Mapping Water Use and Drought with Satellite Remote Sensing

Christopher Hain, Li Fang, Mitch Schull

Earth System Science Interdisciplinary Center, University of Maryland, NOAA-NESDIS-STAR

Martha C. Anderson, Bill Kustas, Feng Gao, Yun Yang, Yang Yang, Liang Sun

USDA-Agricultural Research Service Hydrology and Remote Sensing Laboratory Beltsville, MD

Xiwu Zhan

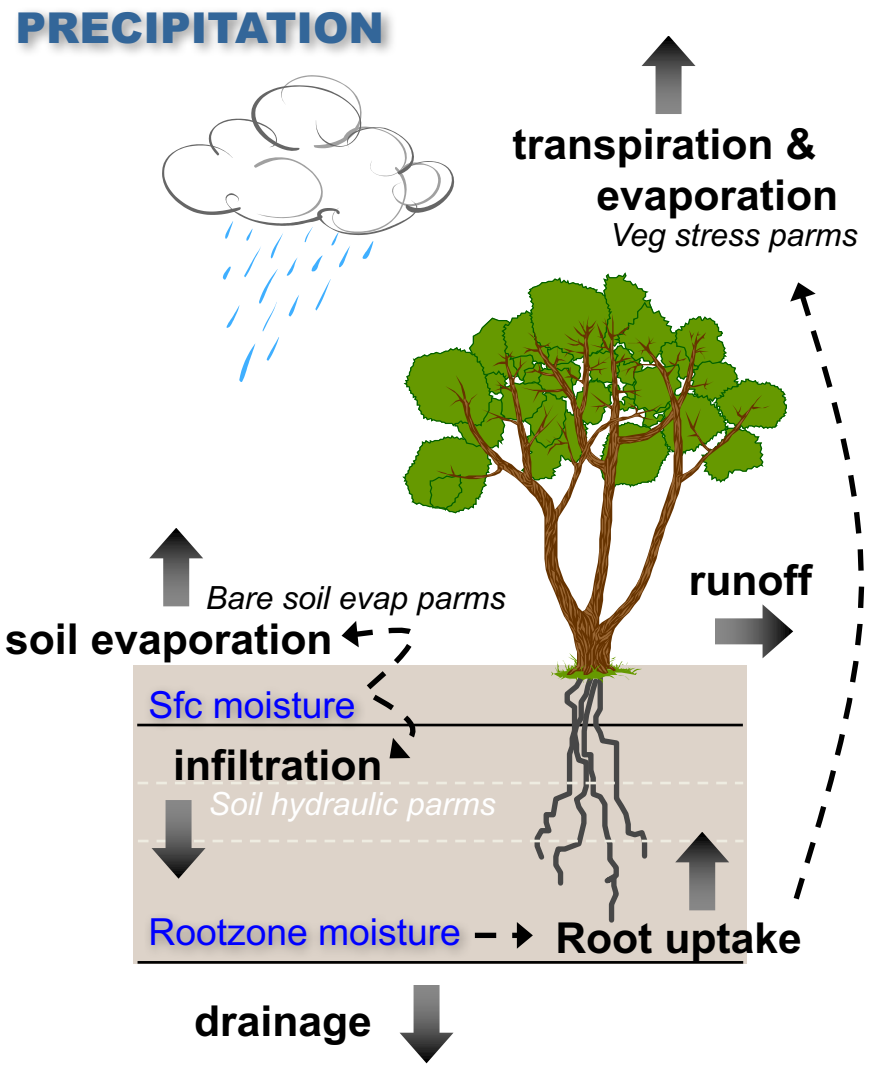
NOAA-NESDIS-STAR

Jason Otkin

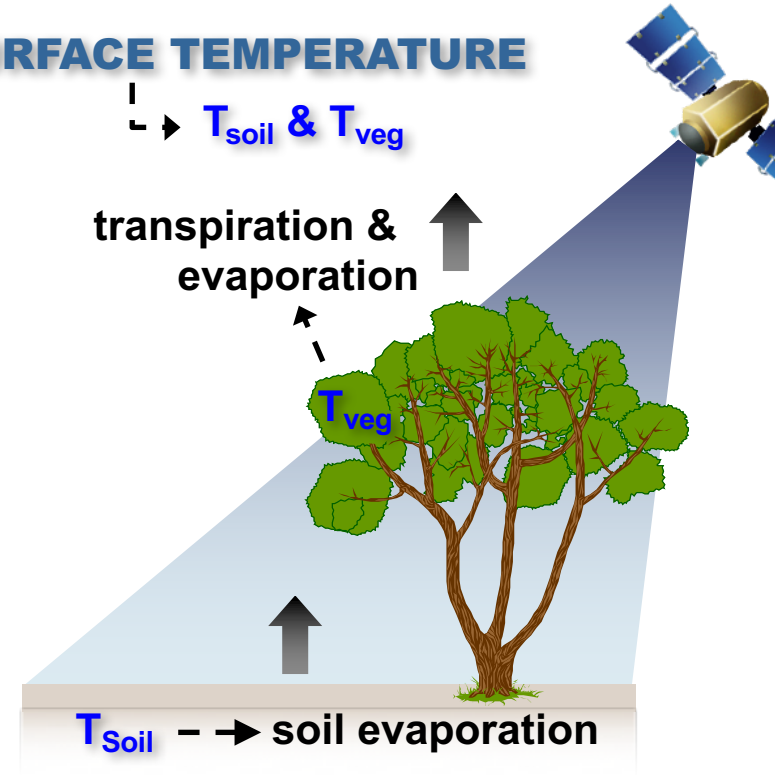
University of Wisconsin

Thomas Holmes

NASA-GSFC

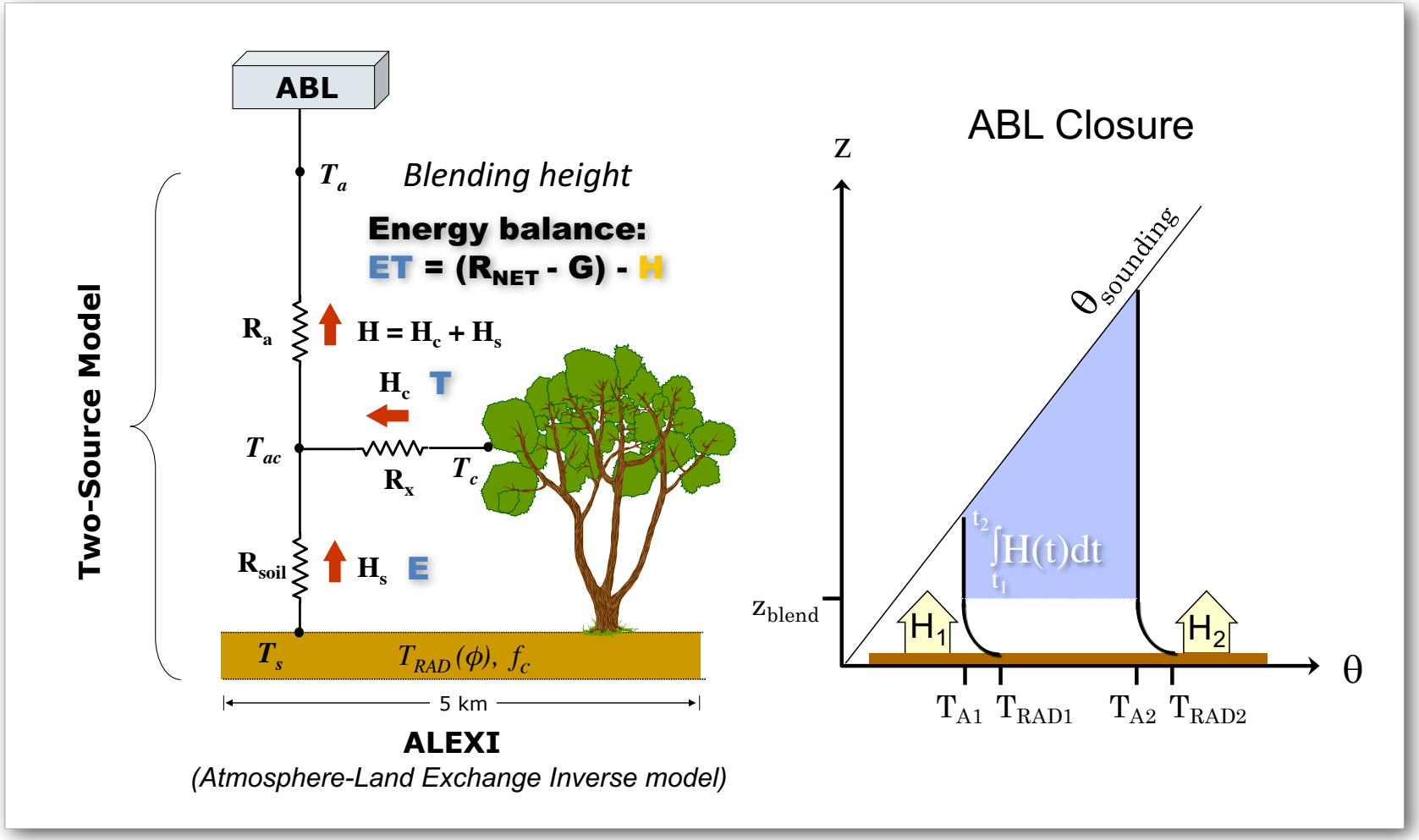


WATER BALANCE APPROACH
(prognostic modeling)



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

ENERGY BALANCE APPROACH
(diagnostic modeling)



Regional scale

Surface temp: ΔT_{RAD} - Geostationary

Air temp: T_a - ABL model

COMPARISON of ET from energy and water balance models (ALEXI vs. Noah)

(Green indicates energy balance ET is persistently wetter than expected based on local water balance)

