Monitoring Evapotranspiration and Drought using Thermal Remote Sensing

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Multi-scale monitoring toolkit

TOOLS

ALEXI	Multi-scale ET modeling
DMS	Thermal image sharpening
STARFM	Multi-sensor data fusion

ASSETS

		SW/TIR
GEO	Hourly	5km/5km
MODIS	Daily	250m/1km
Landsat	16 day	30m/100m
Lsat-like		~20-60m/ --

APPLICATIONS
(daily/30 m to 10 km)

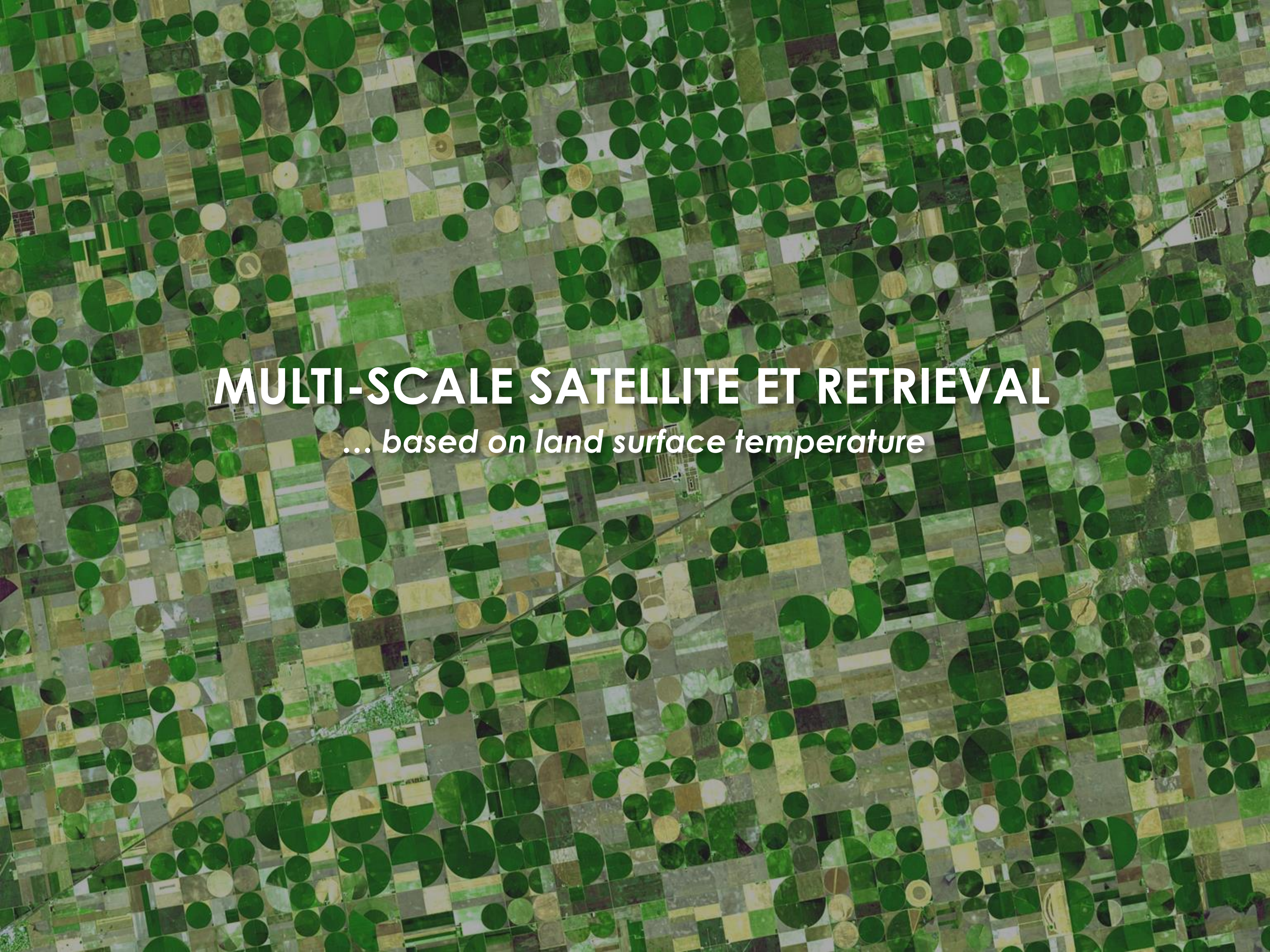
Crop water use
(Evapotranspiration)

Crop phenology
metrics

Crop stress
(drought early warning)

