Mapping Evapotranspiration and Drought at Local to Continental Scales with a Thermal-based Surface Energy Balance Model

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Remote Sensing of Surface Moisture

MICROWAVE
(10-50 km resolution)

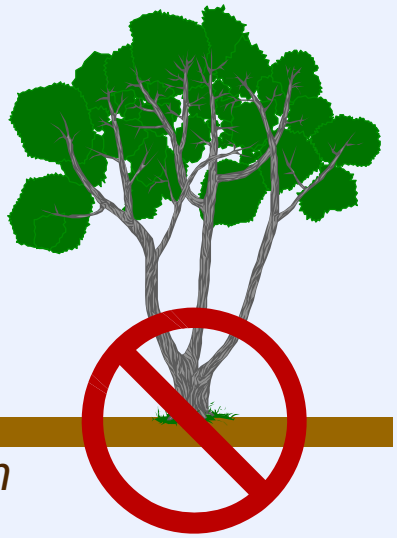
Microwave emissivity

↑

Surface dielectric properties

↑

Surface moisture



Surface layer: ~5cm

THERMAL
(60m – 10km resolution)

Canopy temperature

↑

Canopy transpiration

↑

Root-zone moisture

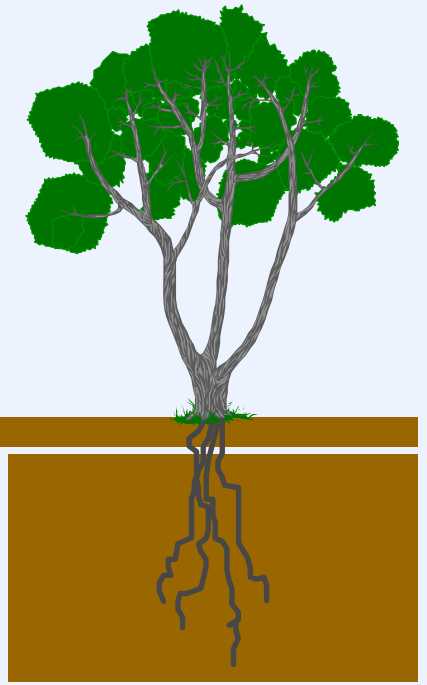
Soil temperature

↑

Soil evaporation

↑

Surface moisture



Rootzone: ~1-2m

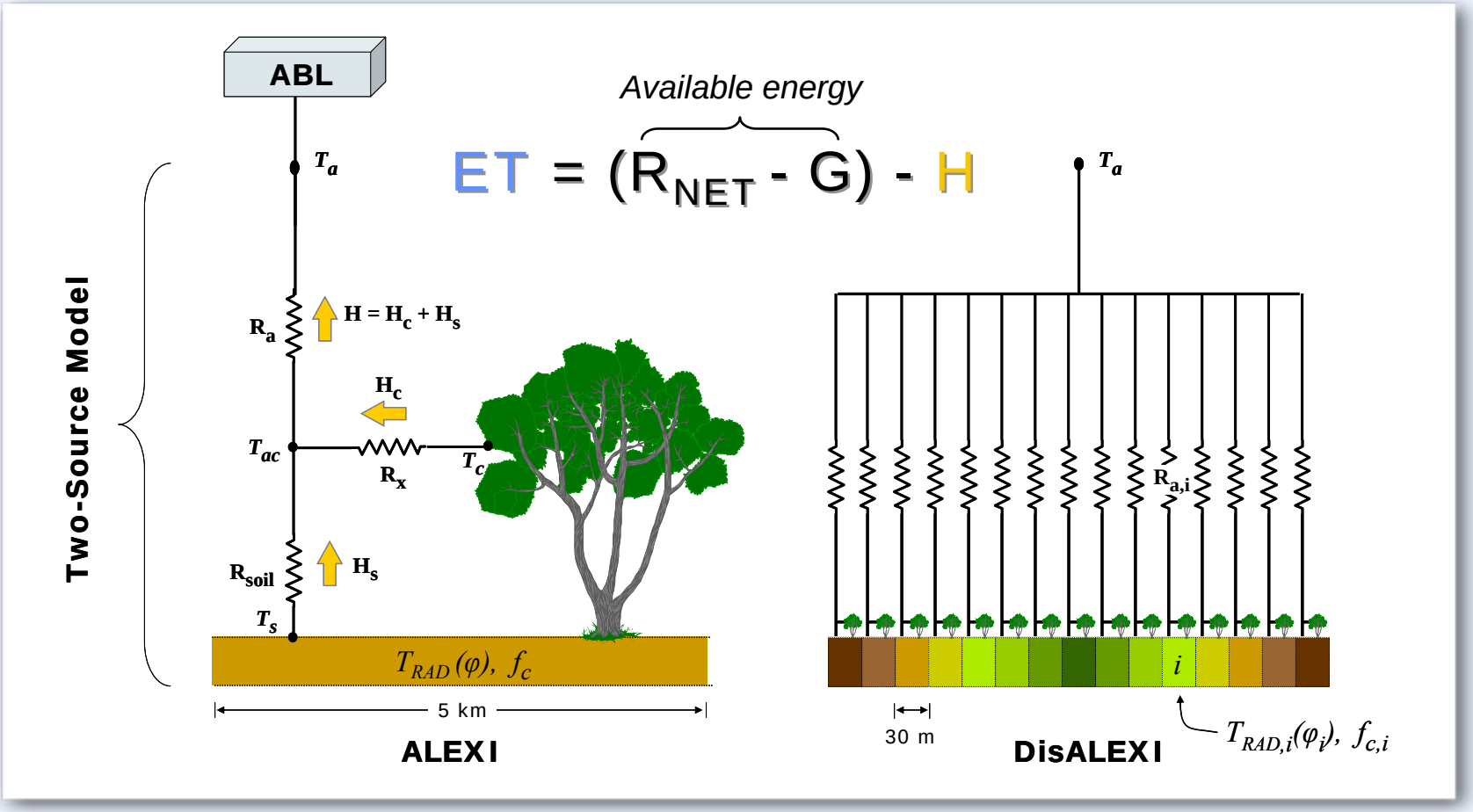
Satellite Thermal Imaging Systems

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	

Table from S. Hook

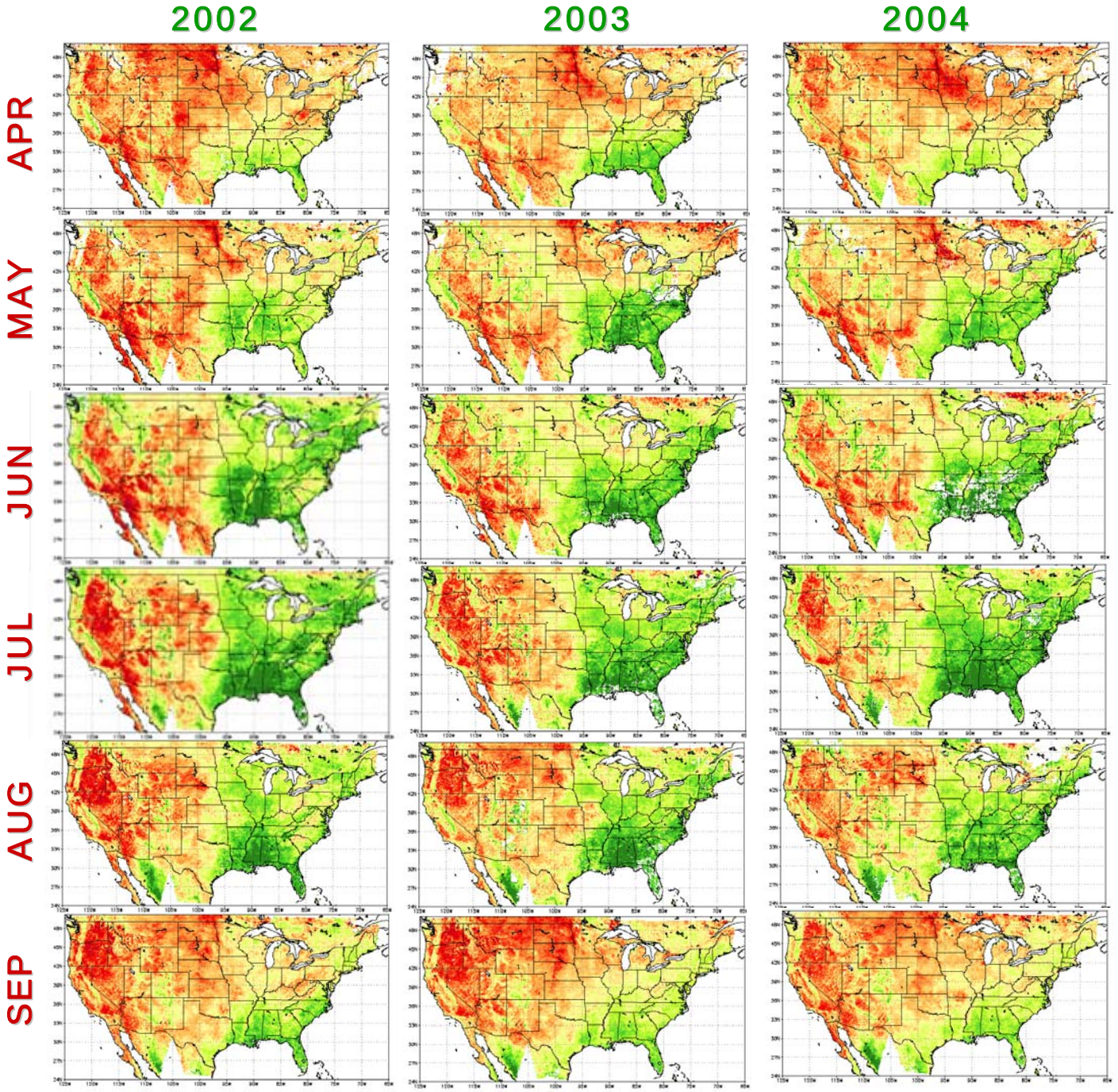
APPLICATIONS
... evapotranspiration
ALEXI – Atmosphere-Land Exchange Inverse Model
(Anderson et al, 1997)

