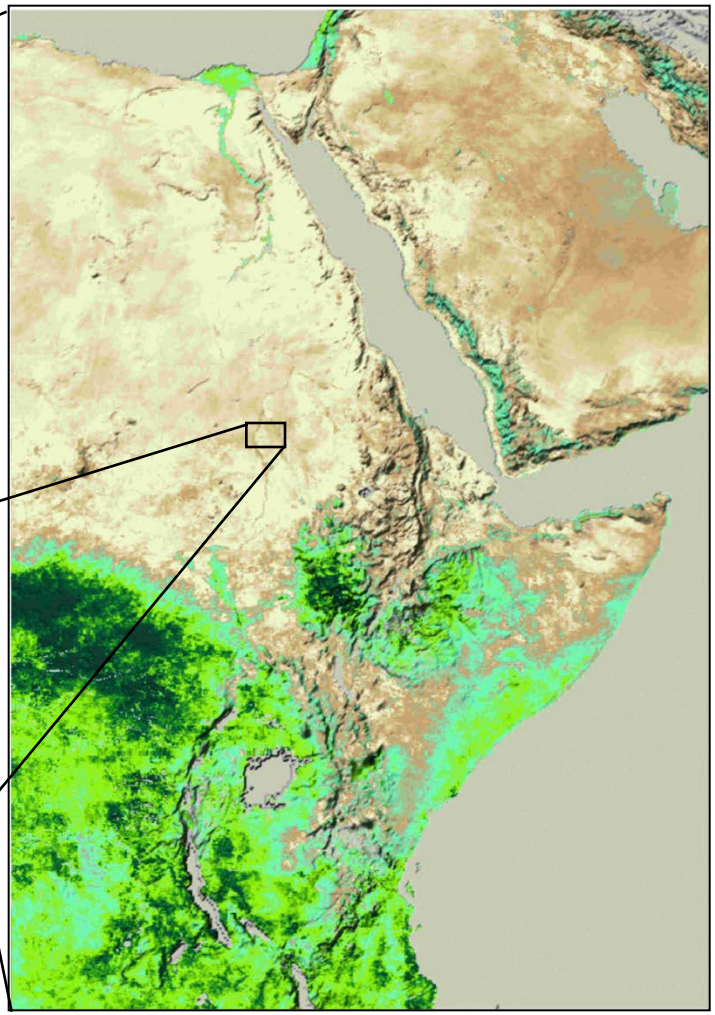
METEOSAT COVERAGE



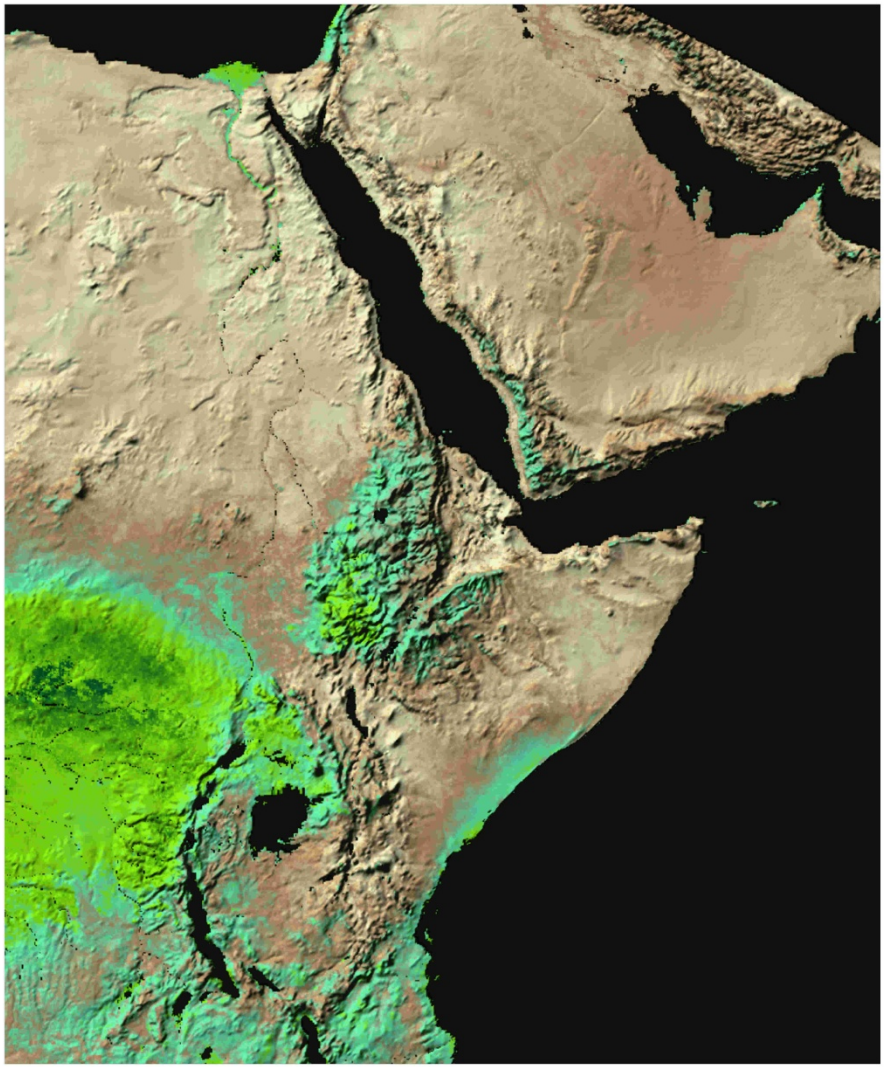