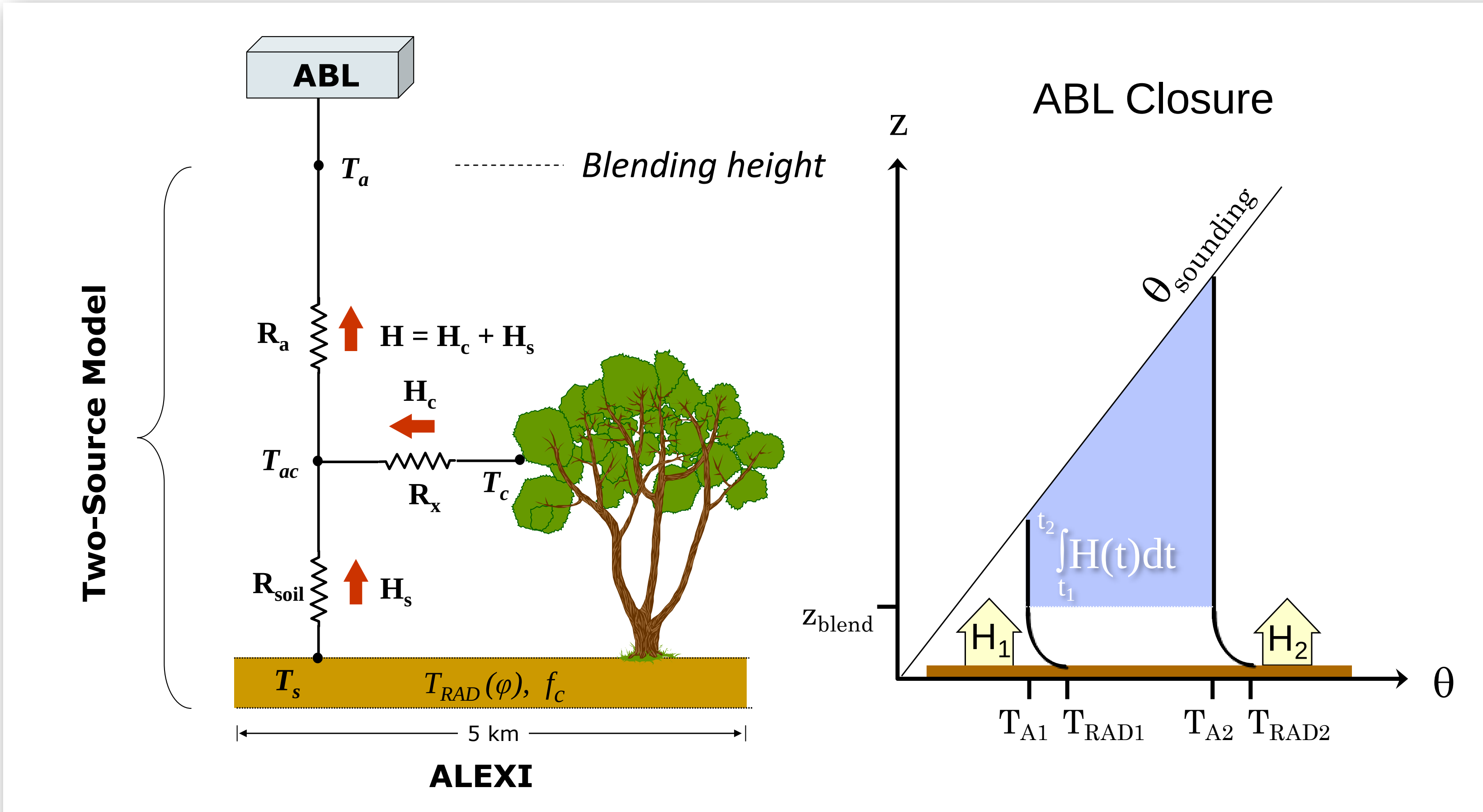
NEW ASSET

		MW
Ka LST	All-sky	> 5km



MULTI-SCALE SATELLITE ET RETRIEVAL

… based on land surface temperature



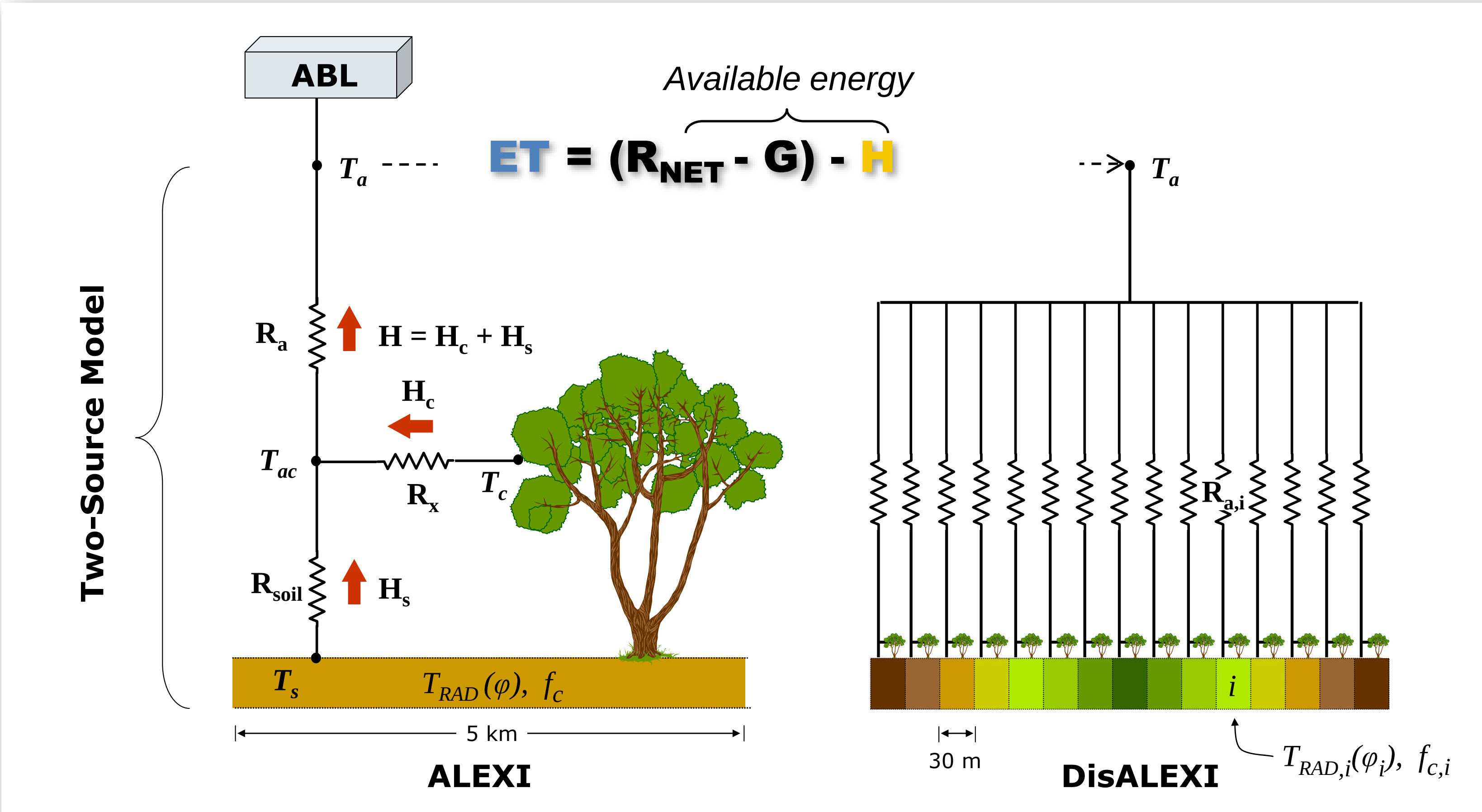
Regional scale

Surface temp: ΔT_{RAD} - Geostationary

Air temp: T_a - Diagnosed by ABL model

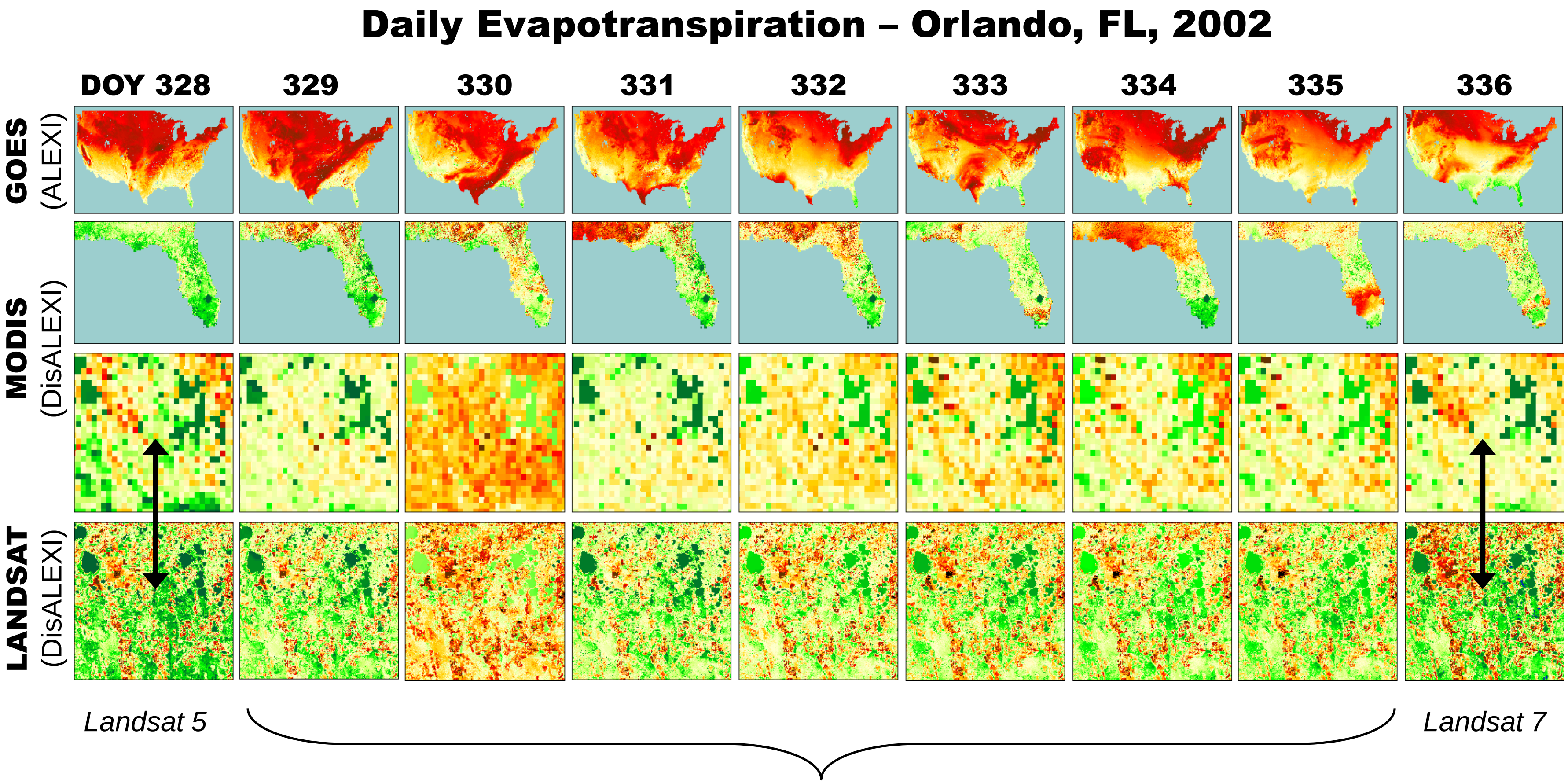
Given known radiative energy inputs, how much water loss is required to keep the soil and vegetation at the observed temperatures?

Atmosphere-Land Exchange Inverse



	Regional scale		Landscape scale	
Surface temp:	ΔT_{RAD}	- Geostationary	T_{RAD}	- Landsat, MODIS
Air temp:	T_a	- ABL model	T_a	- ALEXI