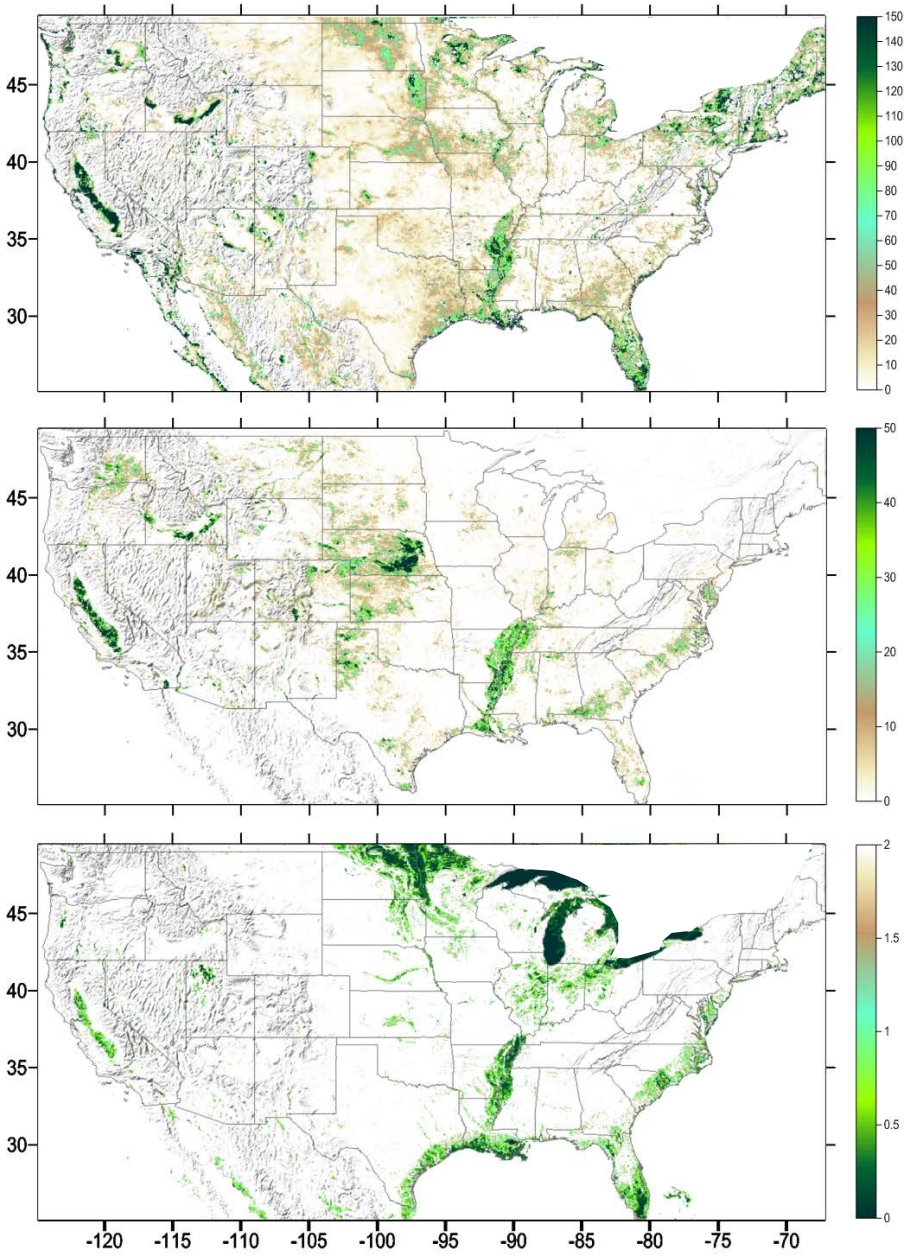
Differences are primarily related to:

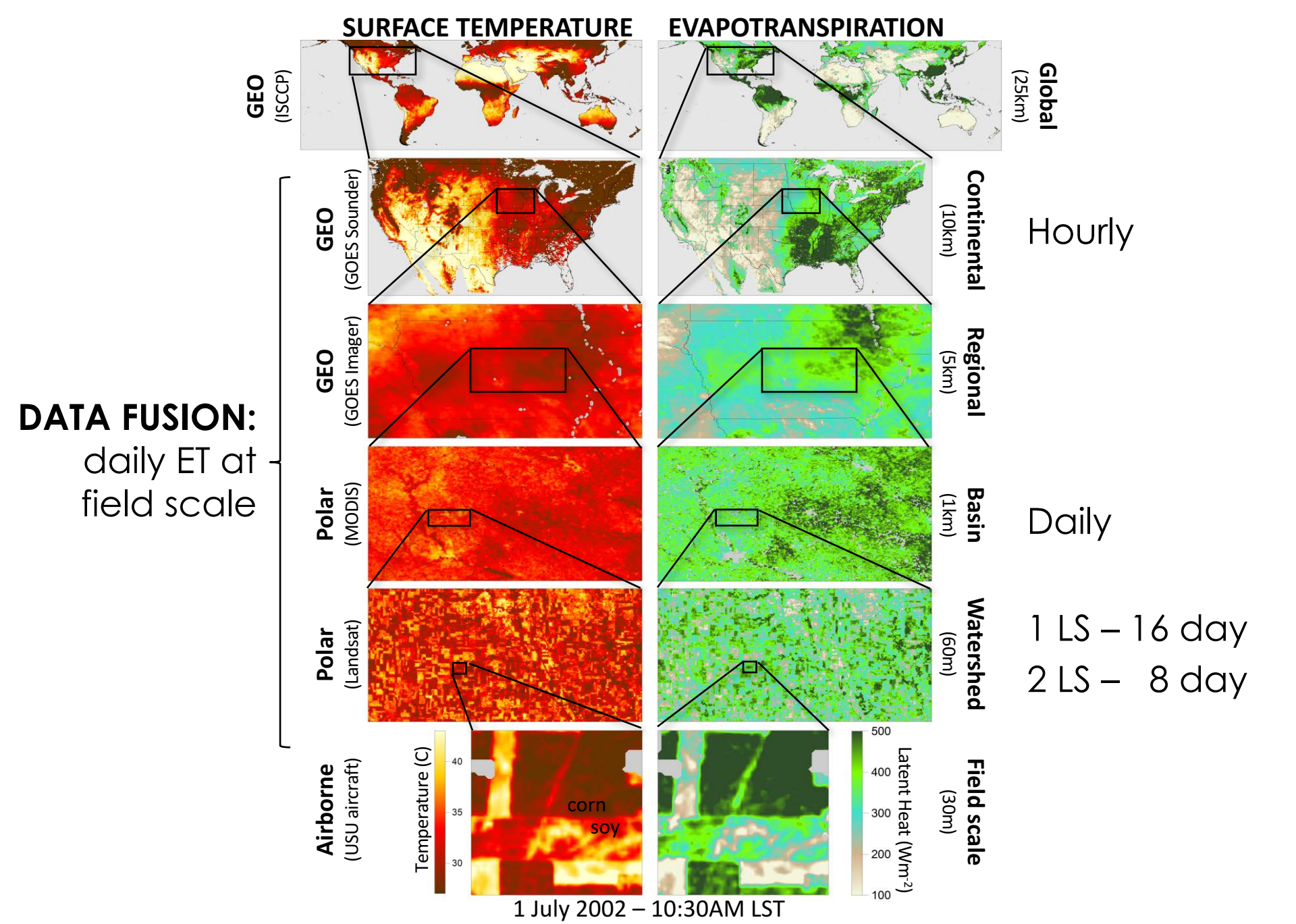
% Irrigation

Depth to water table (m)

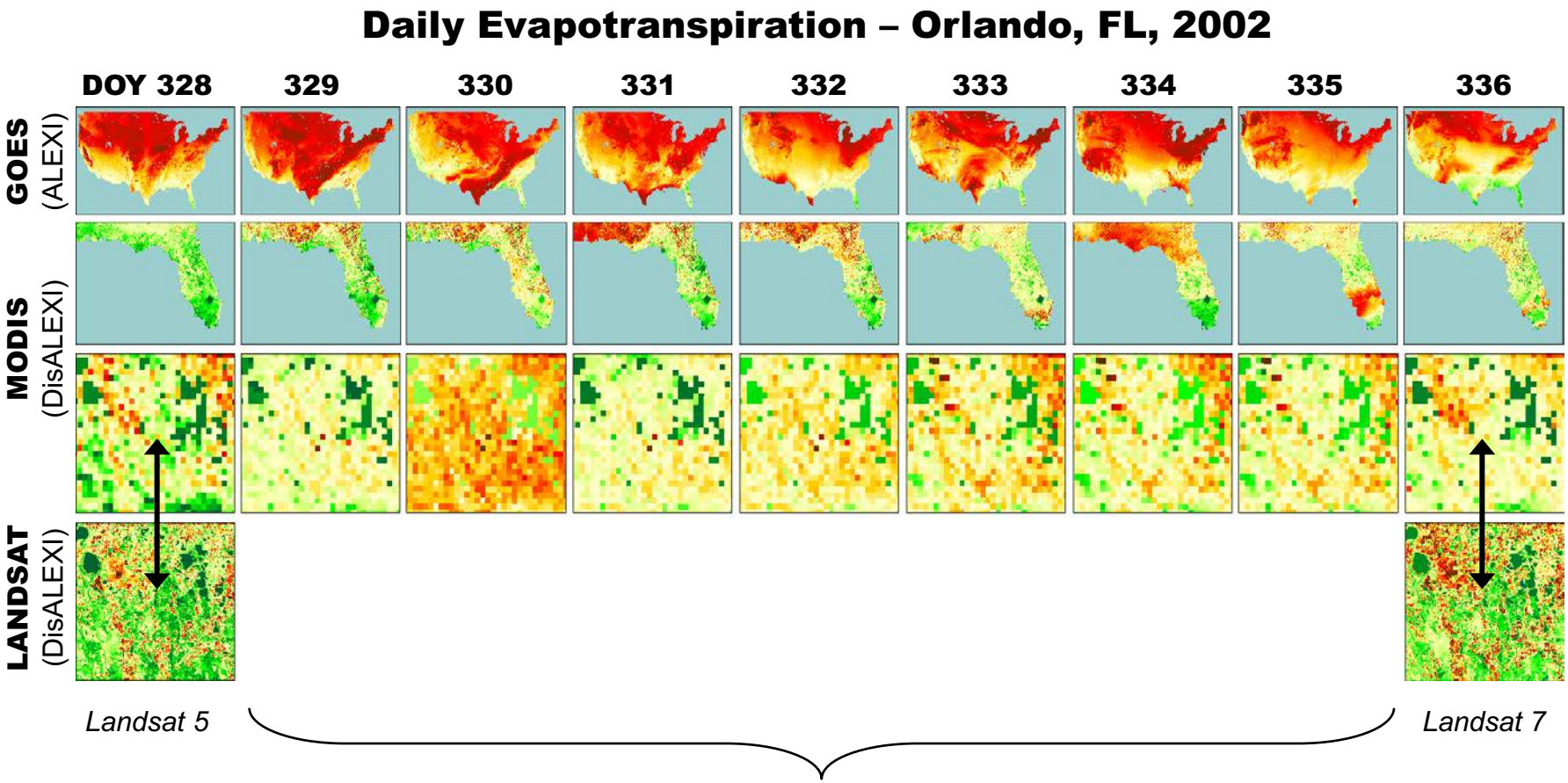
(as well as density of subpixel water bodies)

Hain, et al. (2014)