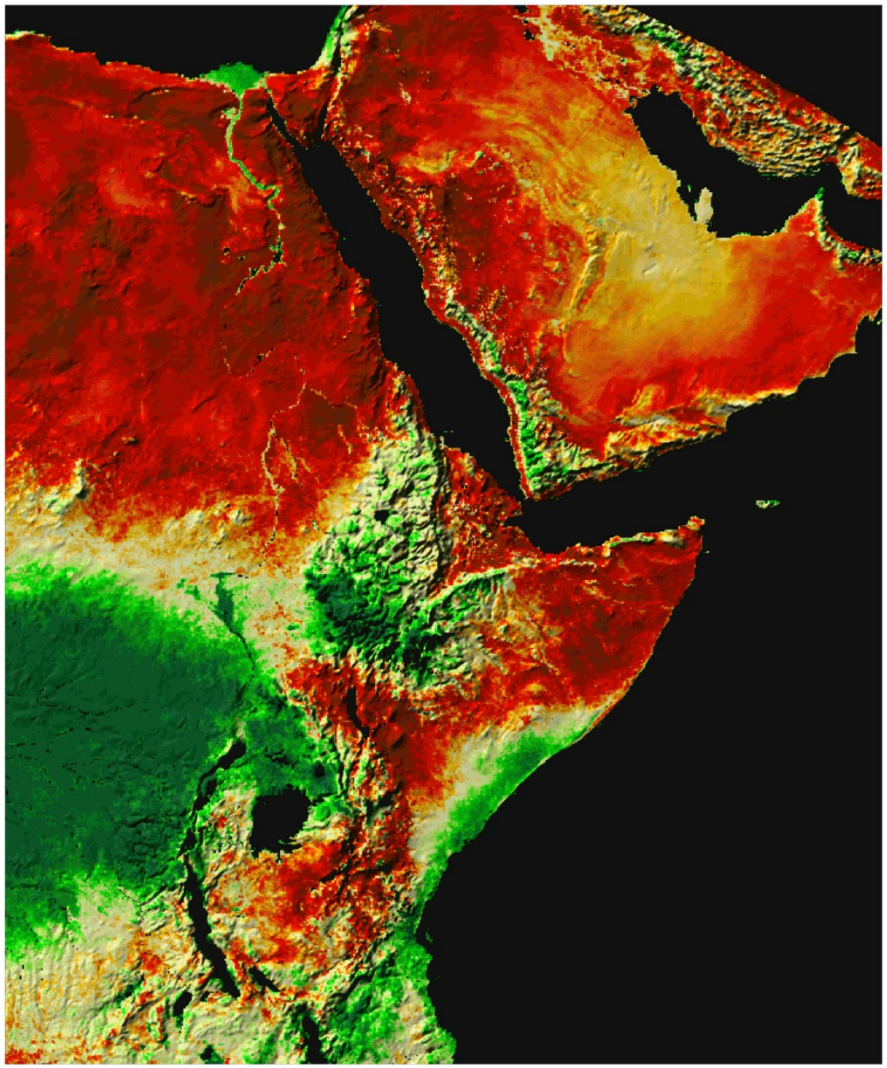
L7-ETM+ 1/12/02 USGS Image Gallery