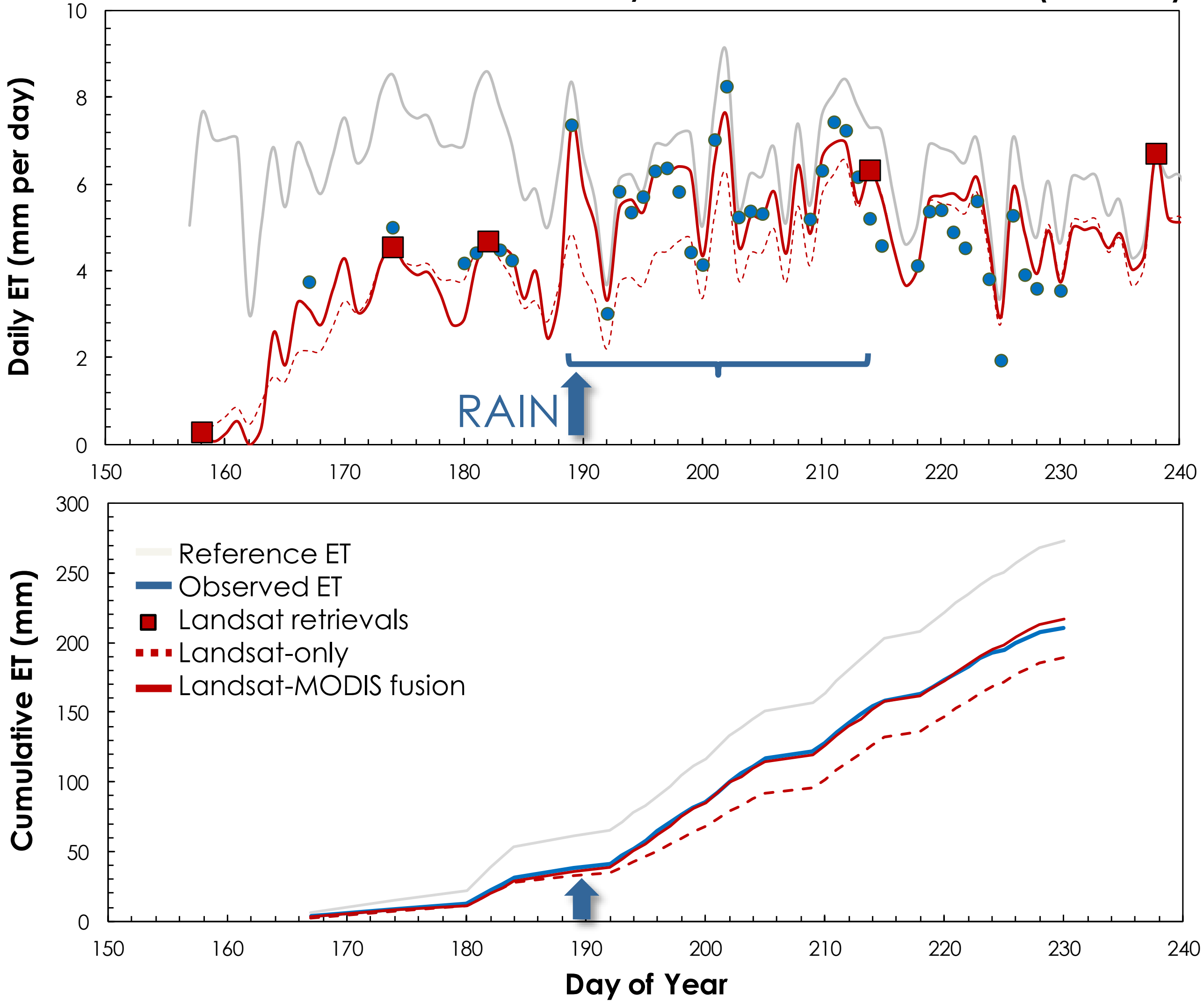
GOES/MODIS/Landsat FUSION



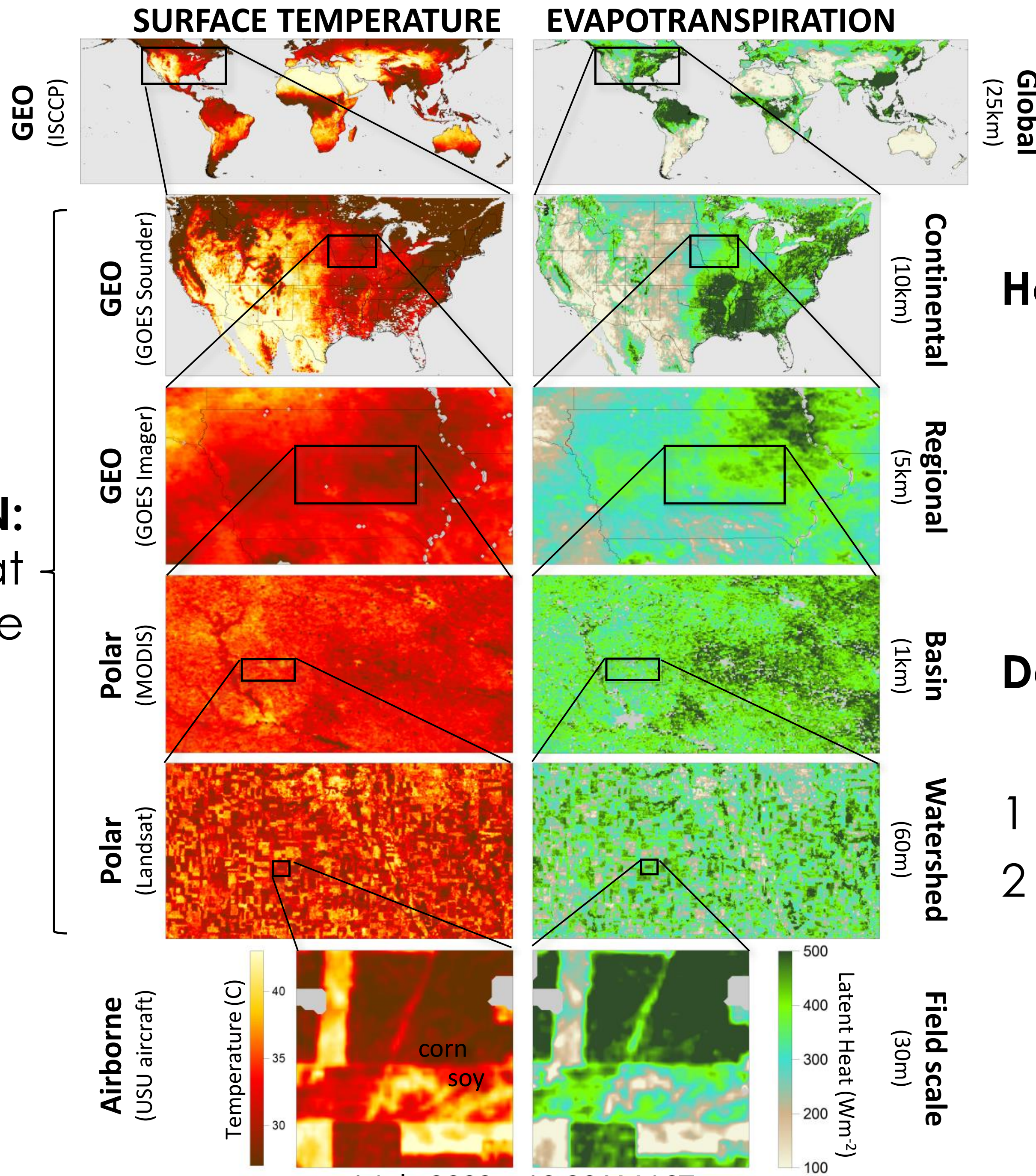
Spatial Temporal Adaptive Reflectance Fusion Model (STARFM) *(Gao et al, 2006)*

Validation using flux tower data

Rainfed soybean – SMEX02 (Iowa)