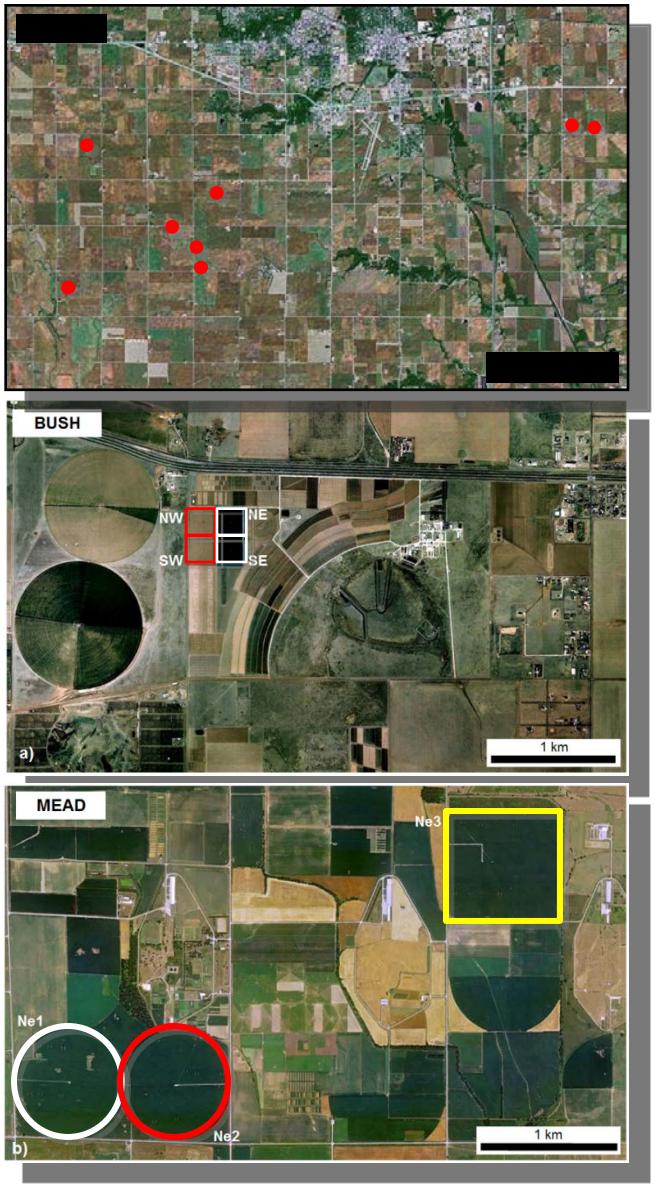



SURFACE TEMPERATURE
EVAPOTRANSPIRATION
GEO (ISCCP)
Global (25km)
GEO (GOES Sounder)
Continental (10km)
GEO (GOES Imager)
Regional (5km)
Polar (MODIS)
Basin (1km)
Polar (Landsat)
Watershed (60m)
Airborne (USU aircraft)
Field scale (30m)
Temperature (C)
40
35
30
corn
soy
500
400
300
200
100
Latent Heat (Wm-2)
1 July 2002 – 10:30AM LST
DATA FUSION:
daily ET at field scale
Hourly
Daily
1 LS – 16 day
2 LS – 8 day

GOES/MODIS/Landsat FUSION



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



SMEX02

Soil Moisture Experiment 2002
Ames, Iowa
Rainfed corn and soybean

BEAREX08

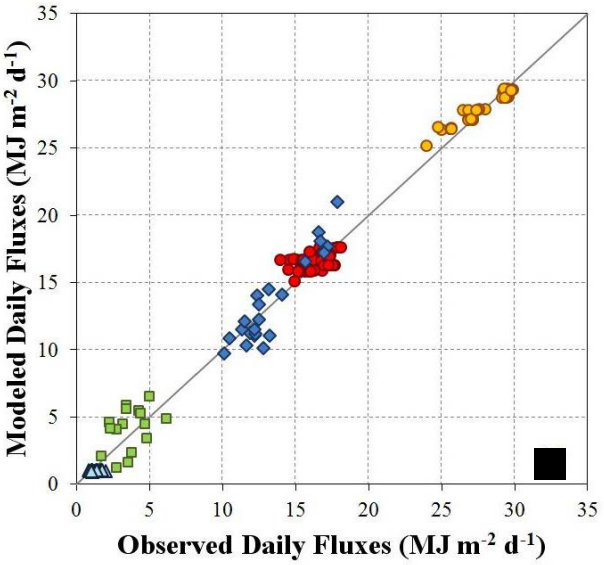
Bushland ET and Remote sensing Experiment 2008
Bushland, Texas
Rainfed and irrigated cotton

MEAD

Ameriflux site (S. Verma)
Mead, NE
Rainfed and irrigated corn and soybean

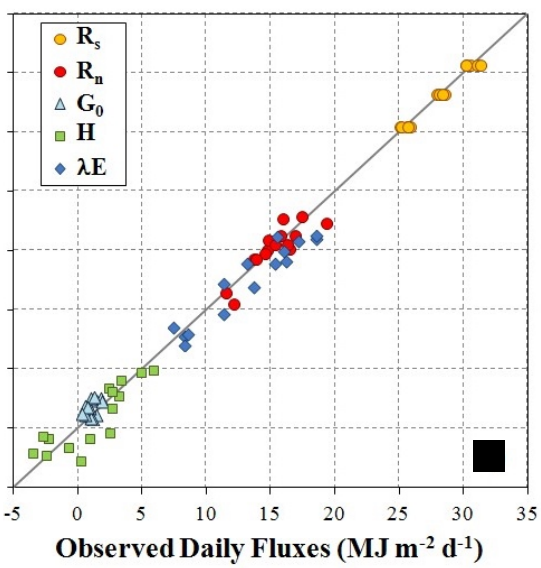
Model performance on Landsat dates

SMEX02



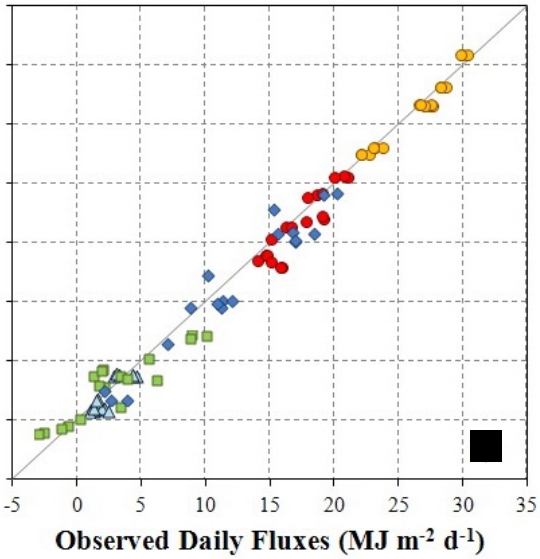
MAE: 1.08 MJ m^{-2} d^{-1}
RE: 8%

BEAREX08



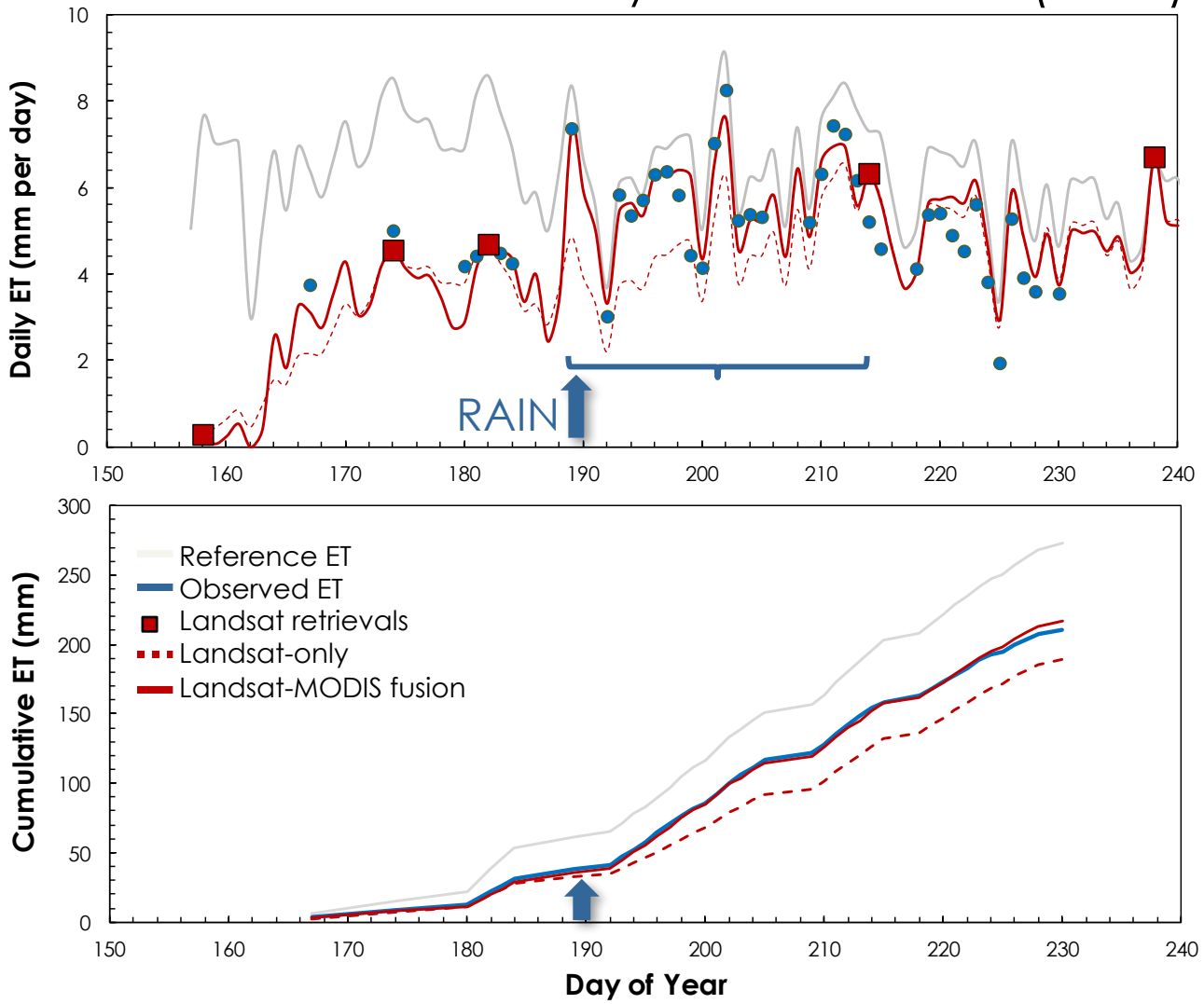
1.3 MJ m^{-2} d^{-1}
10%

MEAD



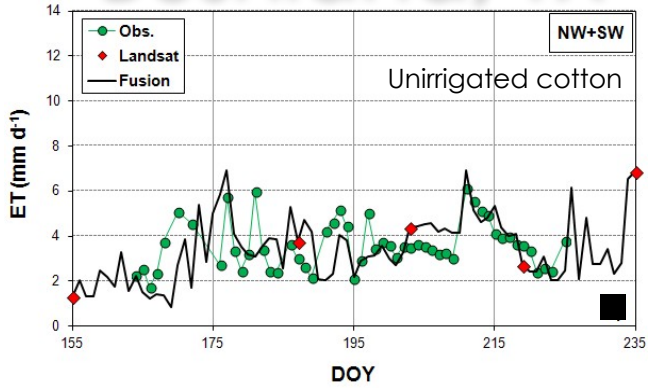
1.3 MJ m^{-2} d^{-1}
11%

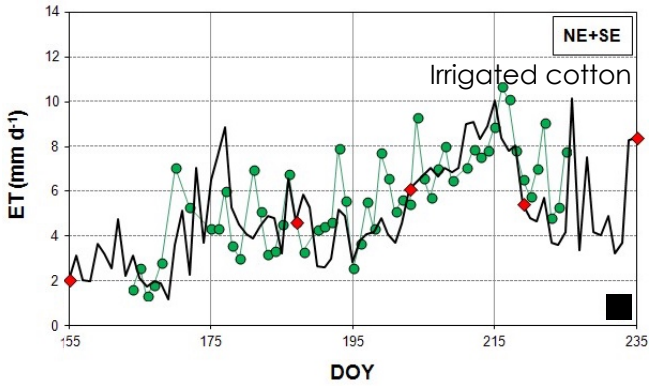
Rainfed soybean – SMEX02 (Iowa)