2009 APRIL-SEPTEMBER



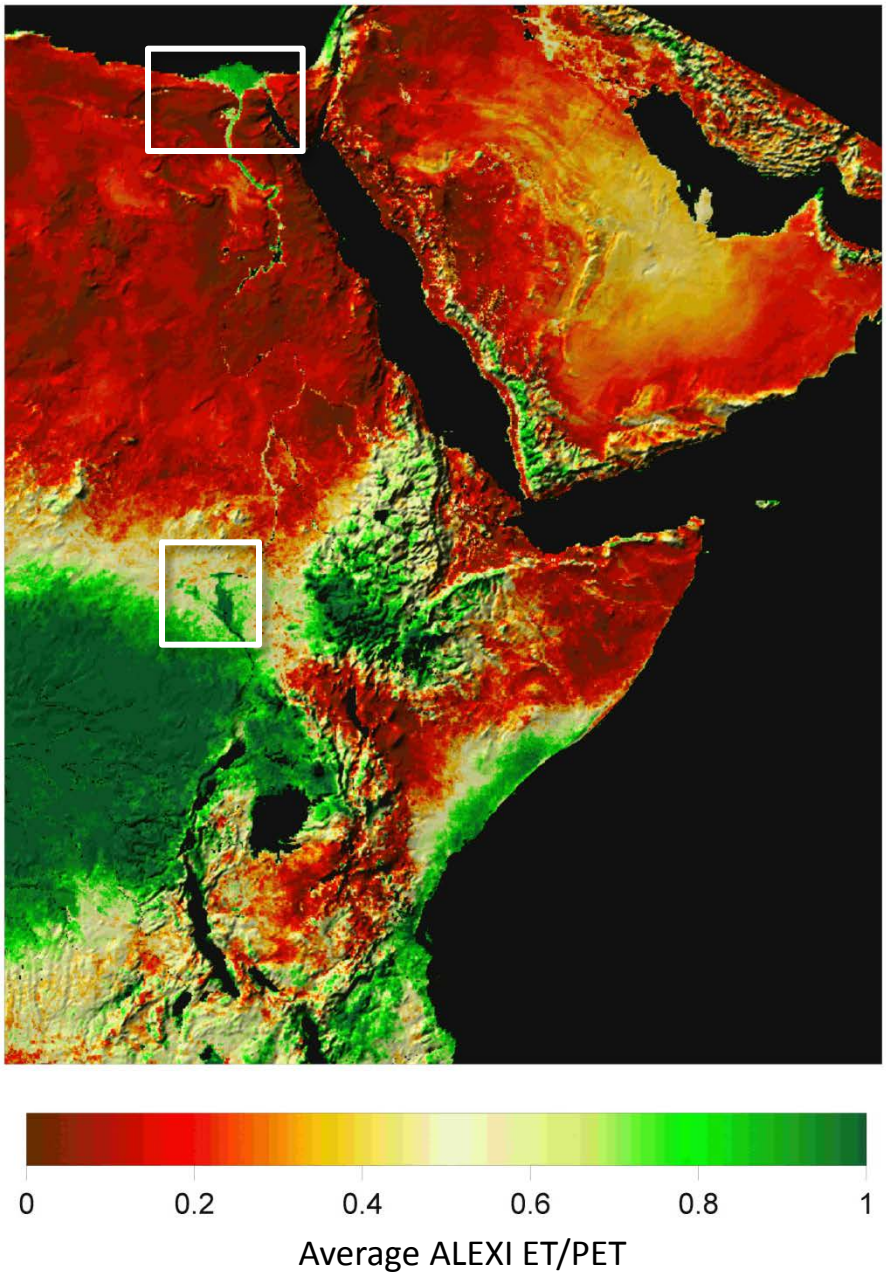
Average ALEXI ET (MJ m^{-2} d^{-1})