DATA FUSION:
daily ET at
field scale

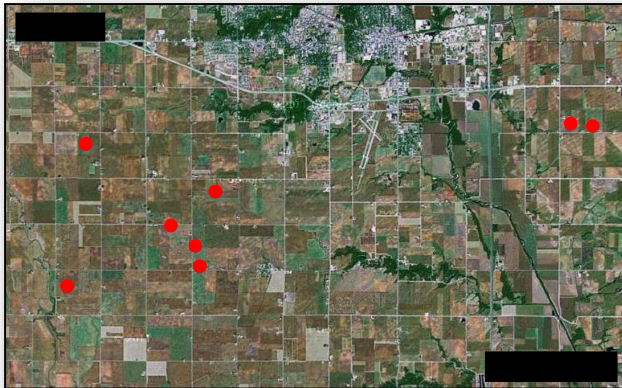


1 July 2002 – 10:30AM LST

Hourly

Daily

1 LS – 16 day
2 LS – 8 day

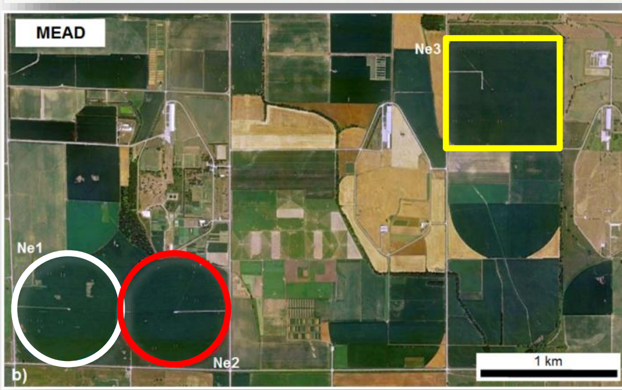


SMEX02

Soil Moisture Experiment 2002
Ames, Iowa
Rainfed corn and soybean

BEAREX08

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

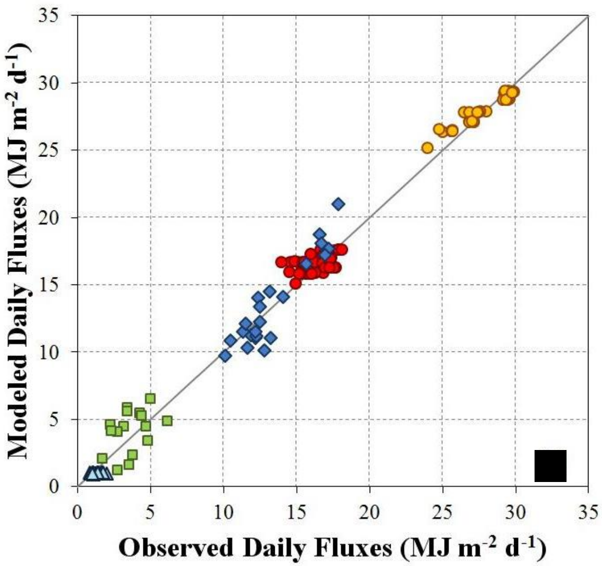


MEAD

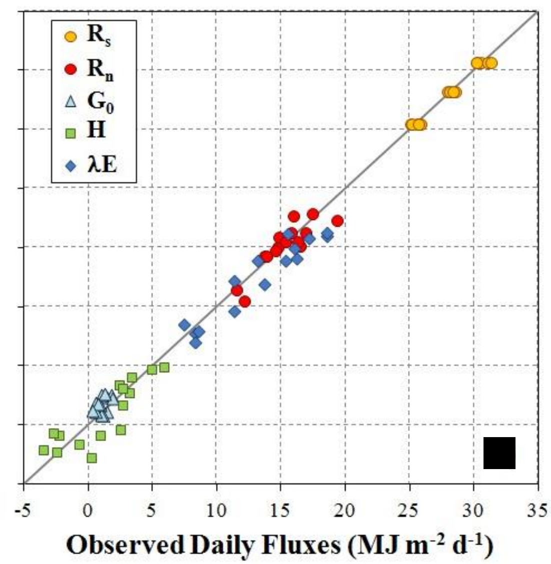
Ameriflux site (S. Verma)
Mead, NE
Rainfed and irrigated corn and soybean

Model performance on Landsat dates

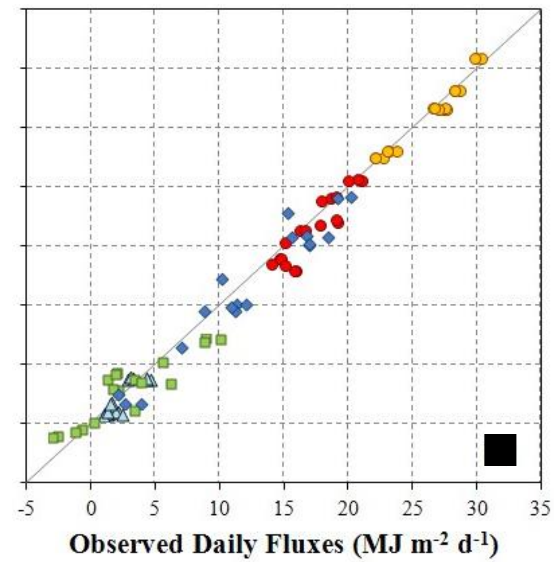
SMEX02



BEAREX08



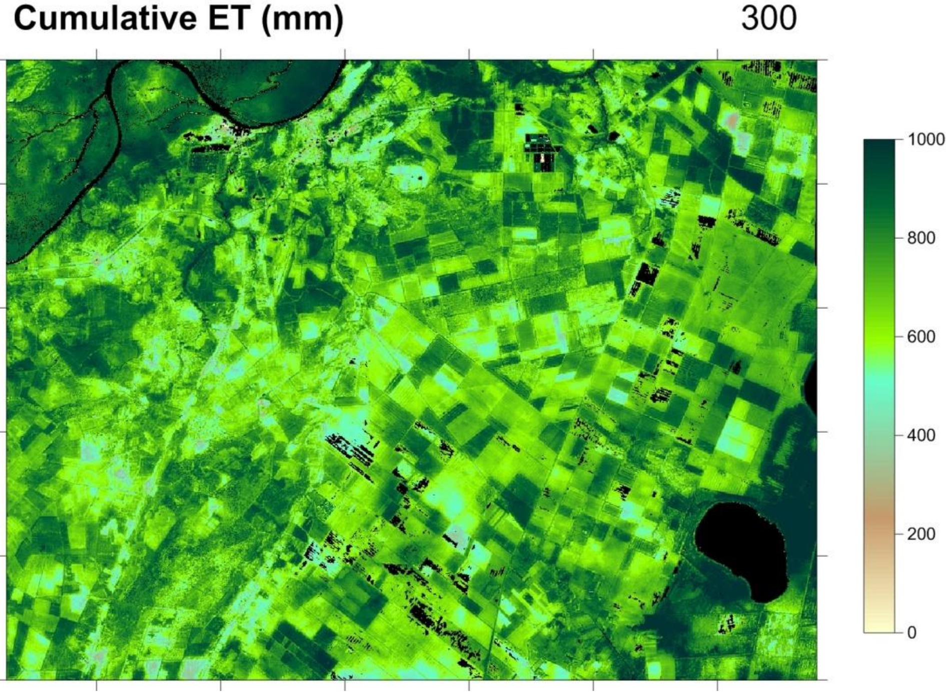
MEAD



	SMEX02	BEAREX08	MEAD
MAE:	1.08 MJ m^{-2} d^{-1}	1.3 MJ m^{-2} d^{-1}	1.3 MJ m^{-2} d^{-1}
RE:	8%	10%	11%

Effect of forest management

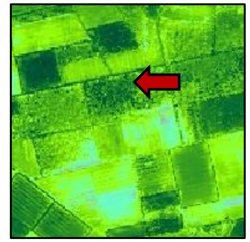
Loblolly Pine Plantation, NC



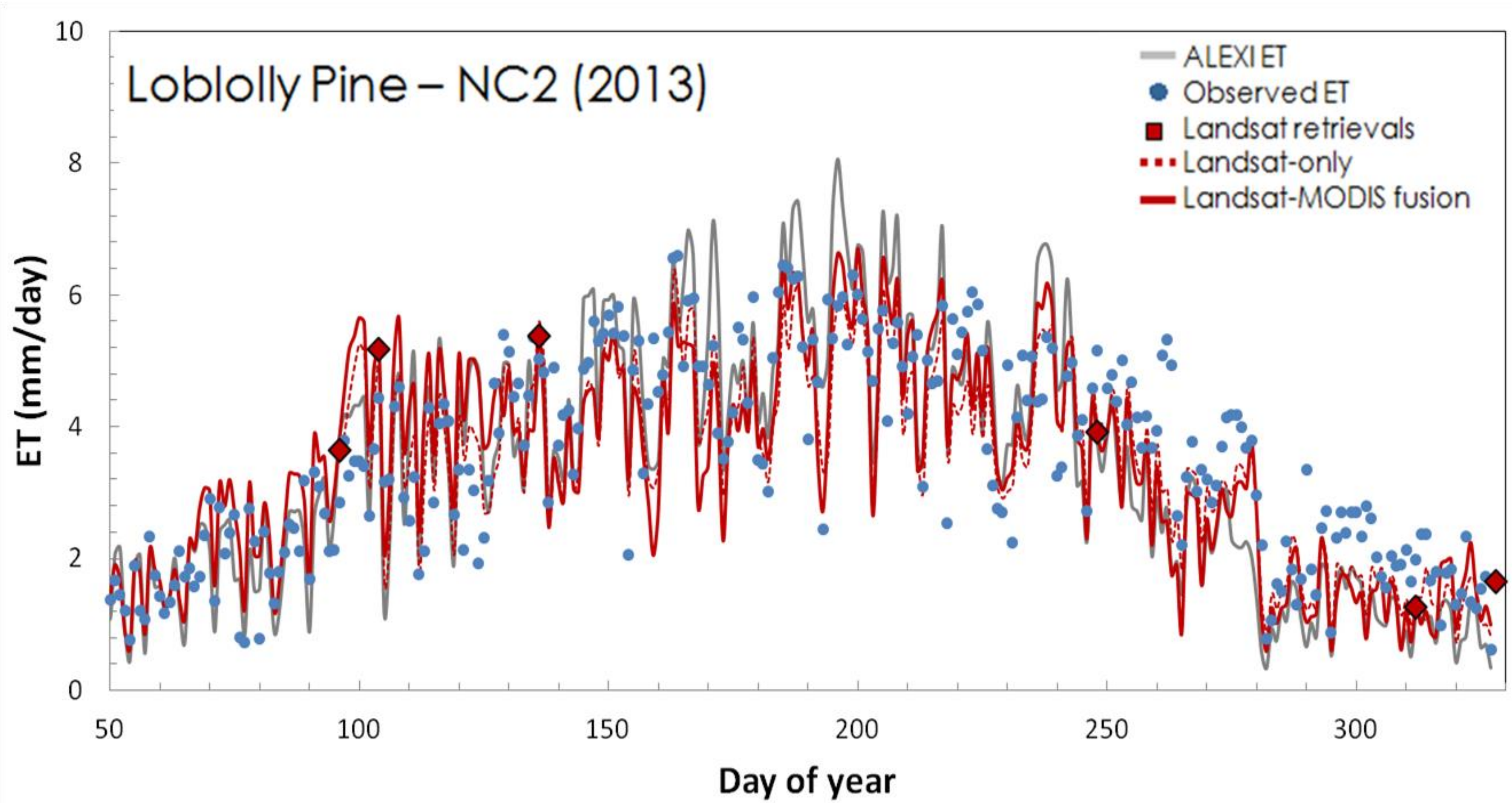
Landsat 8 - 2013

Effect of forest management

ALEXI ET
Observed ET
Landsat retrievals
Landsat-only
Landsat-MODIS fusion



NC2:
Loblolly Pine (2013)