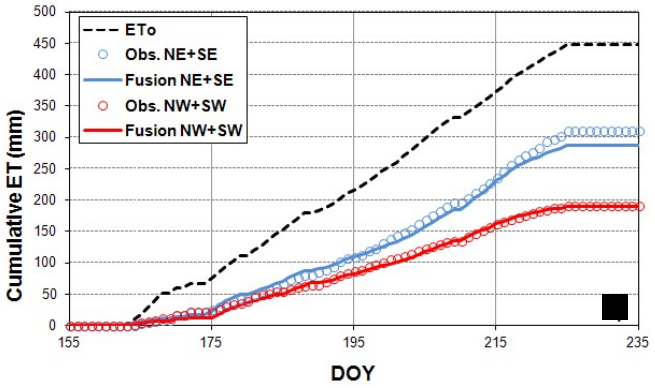


Irrigated vs. rainfed crop water use

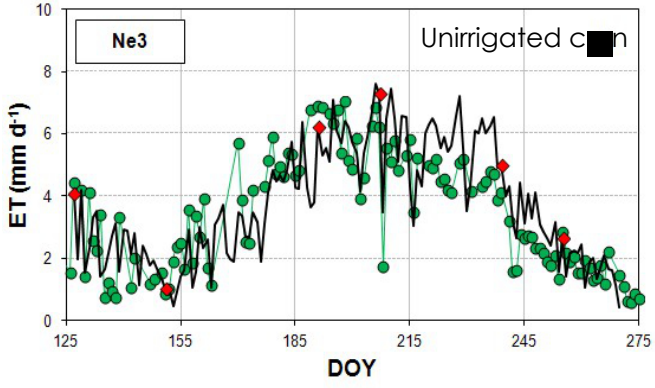
Bushland, TX

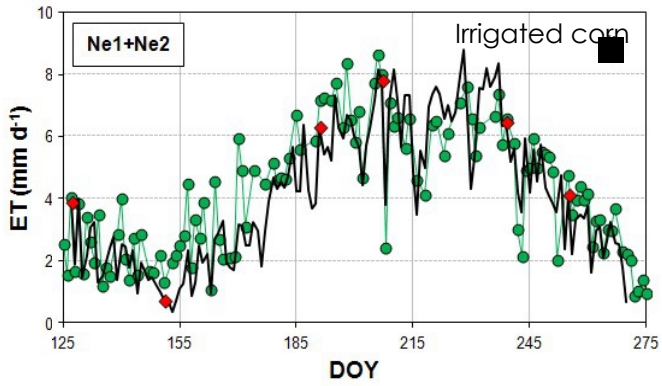


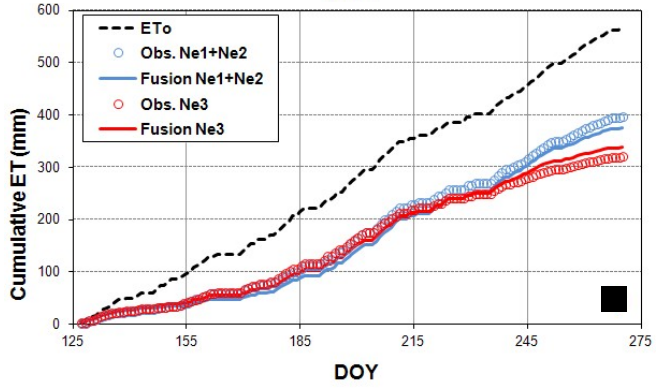




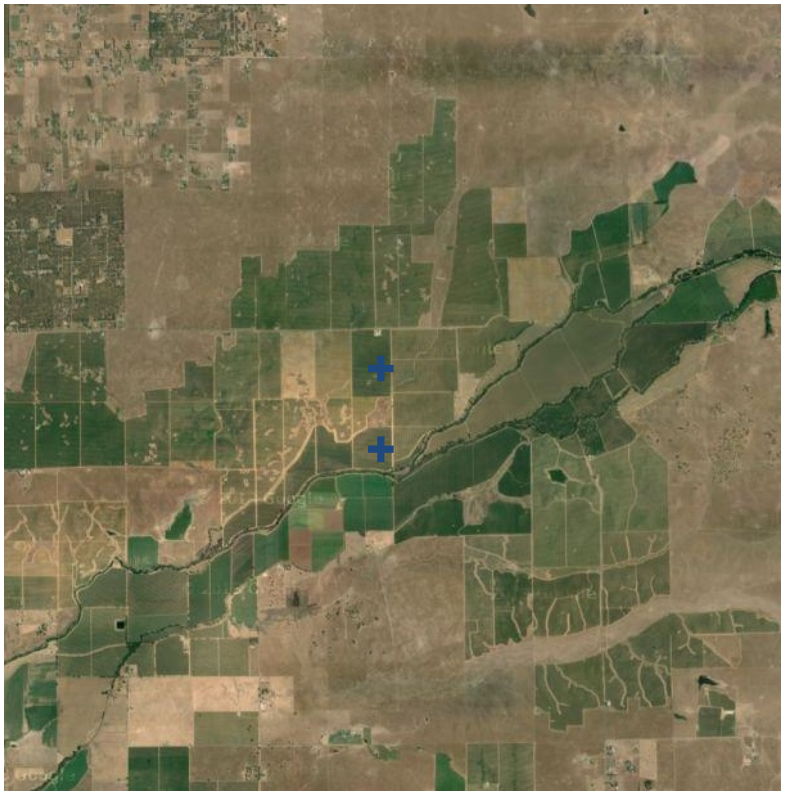
Mead, NE

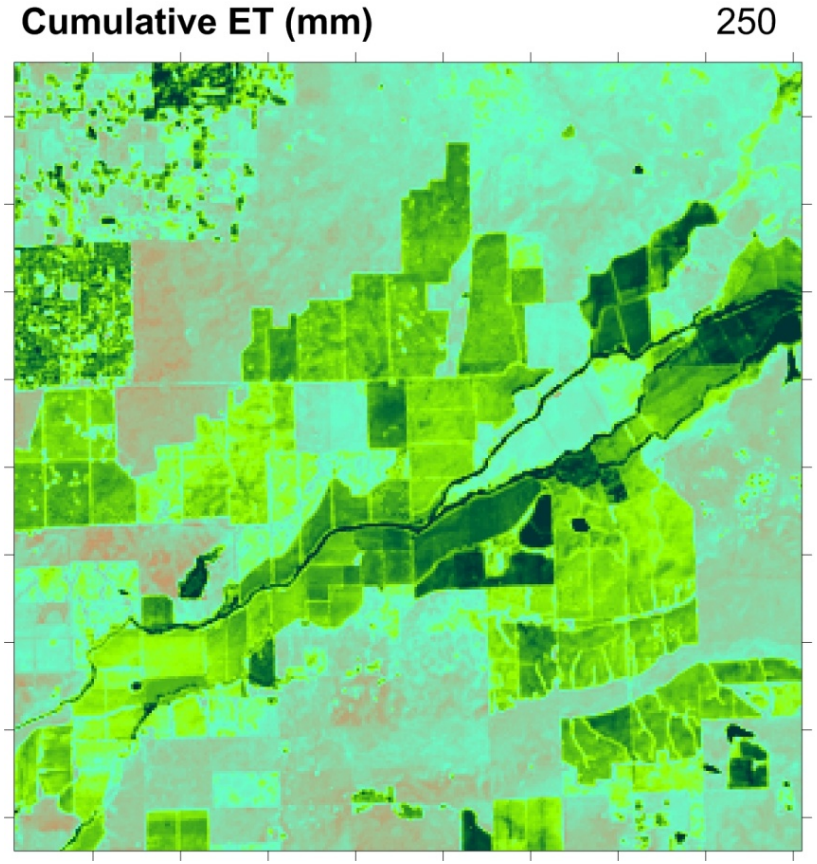




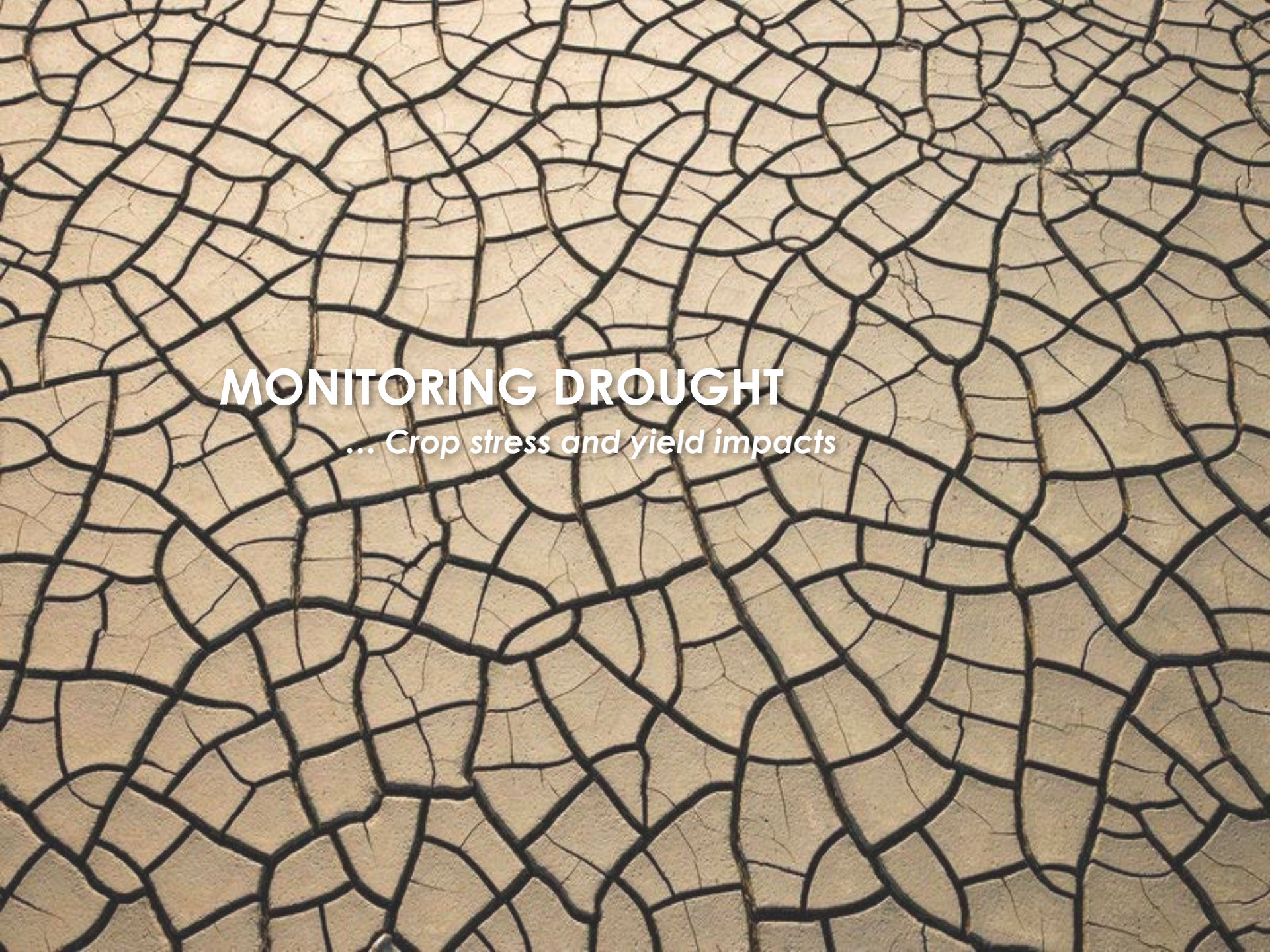


Gallo Vineyards, Lodi CA



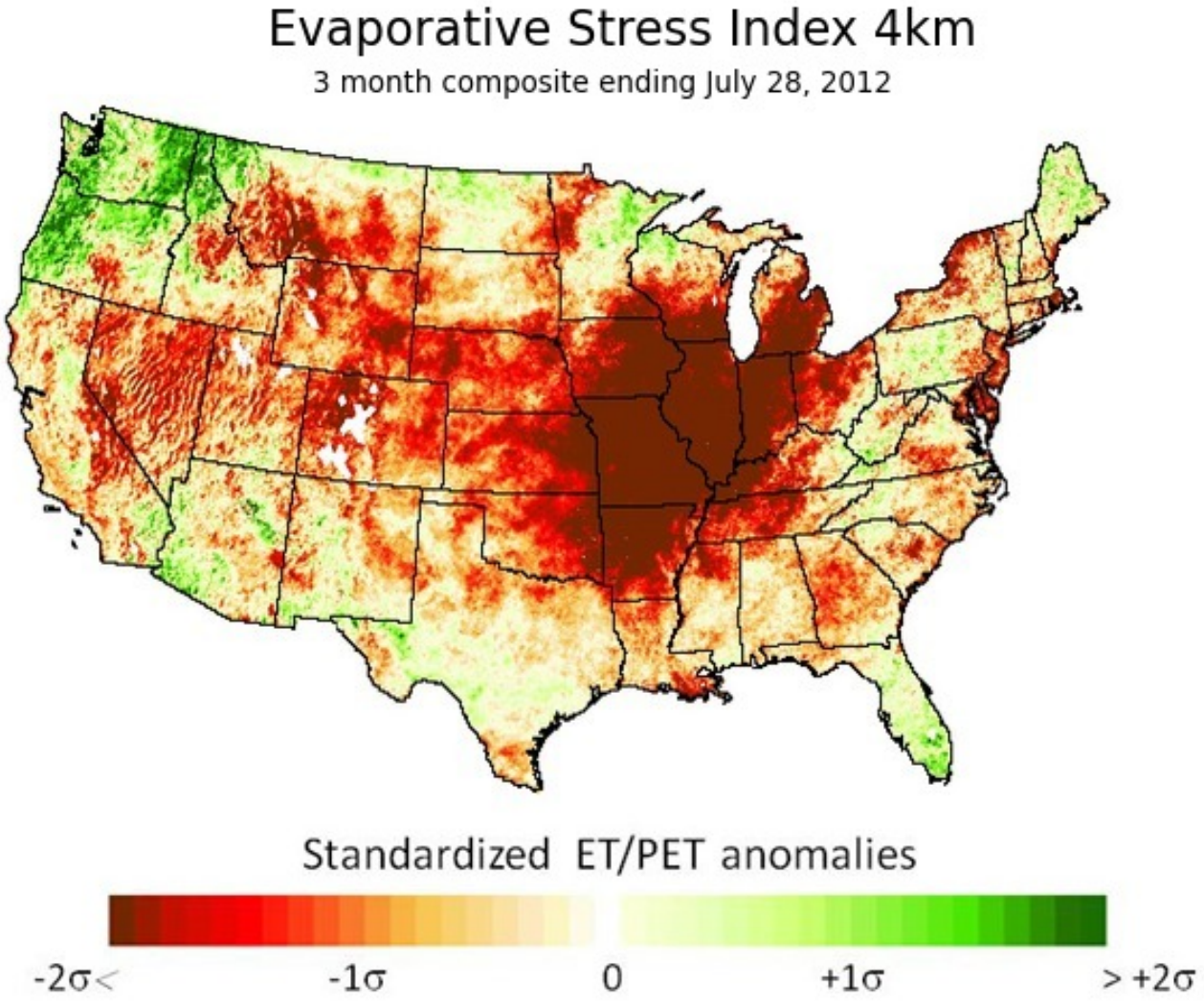


Landsat 8 - 2013



MONITORING DROUGHT

… Crop stress and yield impacts


Evaporative Stress Index 4km
3 month composite ending July 28, 2012
Standardized ET/PET anomalies
-2σ<
-1σ
0
+1σ
> +2σ

ESI Methodology

ALEXI ESI represents temporal anomalies in the ratio of actual ET to potential ET.

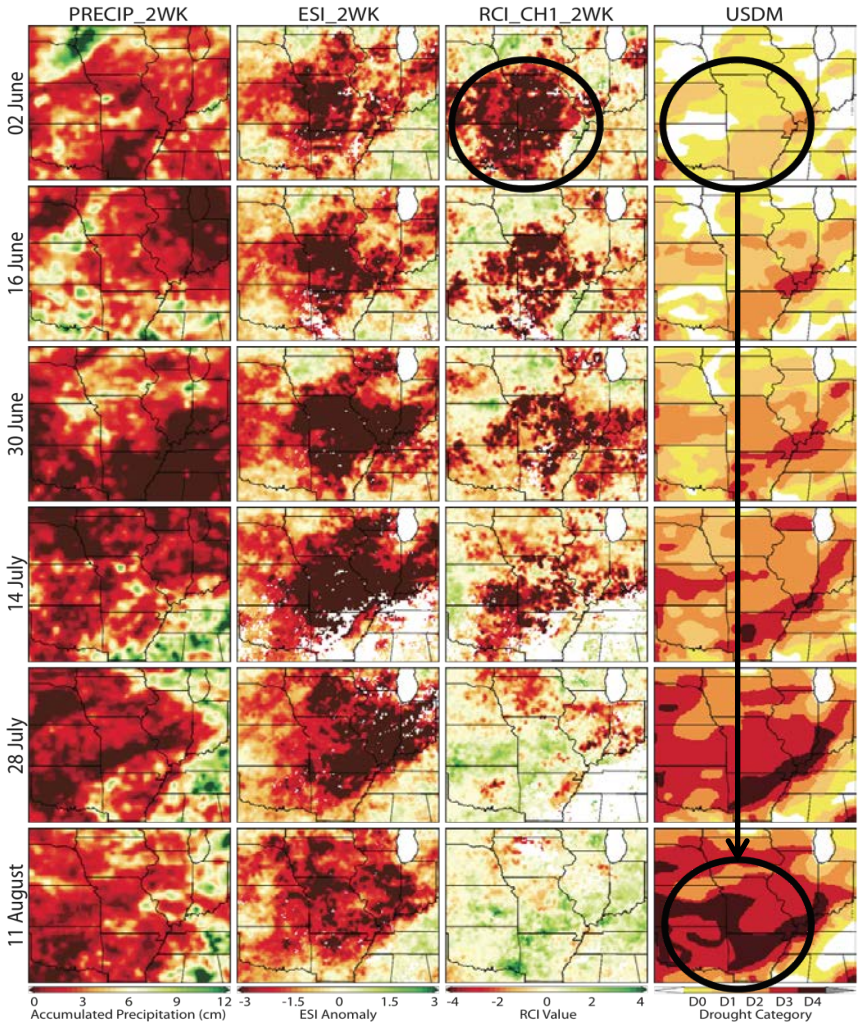
- ESI does not require precipitation data, ***the current surface moisture state is deduced directly from the remotely sensed LST*** , therefore it may be more robust in regions with minimal in-situ precipitation monitoring.

- Signatures of vegetation stress are manifested in the LST signal before any deterioration of vegetation cover occurs, for as example as indicated in NDVI, so TIR-based indices such as ESI can provide an effective early warning signal of impending agricultural drought.