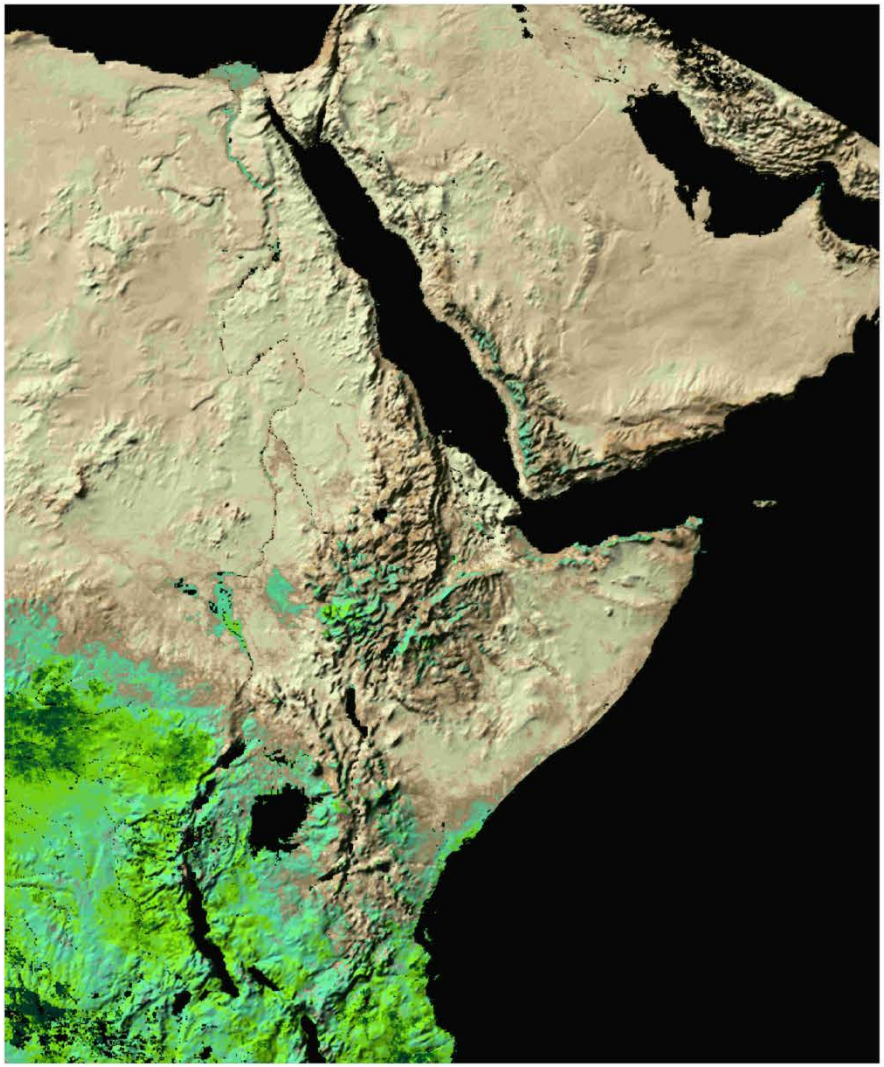
Average ALEXI ET/PET

Nile
Delta

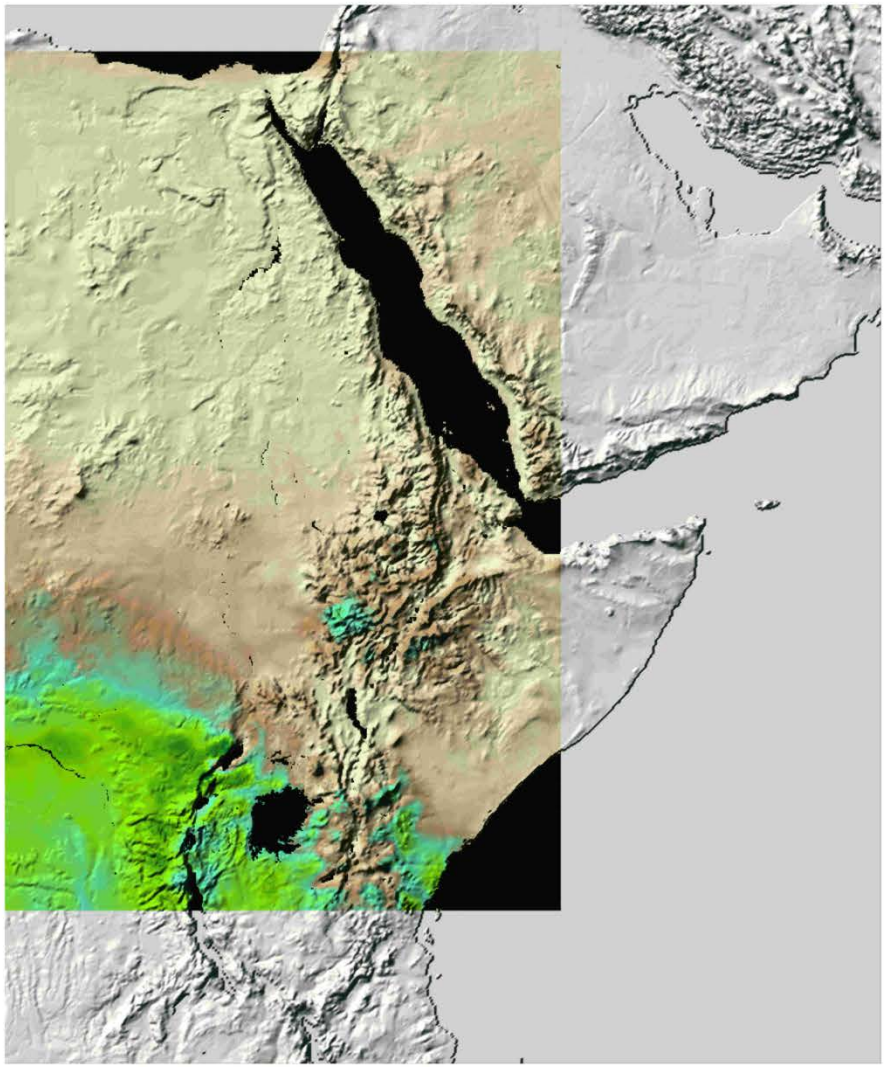
Sudd Wetland


0
0.2
0.4
0.6
0.8
1
Average ALEXI ET/PET

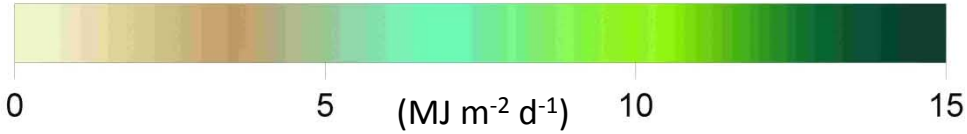