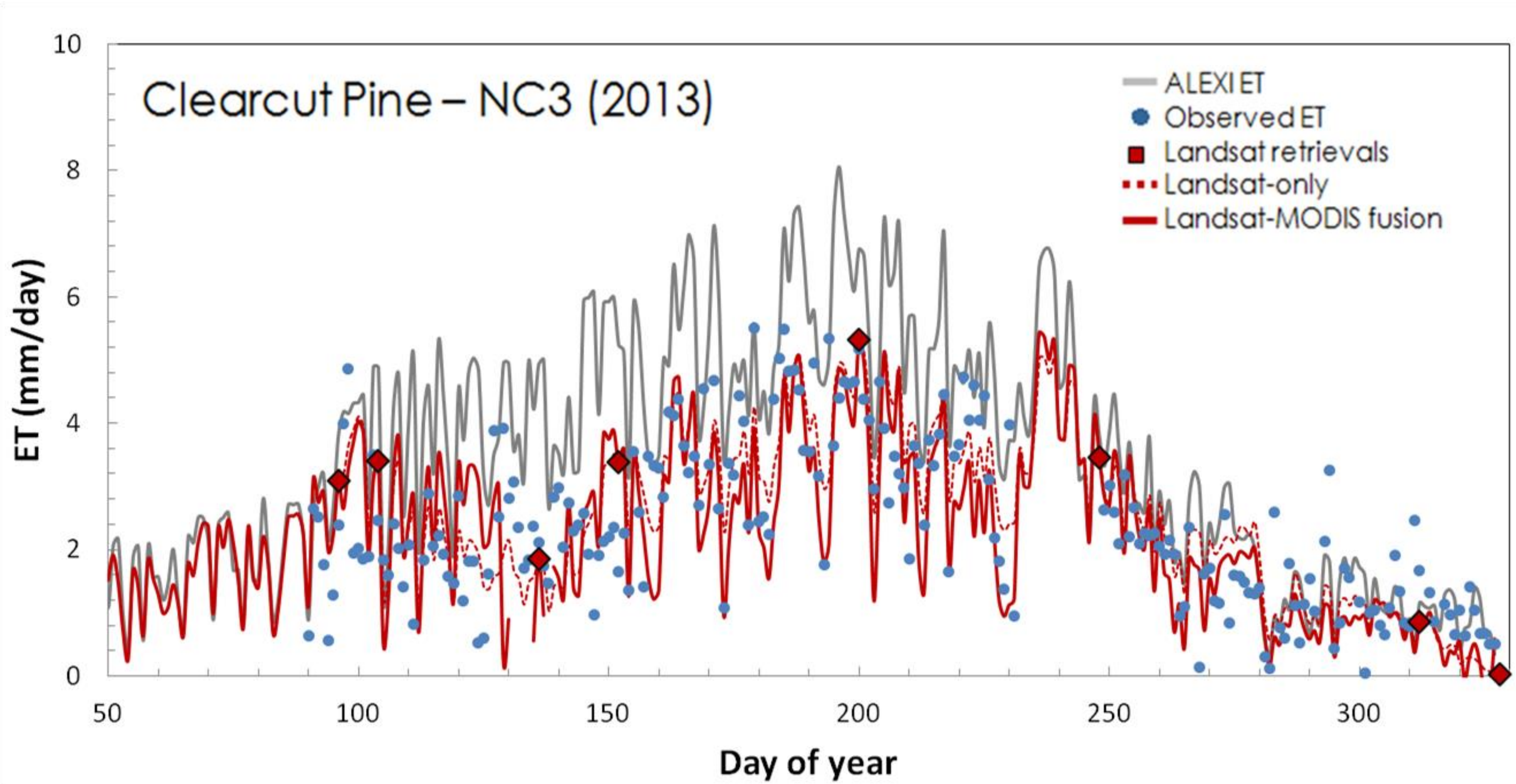


(Yang et al., 2015)

Effect of forest management

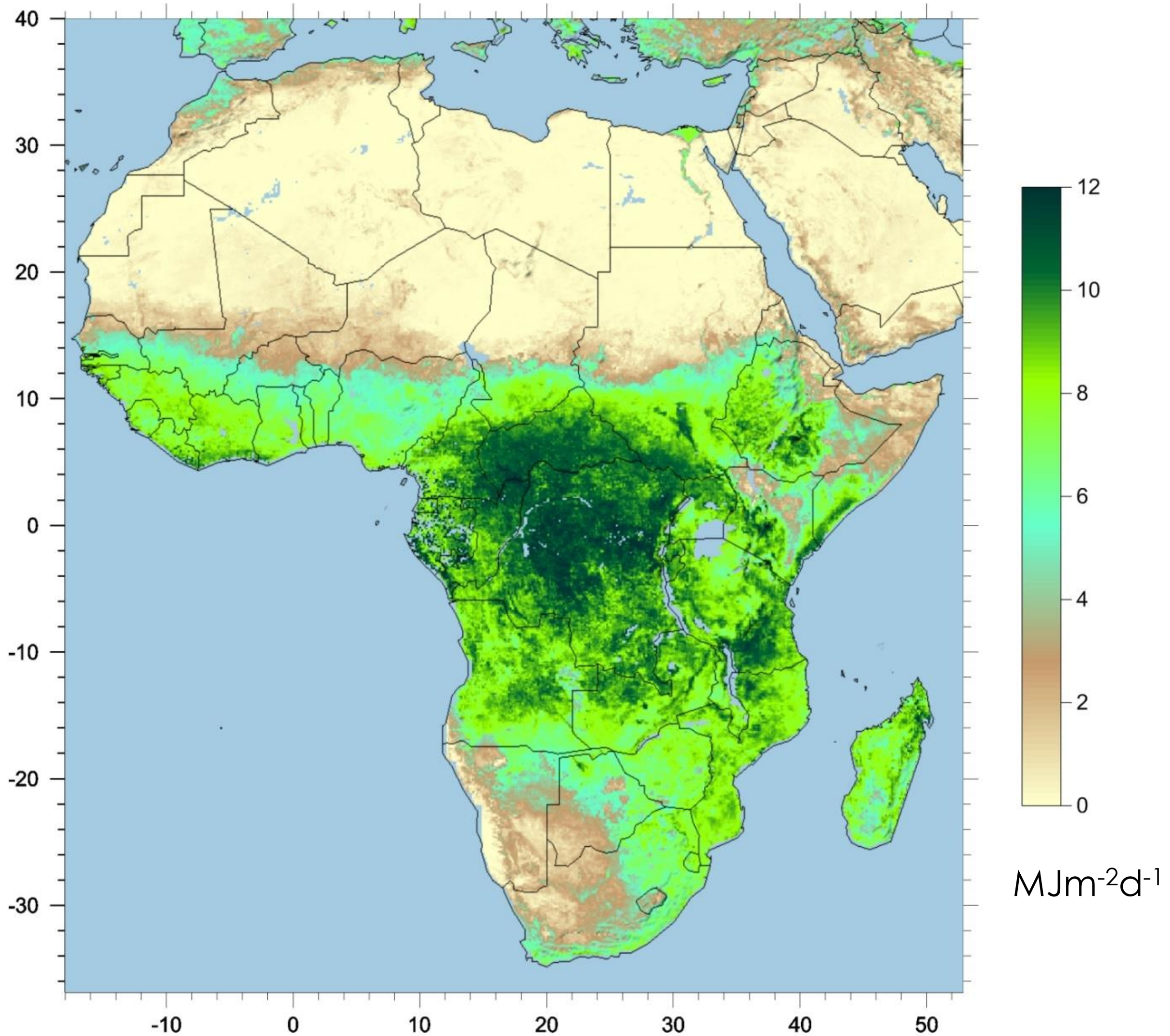
ALEXI ET
Observed ET
Landsat retrievals
Landsat-only
Landsat-MODIS fusion

NC3:
Clearcut Pine (2013)