- ALEXI ESI inherently includes non-precipitation related moisture signals (such as irrigation; vegetation rooted to groundwater; lateral flows) that need to be modeled a priori in prognostic LSM schemes.

Central US Flash Drought of 2012

Flash drought are rapid onset events typically driven by precipitation deficits, high temperature anomalies and often strong winds. ESI has the potential to provide an early warning component during such events as water stress is able to be detected in the LST signal before degradation in the vegetation health occurs.



- Large negative RCI values in the top row indicate that moisture stress was rapidly increasing at the beginning of summer
- Impressive scope of the unusually rapid decrease in the ESI anomalies is clearly depicted by the large area of negative RCI values
- Initial appearance of negative RCI values led the introduction of severe drought in the USDM by more than 4 weeks

Development of a Multi-Scale Remote-Sensing Based Framework for Mapping Drought over North America

C. Hain (UMD), M. Anderson (USDA), X. Zhan (NOAA), M. Svoboda (NDMC), B. Wardlow (NDMC), F. Gao (USDA)

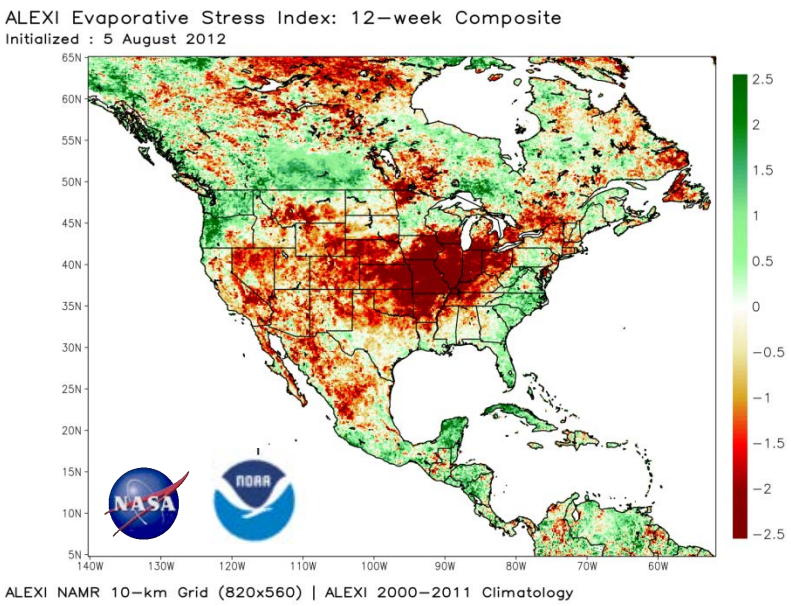
Highlights:

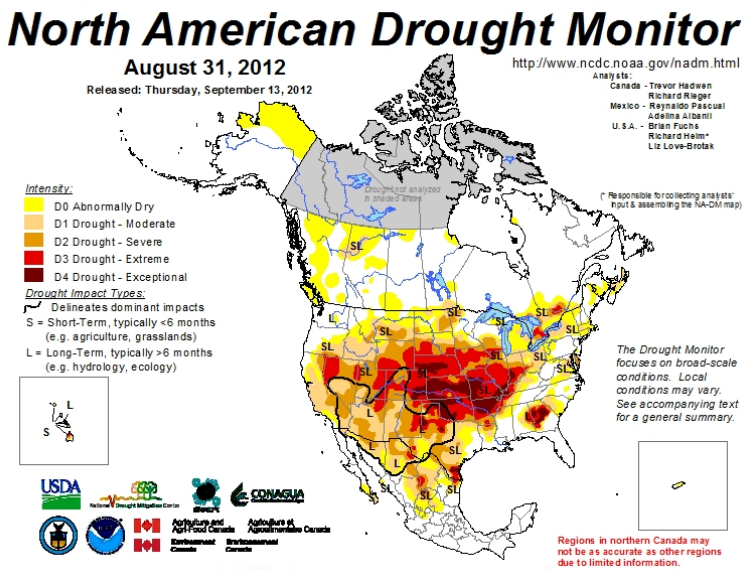
•To address the need for additional remote sensing-based drought monitoring tools covering North America, the current ESI domain has been expanded to include Canada, Mexico and Central America.