Atmosphere-Land Exchange Inverse (ALEXI)



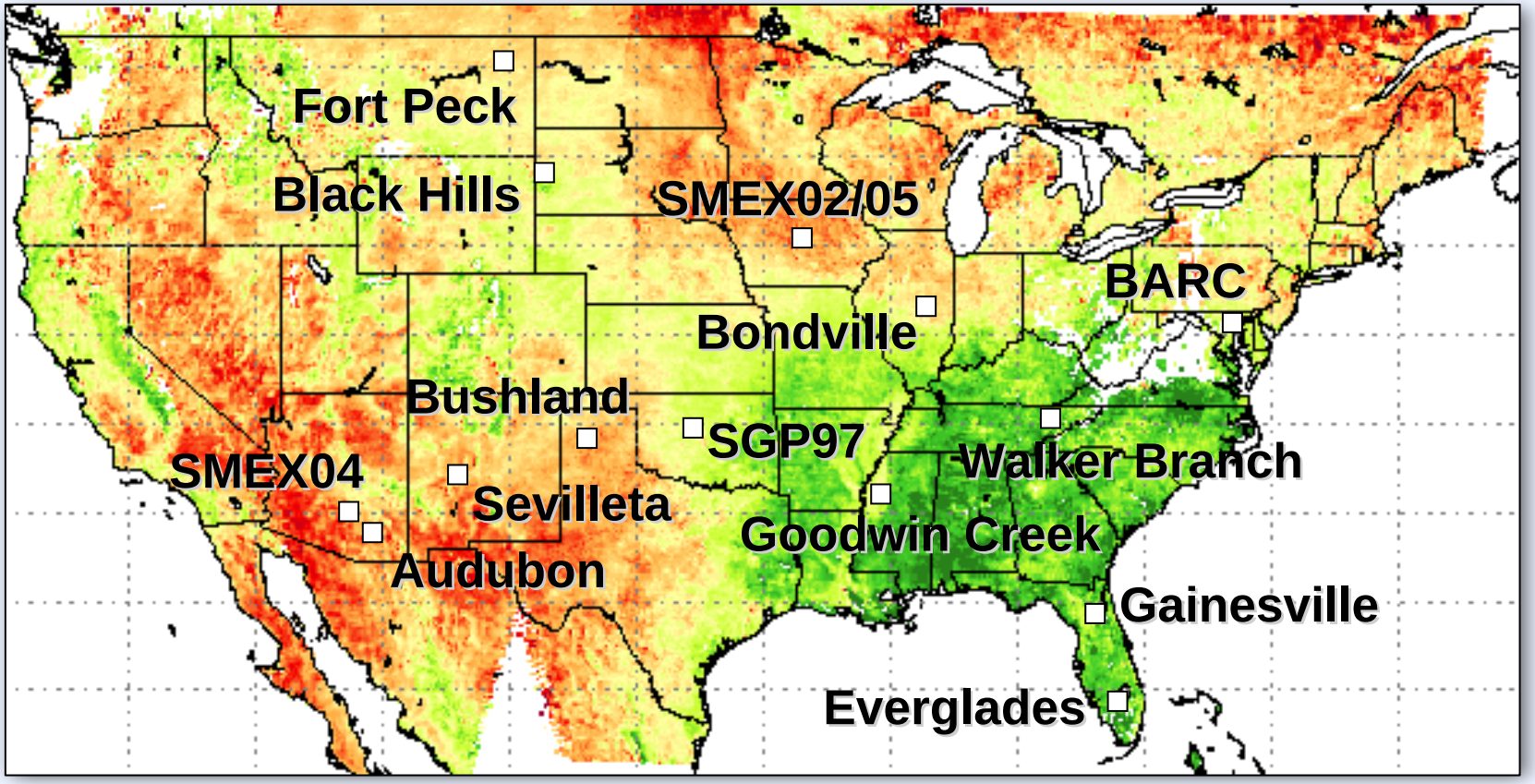
	Regional scale	Landscape scale
Surface temp:	ΔT_{RAD} - GOES	T_{RAD} - TM, ASTER, MODIS
Cover fraction:	f_c - MODIS	f_c - TM, ASTER, MODIS