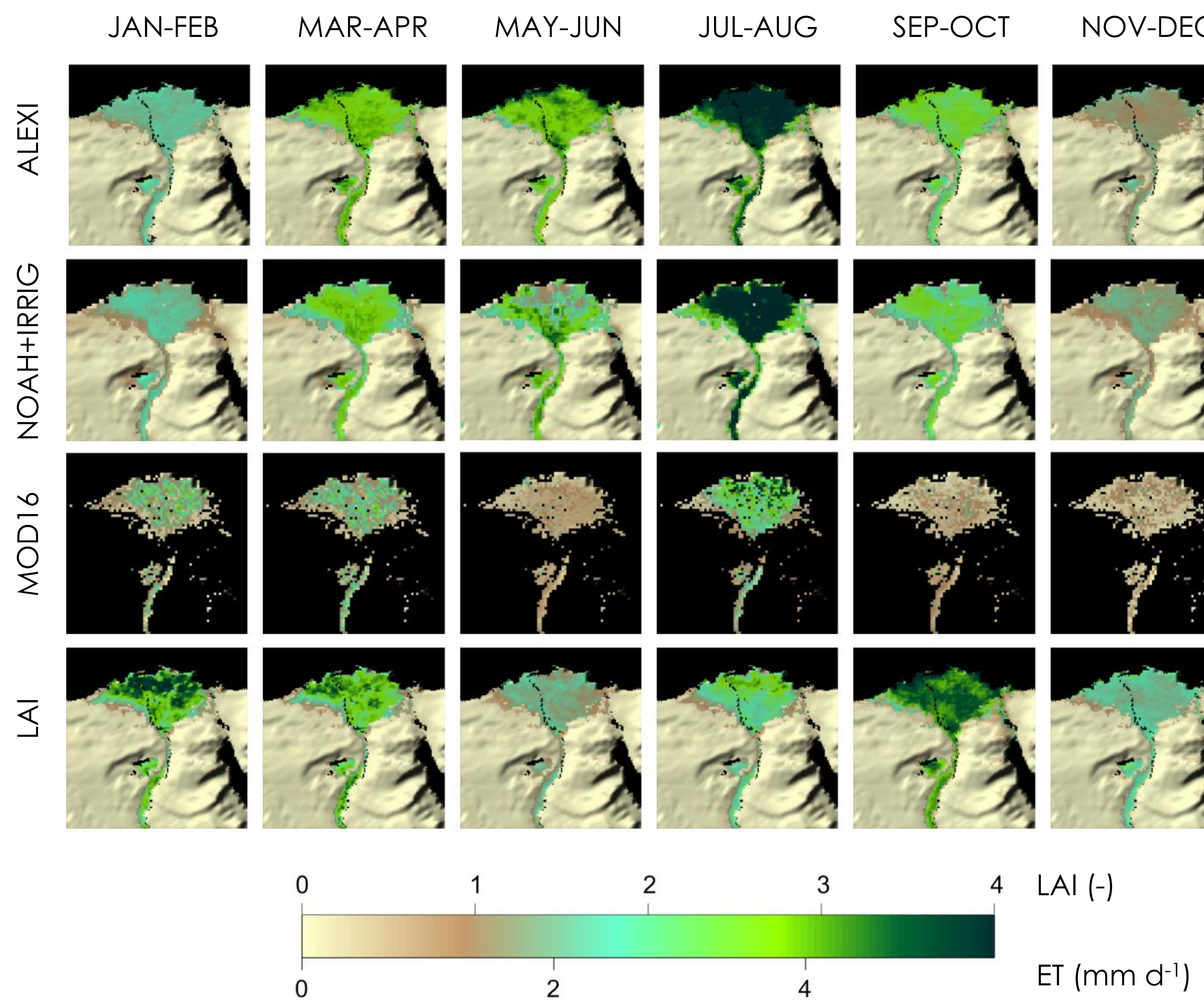
(Yang et al., 2015)

Annual composite of daily latent heat flux for 2013

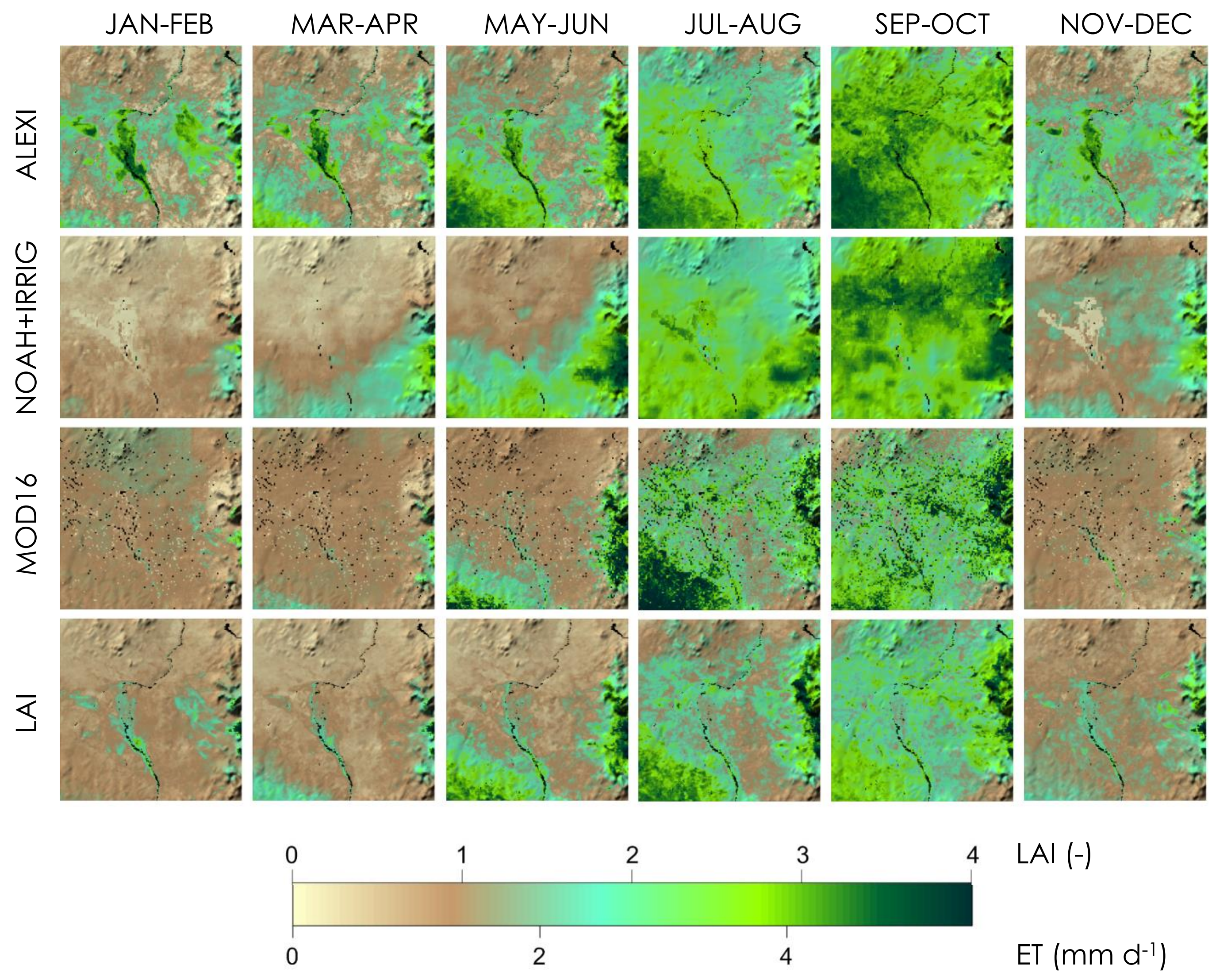


Africa

NILE DELTA

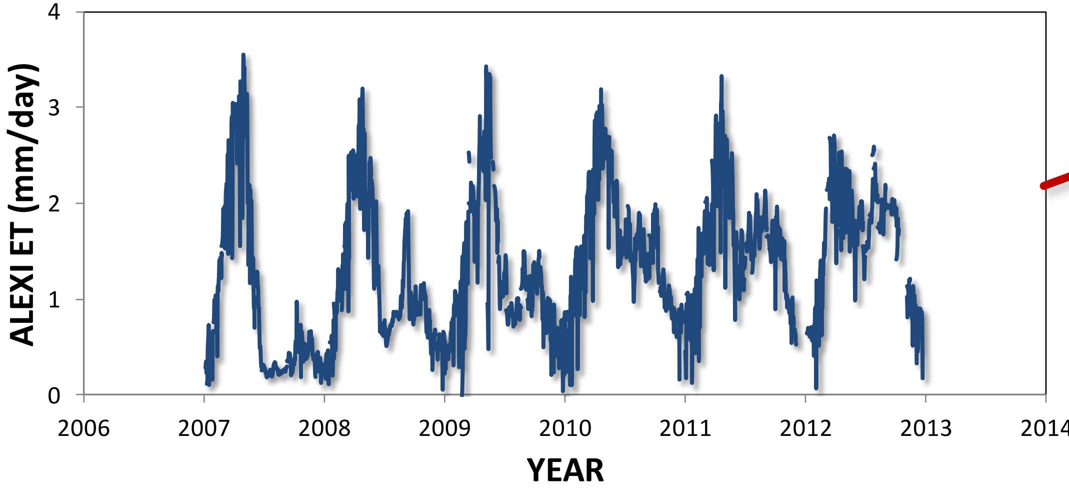

JAN-FEB
MAR-APR
MAY-JUN
JUL-AUG
SEP-OCT
NOV-DEC
ALEXI
NOAH+IRRIG
MOD16
LAI
0
1
2
3
4
LAI (-)
0
2
4
ET (mm d-1)