2009 FEBRUARY

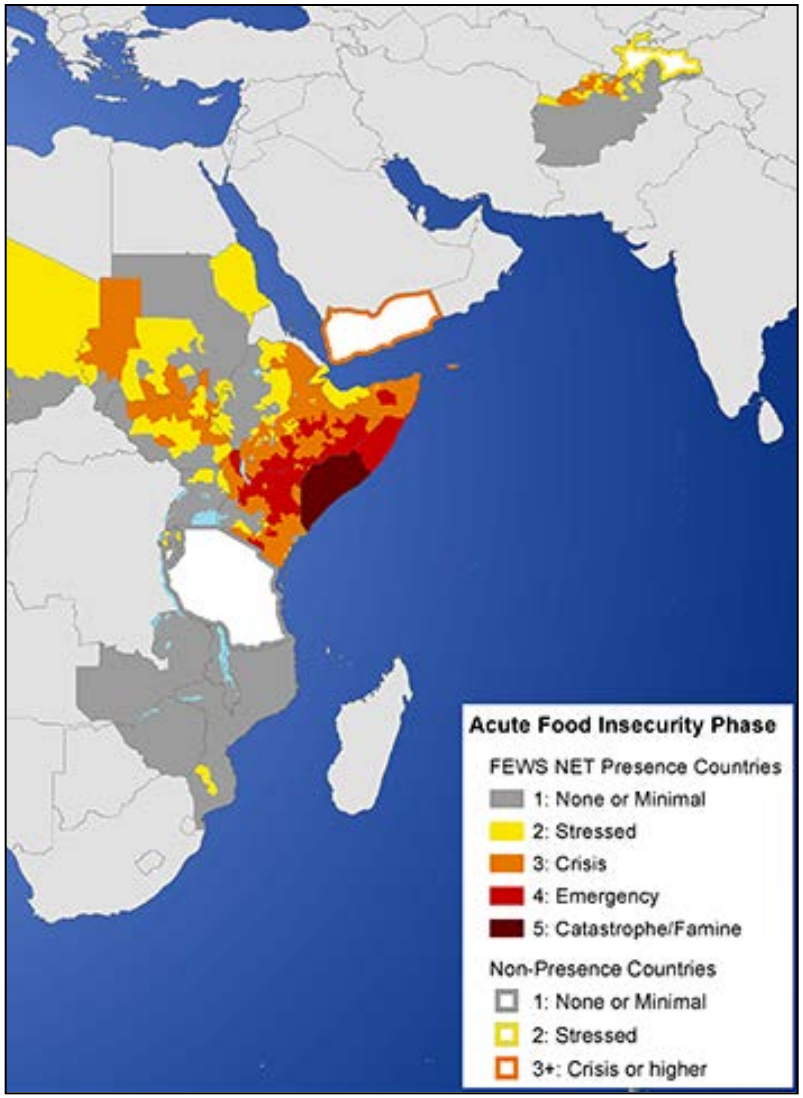


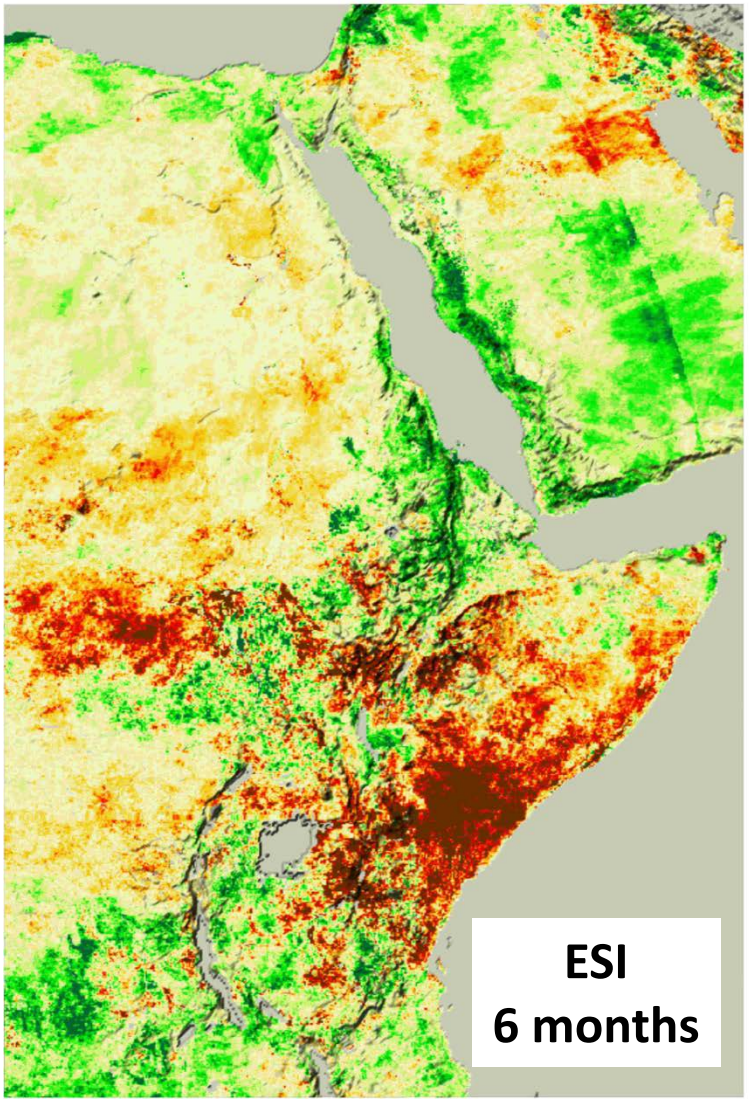
Average ALEXI ET

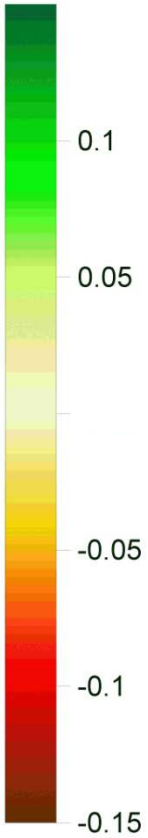


Average LDAS ET

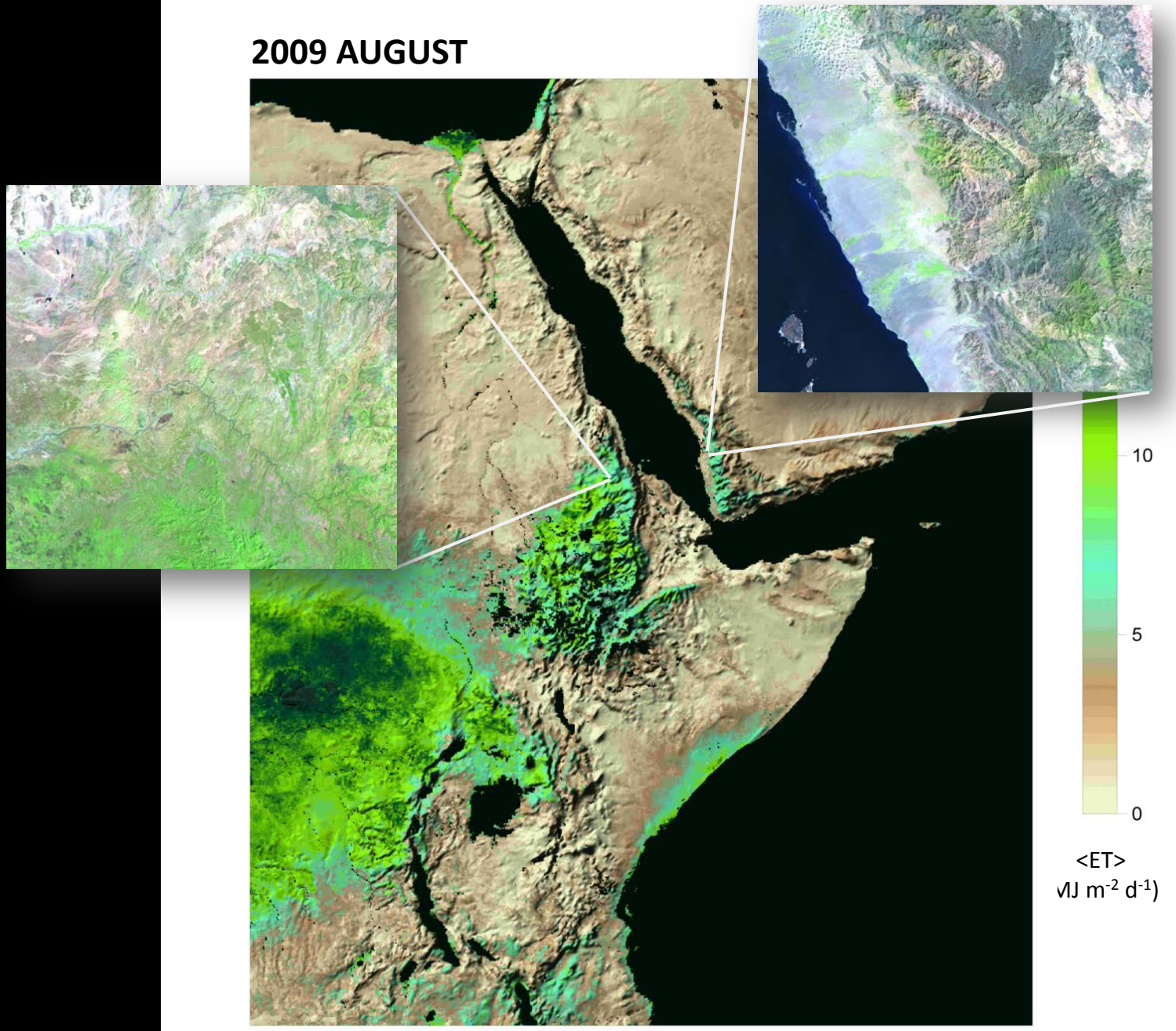



Acute Food Insecurity Phase
FEWS NET Presence Countries
1: None or Minimal
2: Stressed
3: Crisis
4: Emergency
5: Catastrophe/Famine
Non-Presence Countries
1: None or Minimal
2: Stressed
3+: Crisis or higher