SURFACE TEMPERATURE
EVAPOTRANSPIRATION
ALEXI
(GOES Sounder)
ALEXI
(GOES Imager)
DisALEXI
(Landsat)
DisALEXI
(USU aircraft)
Continental
Regional
Watershed
Field scale
CORN
SOY
45
40
35
30
600
500
400
300
200
100
0

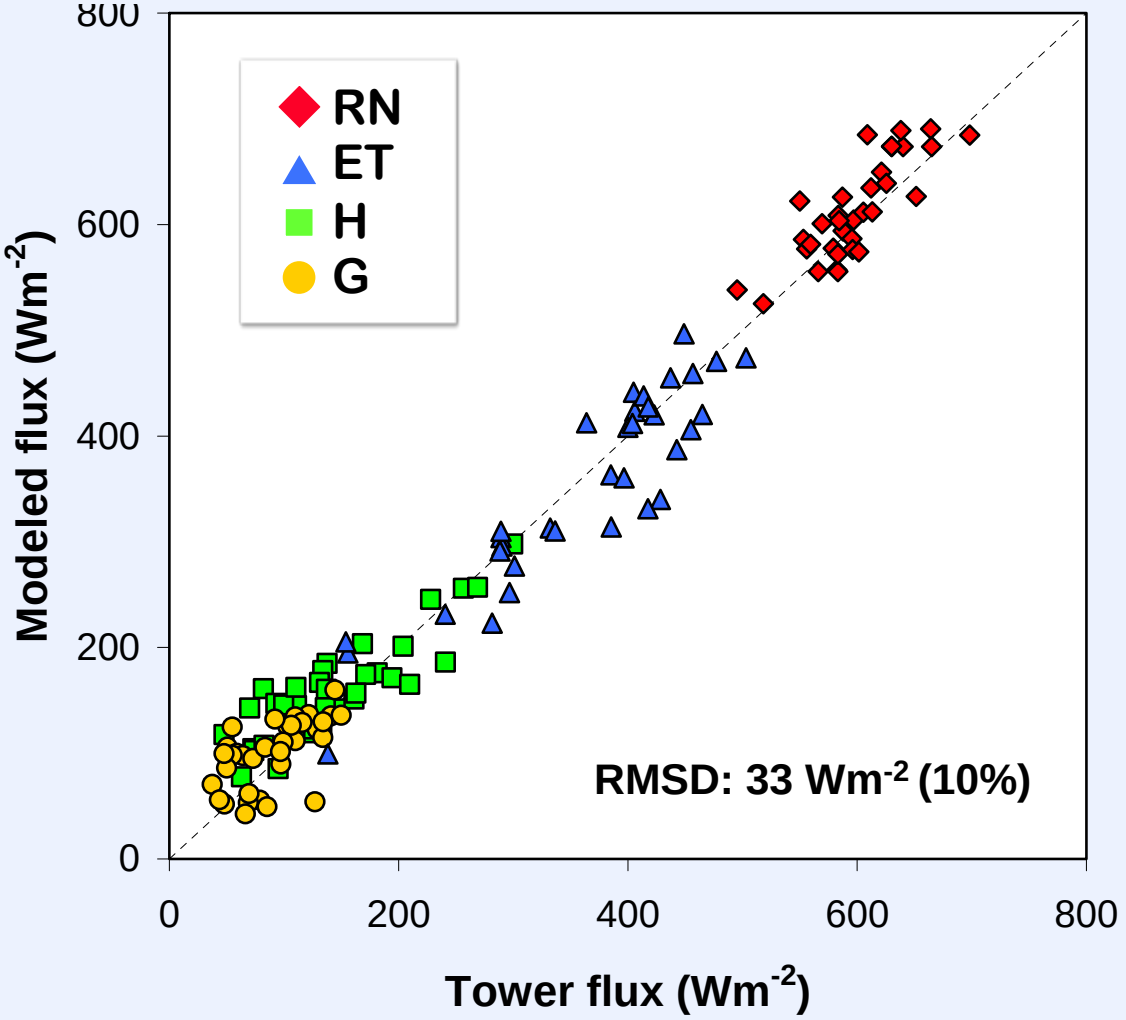


(Anderson et al, 2007)

ALEXI validation sites



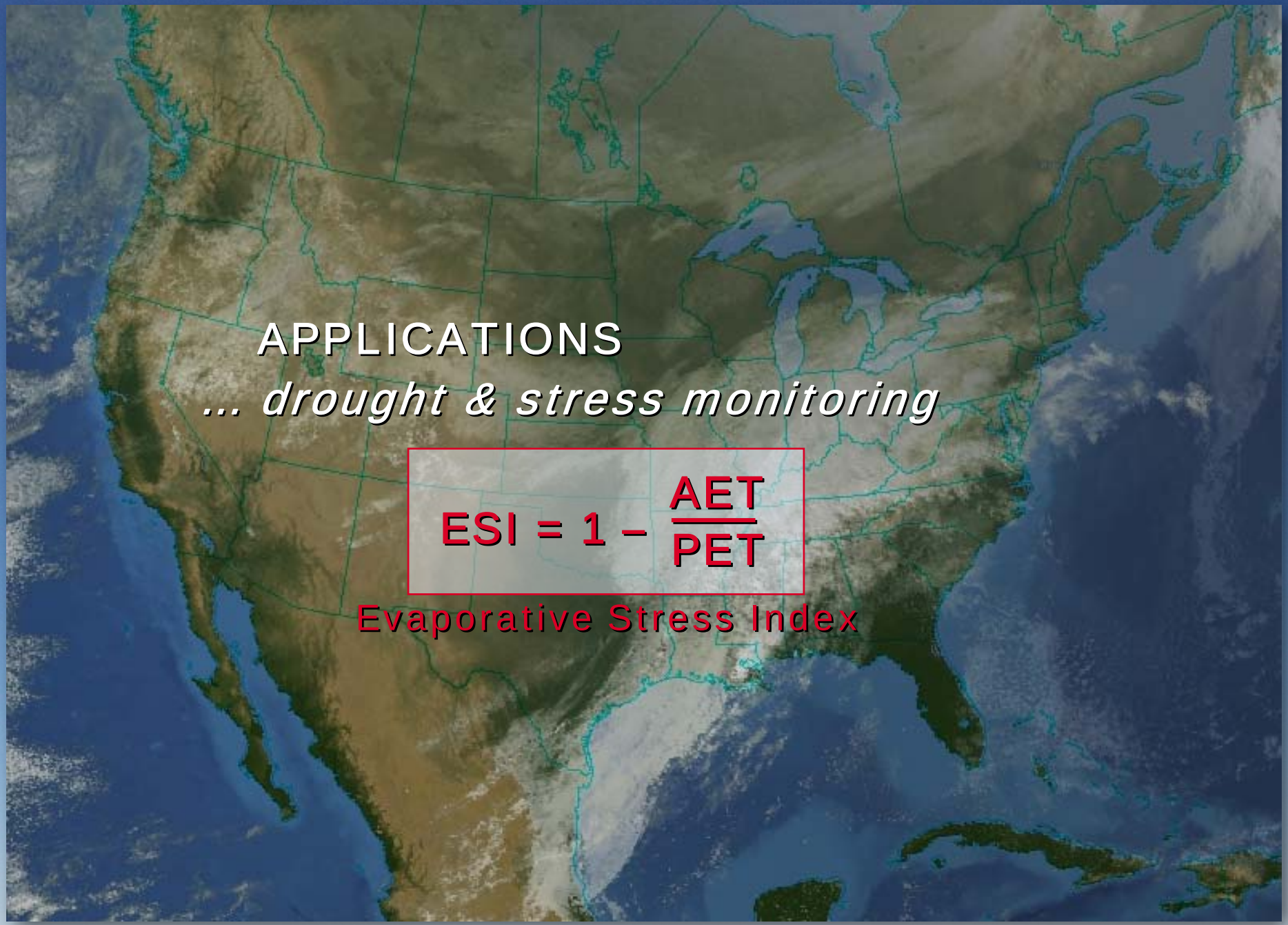
Clear-sky fluxes using Landsat thermal (60m)