SUDD WETLAND

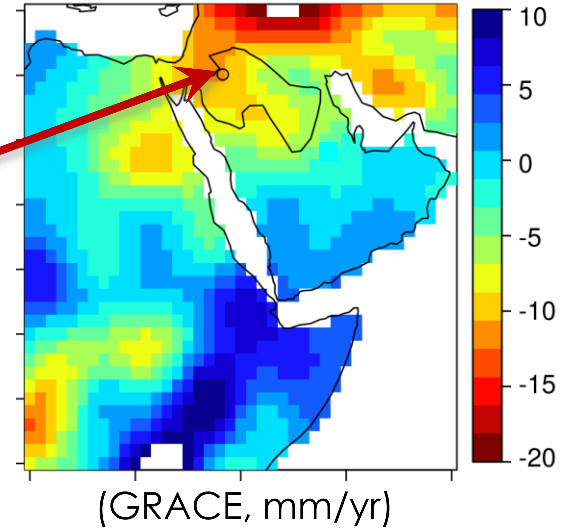


Water use by irrigation

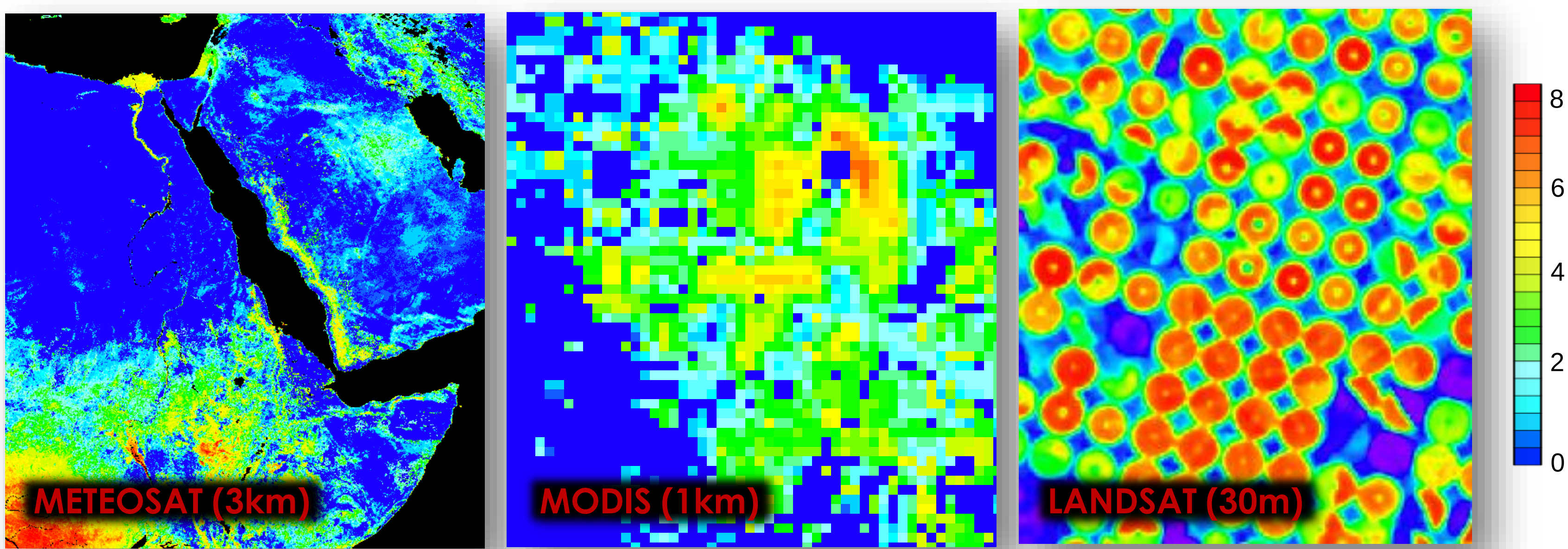
ALEXI ET – AL JOWF IRRIGATION SITE



GROUNDWATER DEPLETION TRENDS



MULTI-SCALE ET MAPPING (mm/day)



Houborg et al., 4th International Symposium of RAQRS, Valencia, Spain, Sept. 2014

MONITORING DROUGHT

… Crop stress and yield impacts

ESI Methodology

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

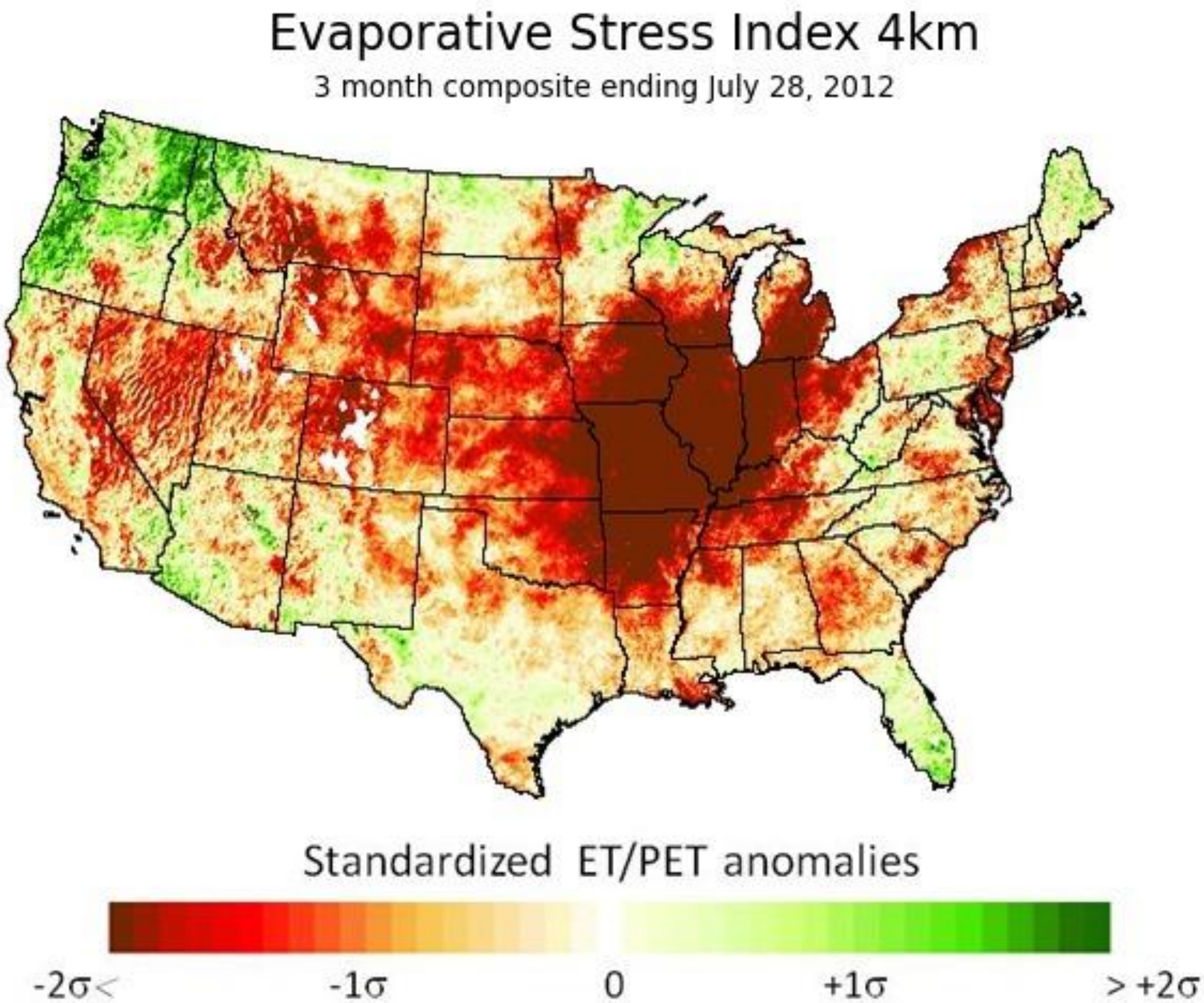
- ESI does not require precipitation data, ***the current surface moisture state is deduced directly from the remotely sensed LST*** , therefore it may be more robust in regions with minimal in-situ precipitation monitoring.

- 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.

- ALEXI ESI provides an independent assessment of current drought conditions, supplementing precipitation and modeling-based indices – an invaluable resource to decision-makers who usually depend on a convergence of information in the decision making process.