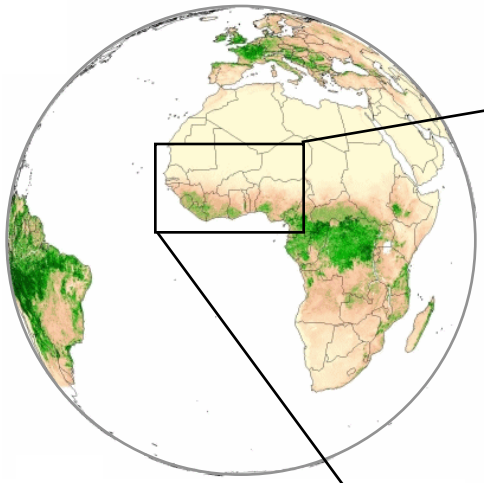

ESI
6 months

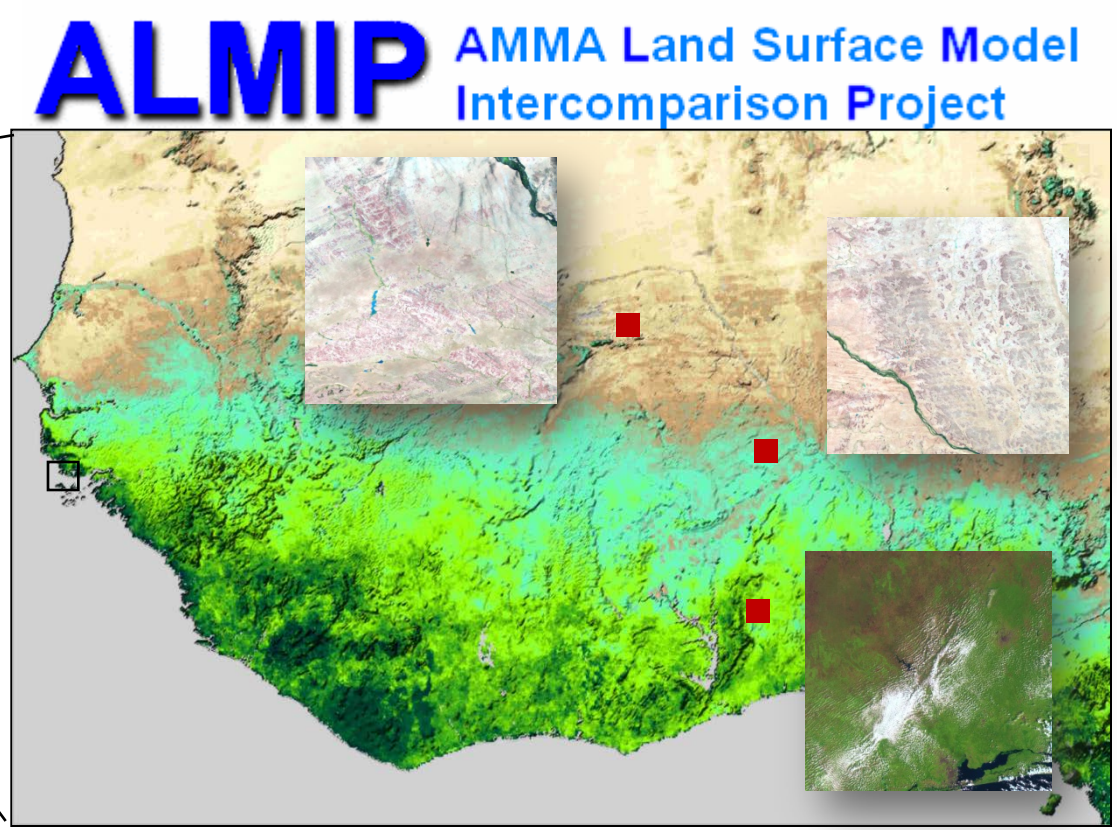

0.1
0.05
-0.05
-0.1
-0.15

2009 AUGUST



Western Africa

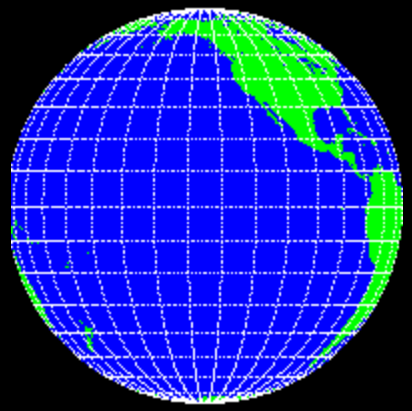




African Monsoon Multidisciplinary Analysis (CNRM, CESBIO)