Relevance to ESD Applied Sciences:

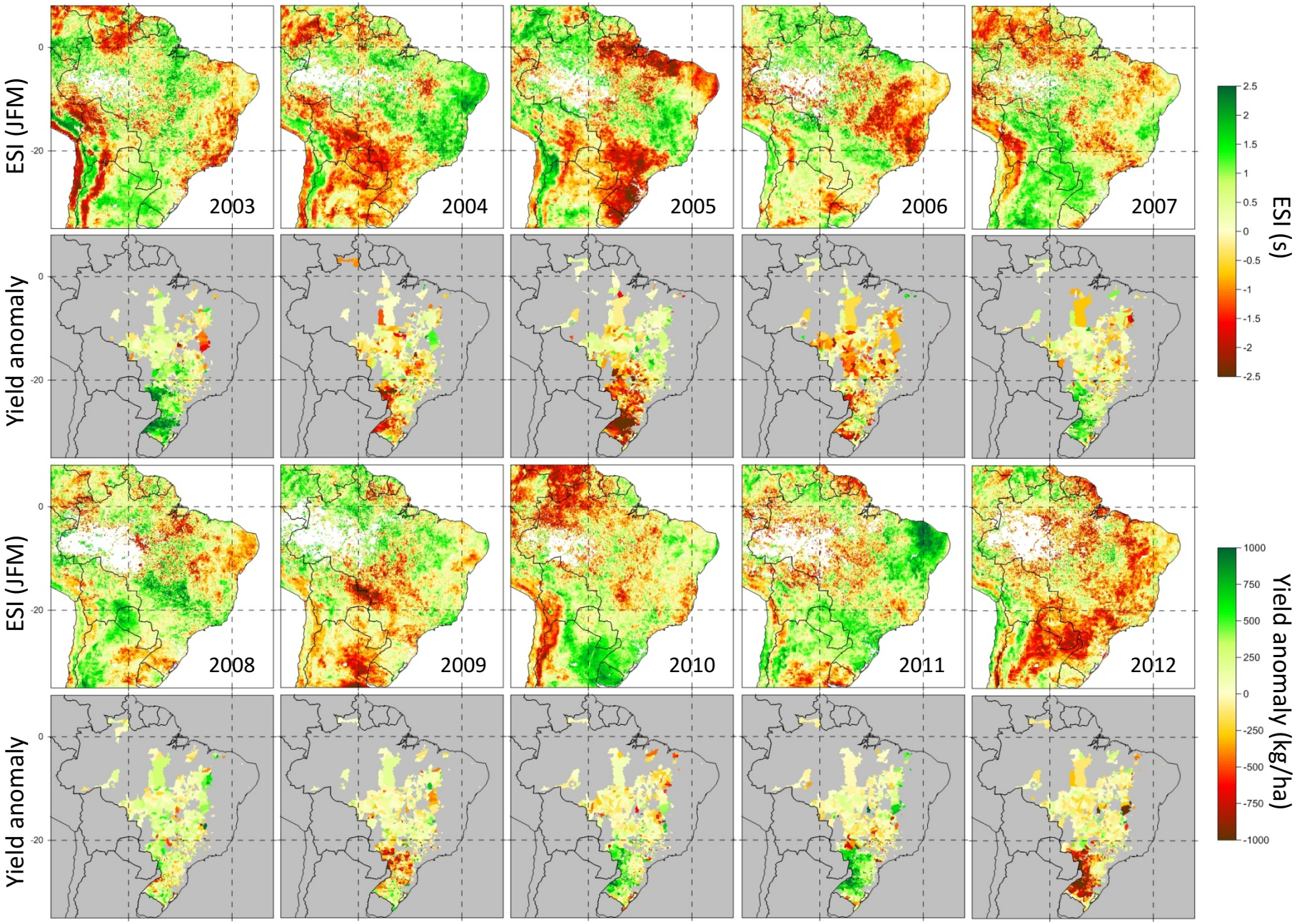
• *Access and availability of actionable drought information* -- ALEXI ESI provides high-resolution spatial information about drought that is independent of many of the most commonly used drought indicators which rely on accurate specification of precipitation as an inputs

• *Drought prediction, assessment, adaptation and mitigation in support of food security and natural resource conservation* -- ALEXI ESI can provide information to end-users with can aid in the decision making process of drought mitigation, yield estimation, plant health, and water use (especially in the agricultural sector).