Satellite ET Drought Indicator



Atmosphere-Land Exchange Inverse Model (ALEXI)

(Anderson et al., 1997, 2007)

2012 FLASH DROUGHT

Monthly changes

	USDM	ESI	NASS SM_{top}	VegDRI	USDM	ESI

APR

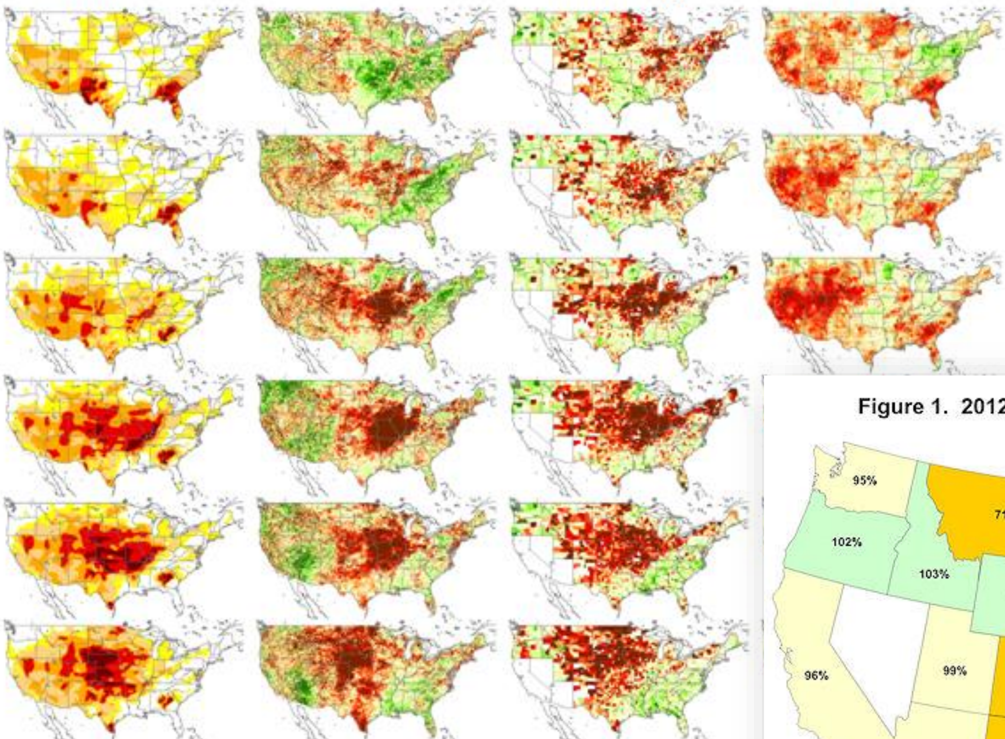
MAY

JUN

JUL

AUG

SEP



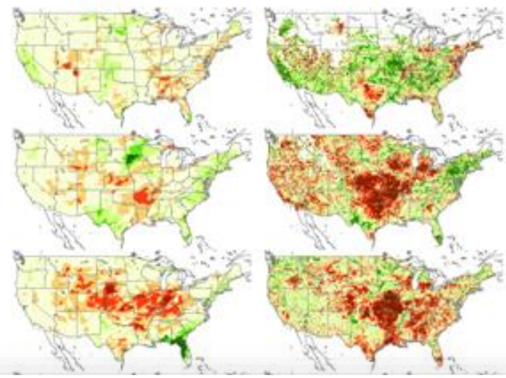
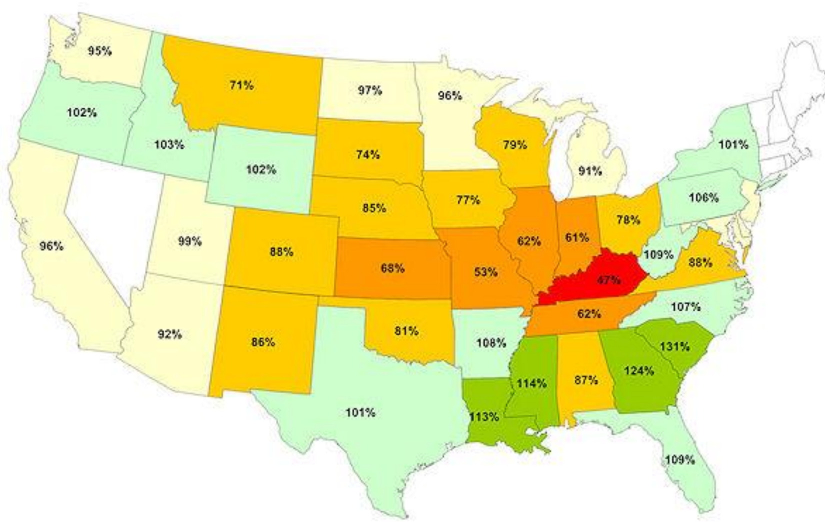
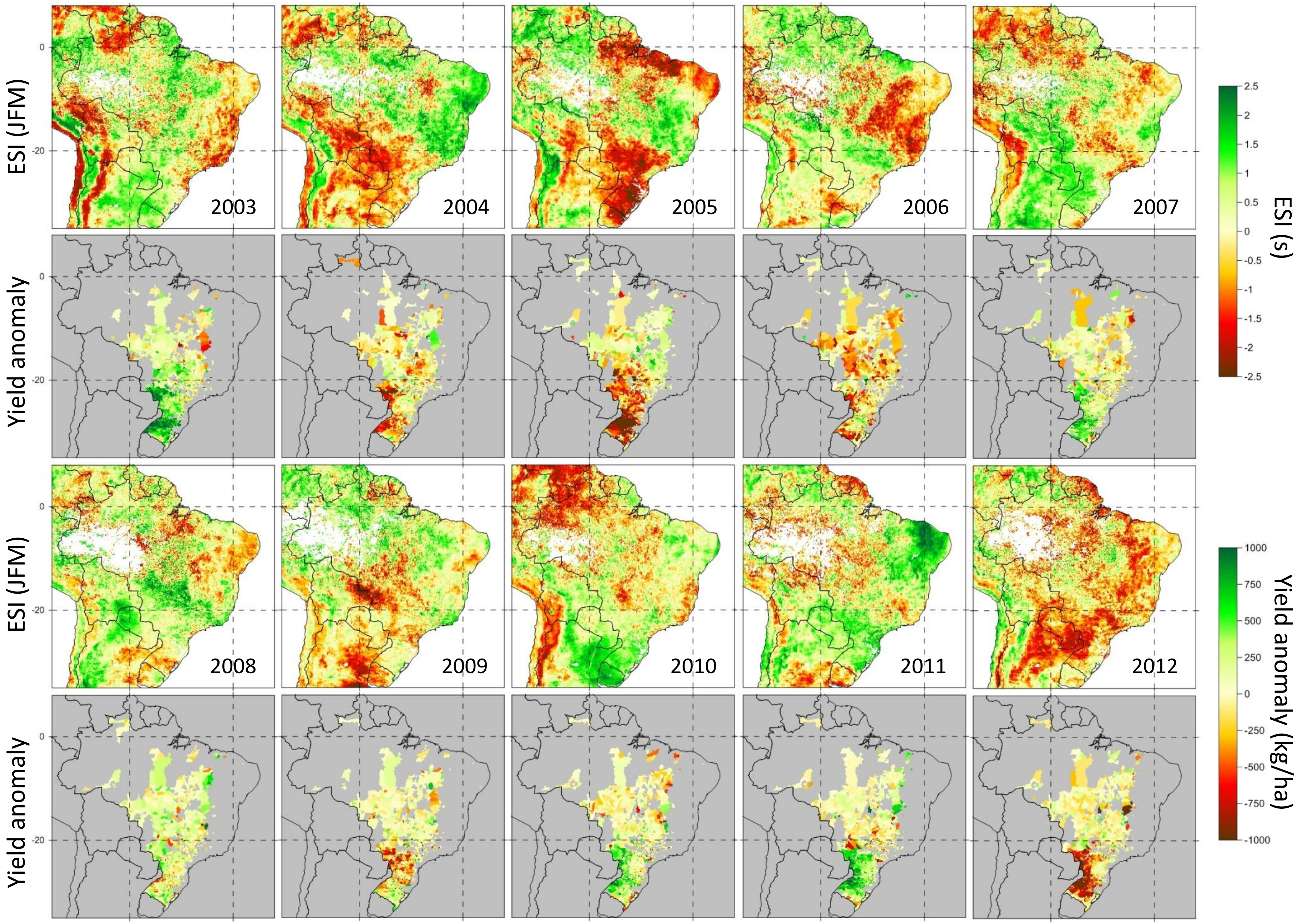


Figure 1. 2012 State Corn Yields as a Percent of Trend Yield.



ANNUAL MUNICIPAL LEVEL SOYBEAN YIELD ANOMALIES



Advantages

- 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
- Captures thermal canopy stress signal – agricultural drought monitoring
- Fast response to variable soil evaporation rates (not captured by NDVI alone)