NEW DOMAINS
... Global mapping

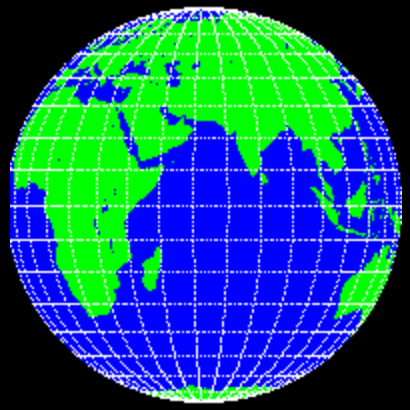
Geostationary Satellite Coverage



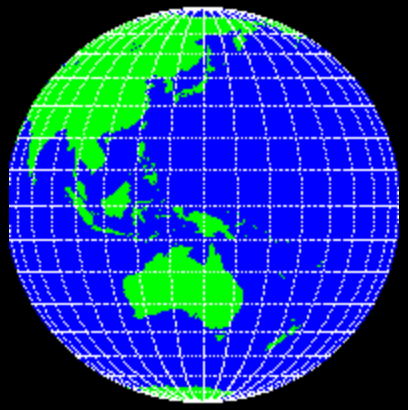
GOES W 135°W
NOAA (US)

GOES E 75°W
NOAA (US)

Meteosat 0°
Eumetsat (EU)



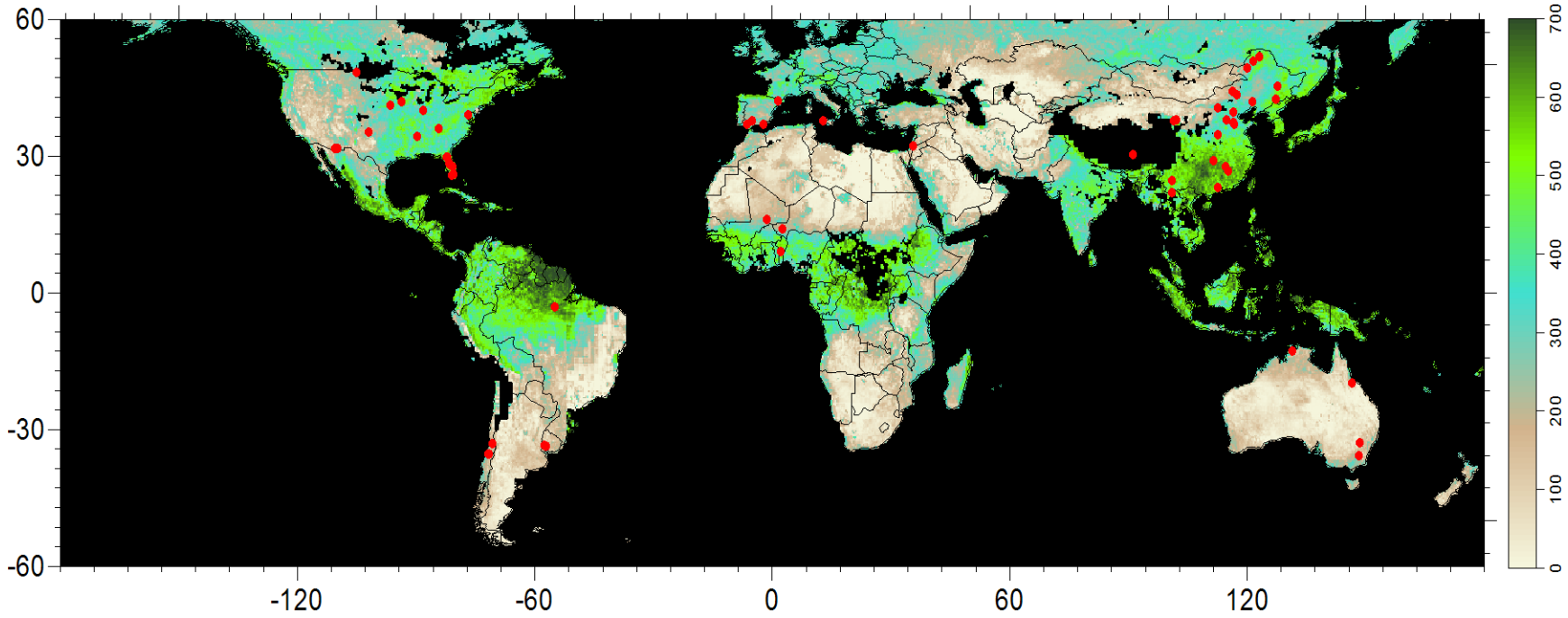
Meteosat 63°E
Eumetsat (EU)



GMS 140°E
JAXA (Japan)

August 2004

Midday latent heat flux (clear-sky composite)



CONCLUSIONS

- THERMAL REMOTE SENSING DATA HAVE GREAT UTILITY:
  - *... multi-scale ET mapping*
  - *... drought monitoring*
  - *... soil moisture mapping*

≤ 8 DAY REVISIT WILL IMPROVE SEASONAL ET

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