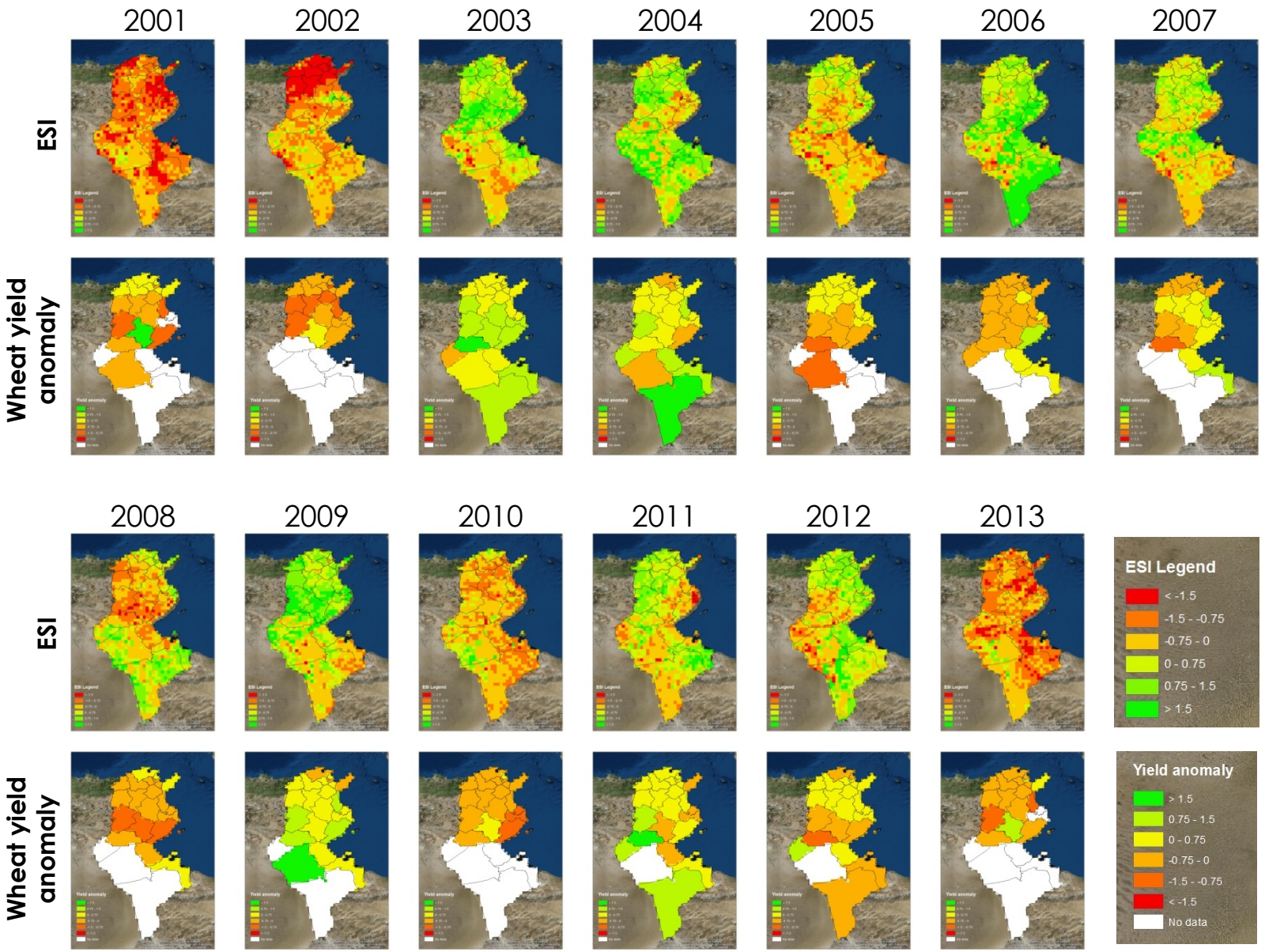




ANNUAL MUNICIPAL LEVEL SOYBEAN YIELD ANOMALIES

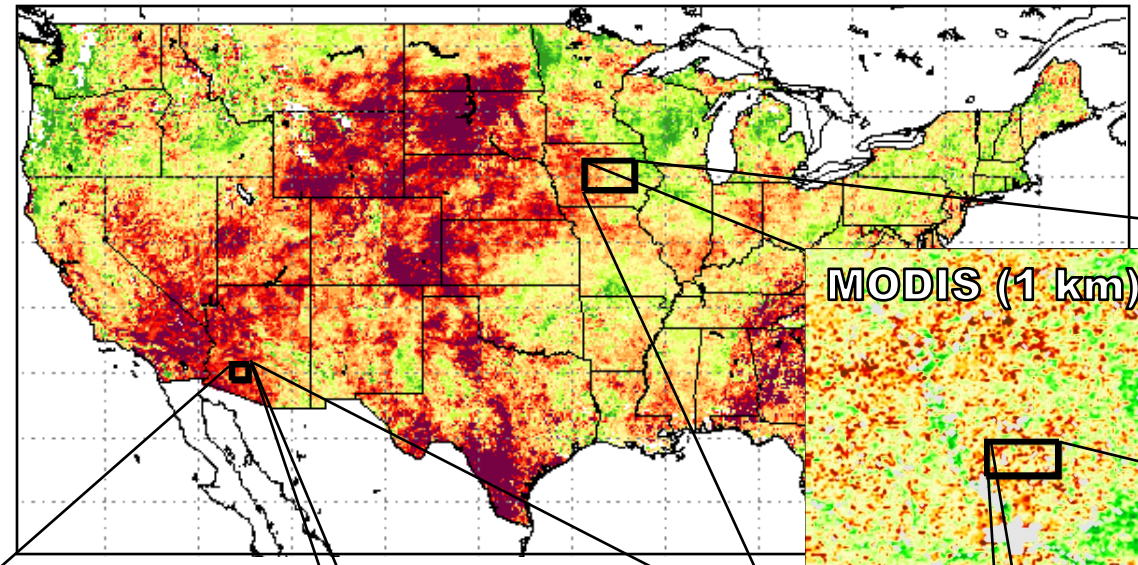


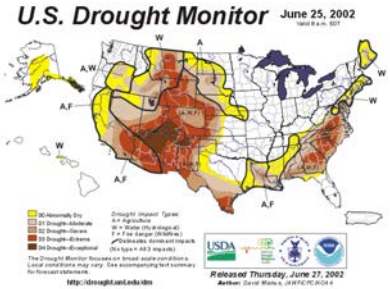
Yield estimation in Tunisia

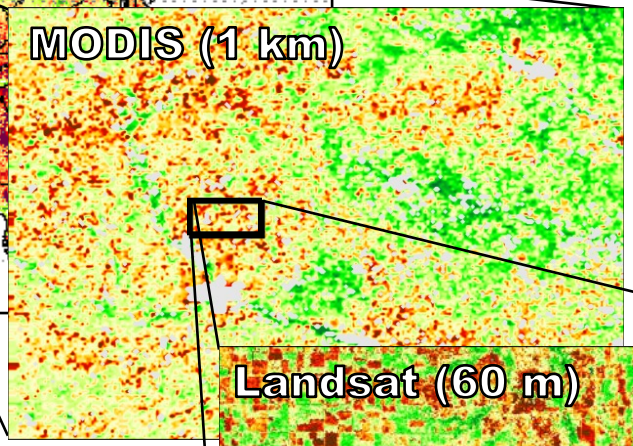


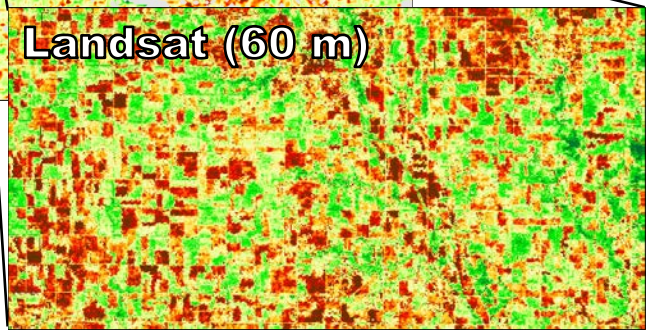
GOES Evaporative Stress Index

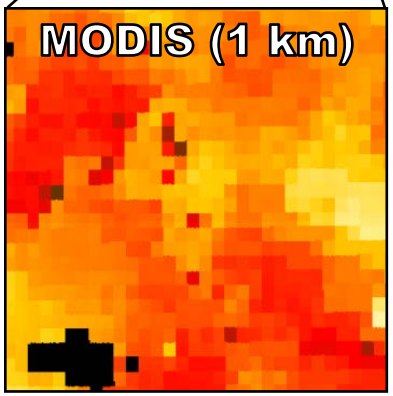
JUNE 2002

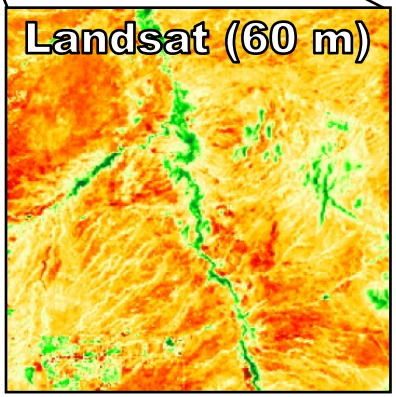








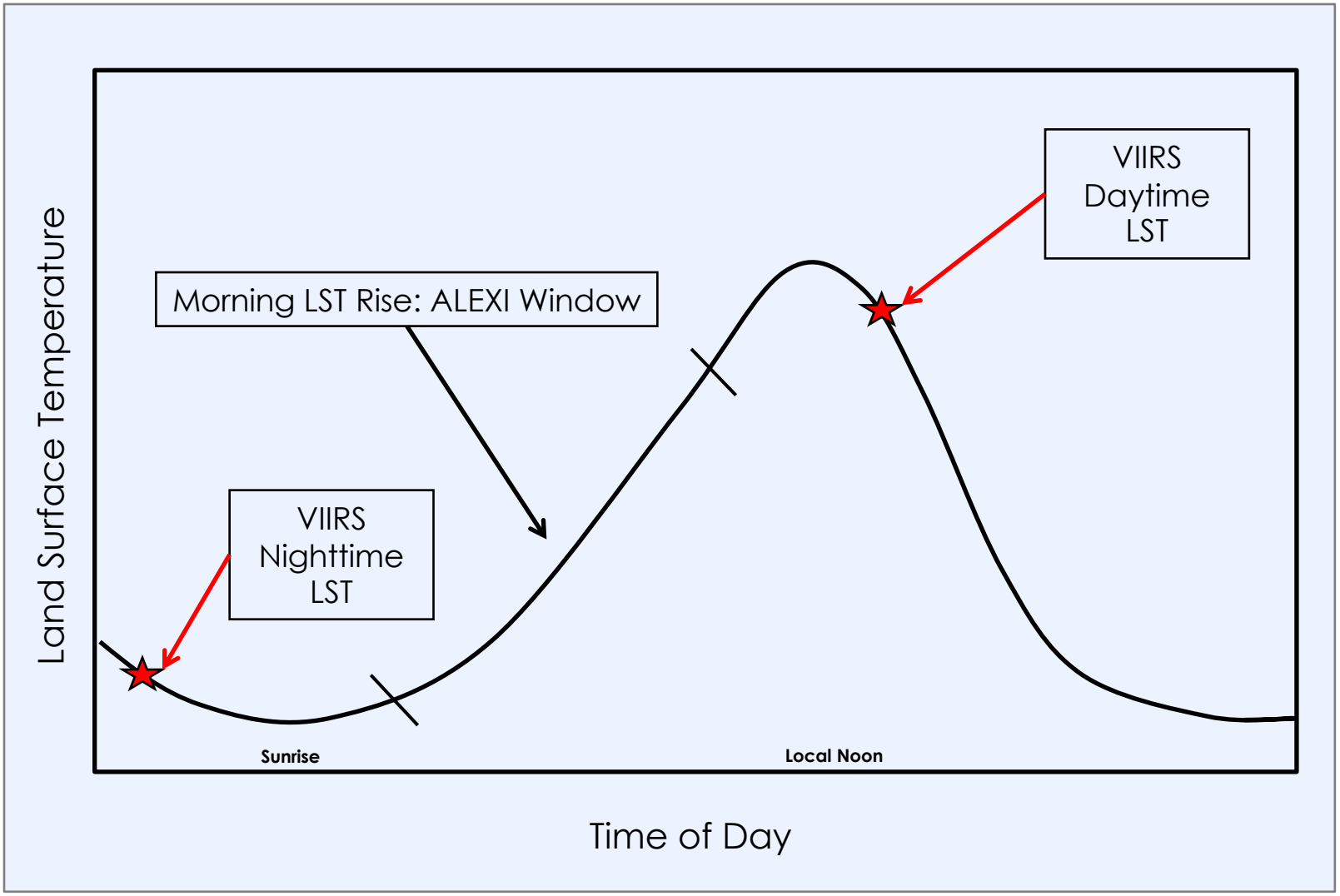




A Look to the Future…..

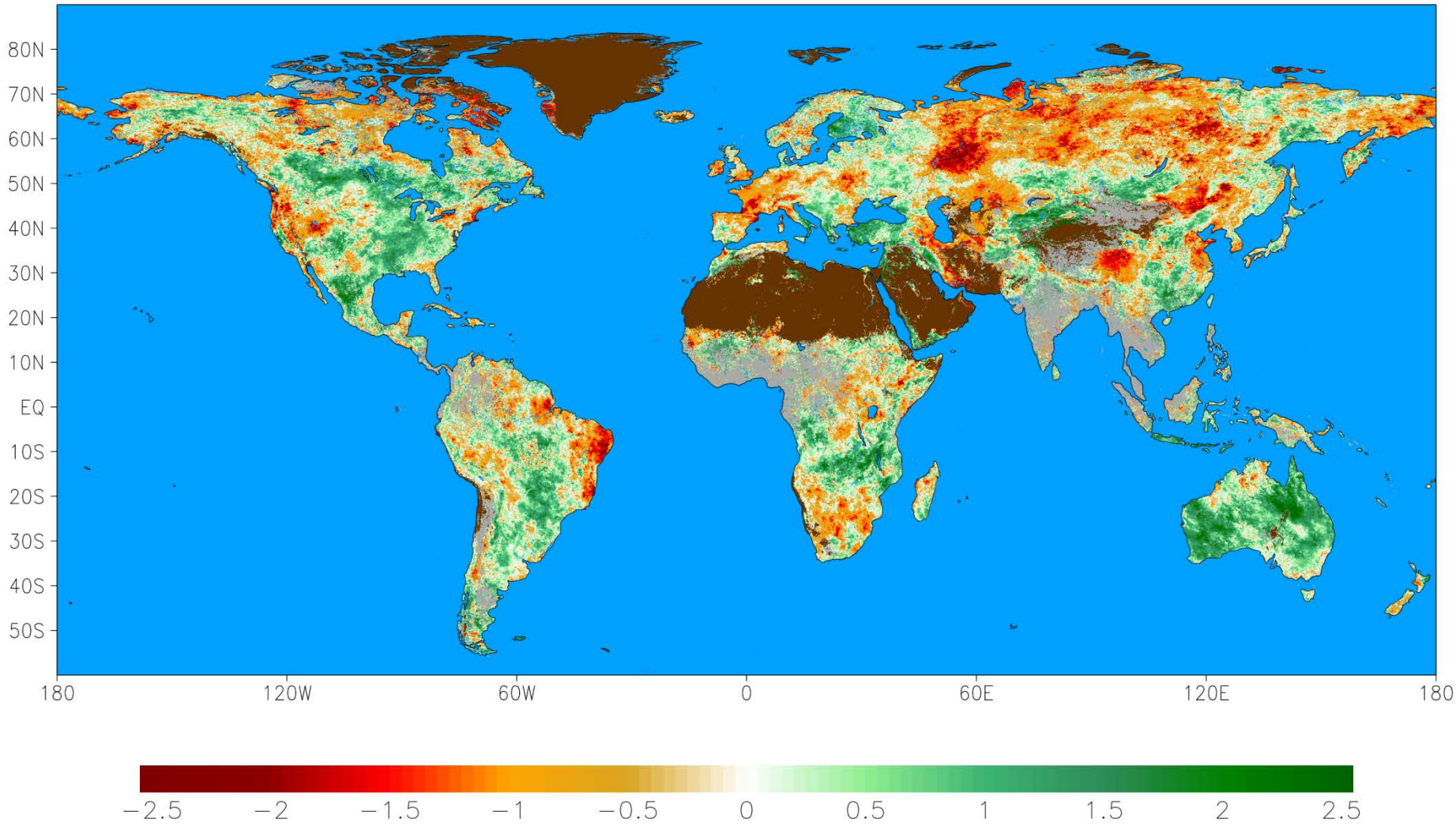
Supplementing ALEXI Capabilities with Polar Orbiting Sensors

A technique has been developed and evaluated using GOES data to train a regression model to use day-night LST differences from MODIS to predict the morning LST rise needed by ALEXI.