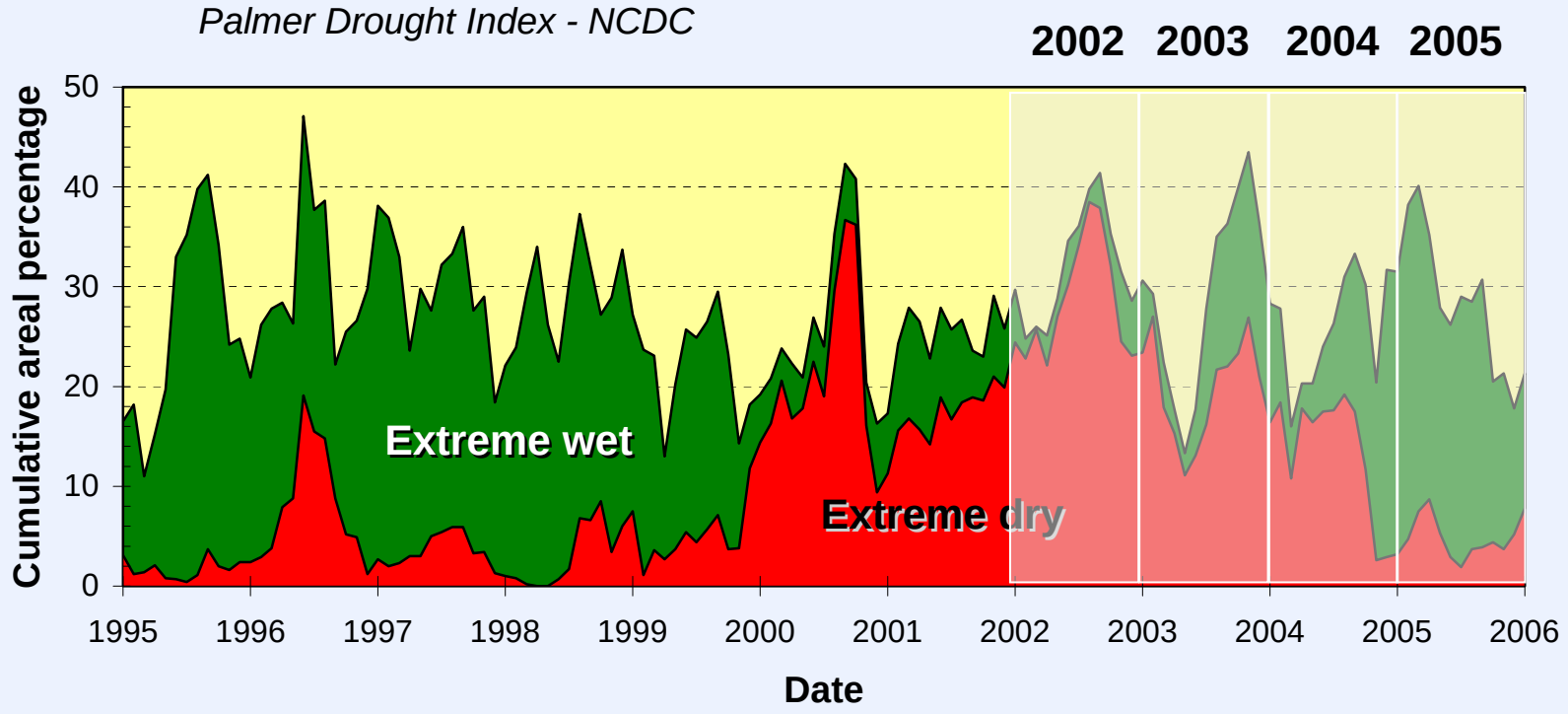
- rangeland
- pasture
- corn