Supplementing ALEXI Capabilities with Polar Orbiting Sensors

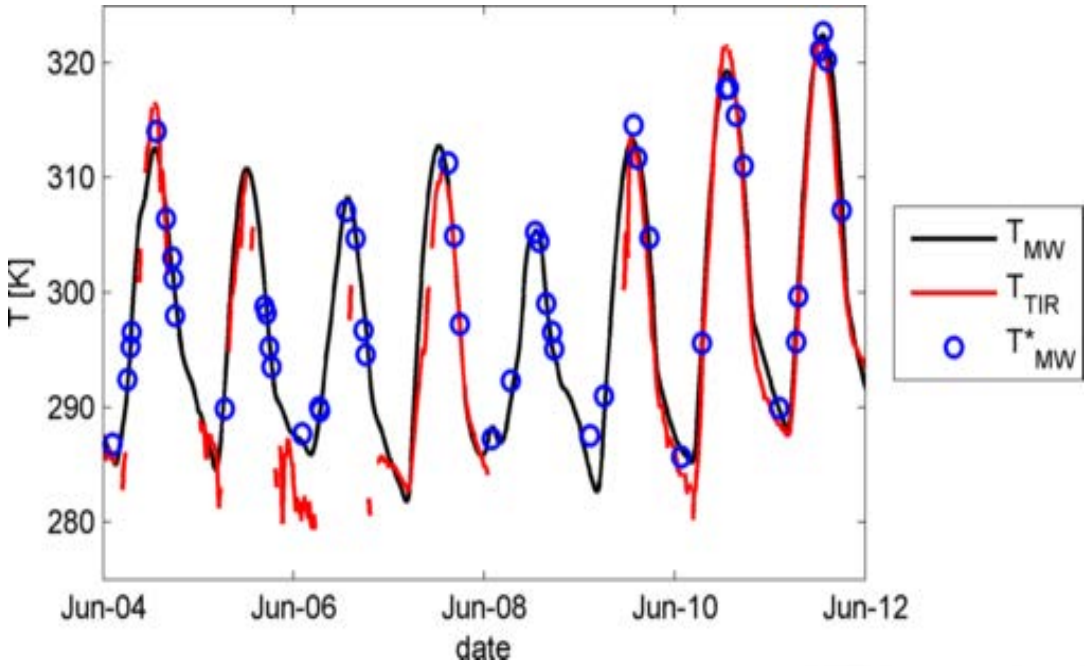
Current 5-km Global ESI – 1 September 2016



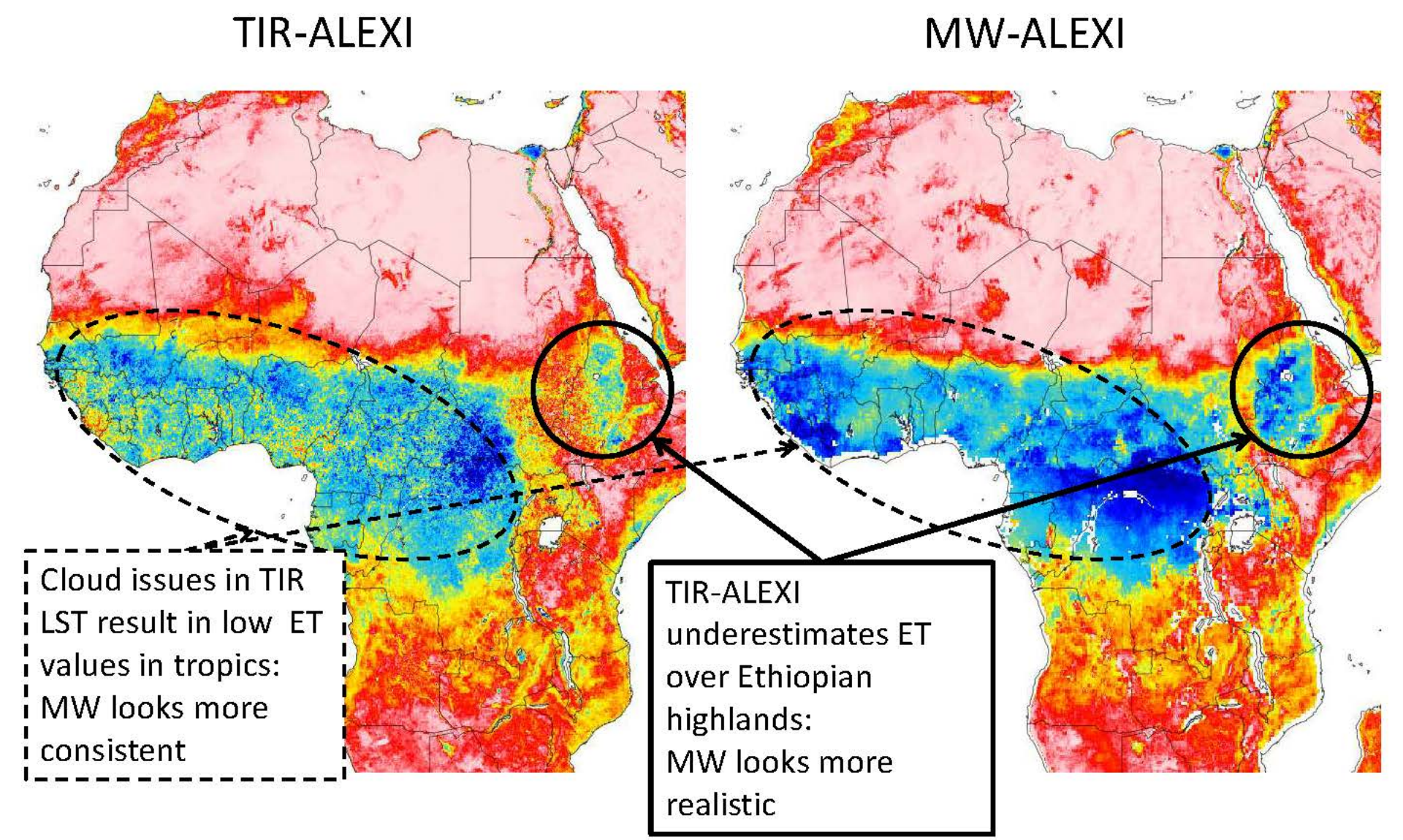
The synergy between TIR and MW observations is further being exploited by the development of LST observations from MW observations(Ka-band).

The integration of MW LST into a coupled TIR/MW ALEXI system will allow for retrieval of surface fluxes under cloud cover (where TIR-only retrievals are not possible).

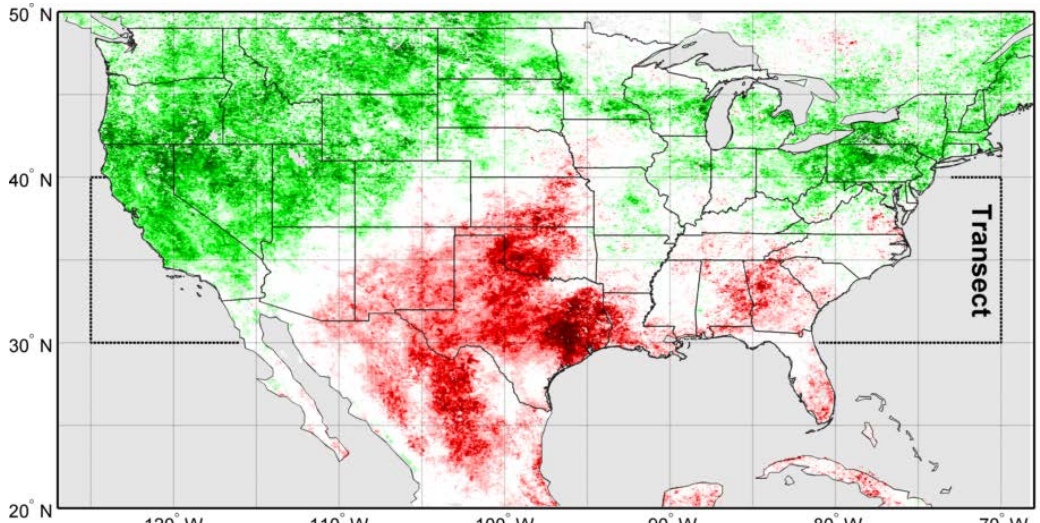
This capability fills in a significant gap in a TIR-only system over tropical equatorial regions where clear-sky retrievals may only be possible 1 to 3 times per month, particularly during the wet season .



Cumulative Evapotranspiration (mm) – JAS 2004



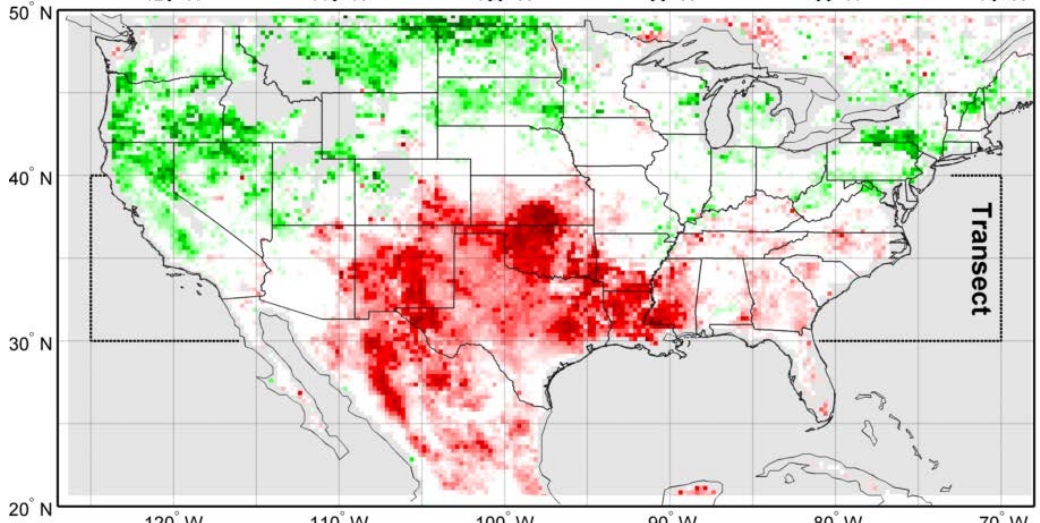
Anomaly analysis with MW-ALEXI
ESI 12week moving window



ALEXI 12WK ESI

3 2 1 0 -1 -2 -3

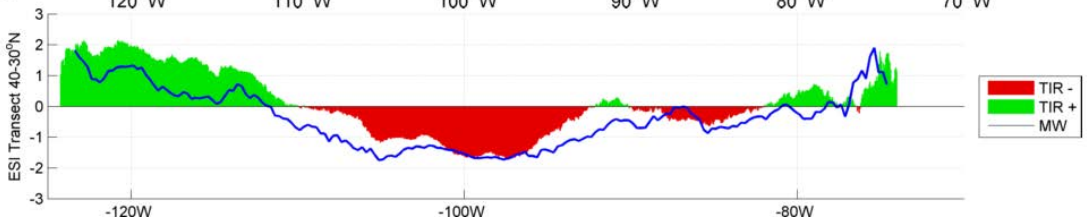
2011-155 LST: IR



ALEXI 12WK ESI

3 2 1 0 -1 -2 -3

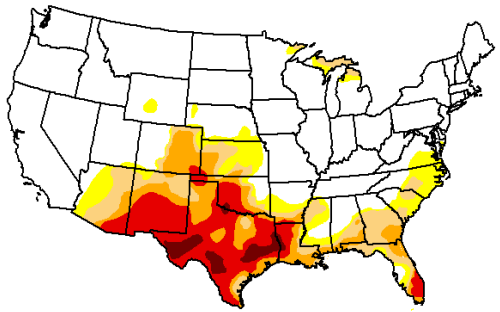
2011-155 LST: MW



U.S. Drought Monitor

CONUS

June 7th, 2011



LST-Based Evapotranspiration

- Diagnostically captures non-precipitation related moisture sources/sinks (irrigation, shallow groundwater, drainage)
- Capacity to map from global to sub-field scales using TIR-based data fusion
- Can be combined with remotely sensed soil moisture and precipitation data to interpret changes in other hydrologic variables

Conclusions

ALEXI: Christopher Hain (chris.hain@noaa.gov)
Martha Anderson (martha.anderson@ars.usda.gov)

Website: http://hrsl.ba.ars.usda.gov/drought/
http://www.ospo.noaa.gov/Products/land/getd/

LST-Based Evapotranspiration

- Diagnostically captures non-precipitation related moisture sources/sinks (irrigation, shallow groundwater, drainage)
- Capacity to map from global to sub-field scales using TIR-based data fusion
- Can be combined with remotely sensed soil moisture and precipitation data to interpret changes in other hydrologic variables