- soybean

…

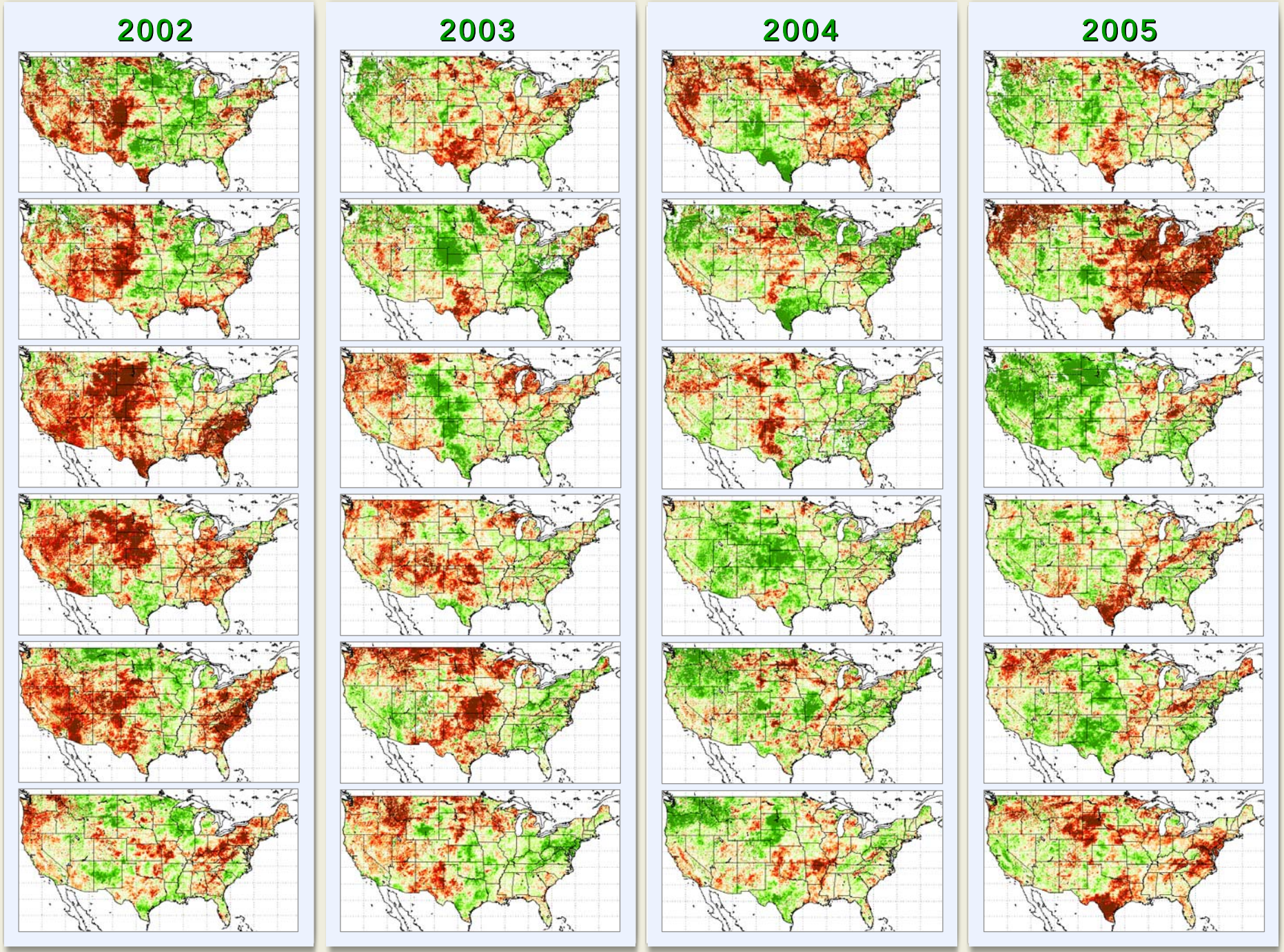
(Anderson et al, 2007)

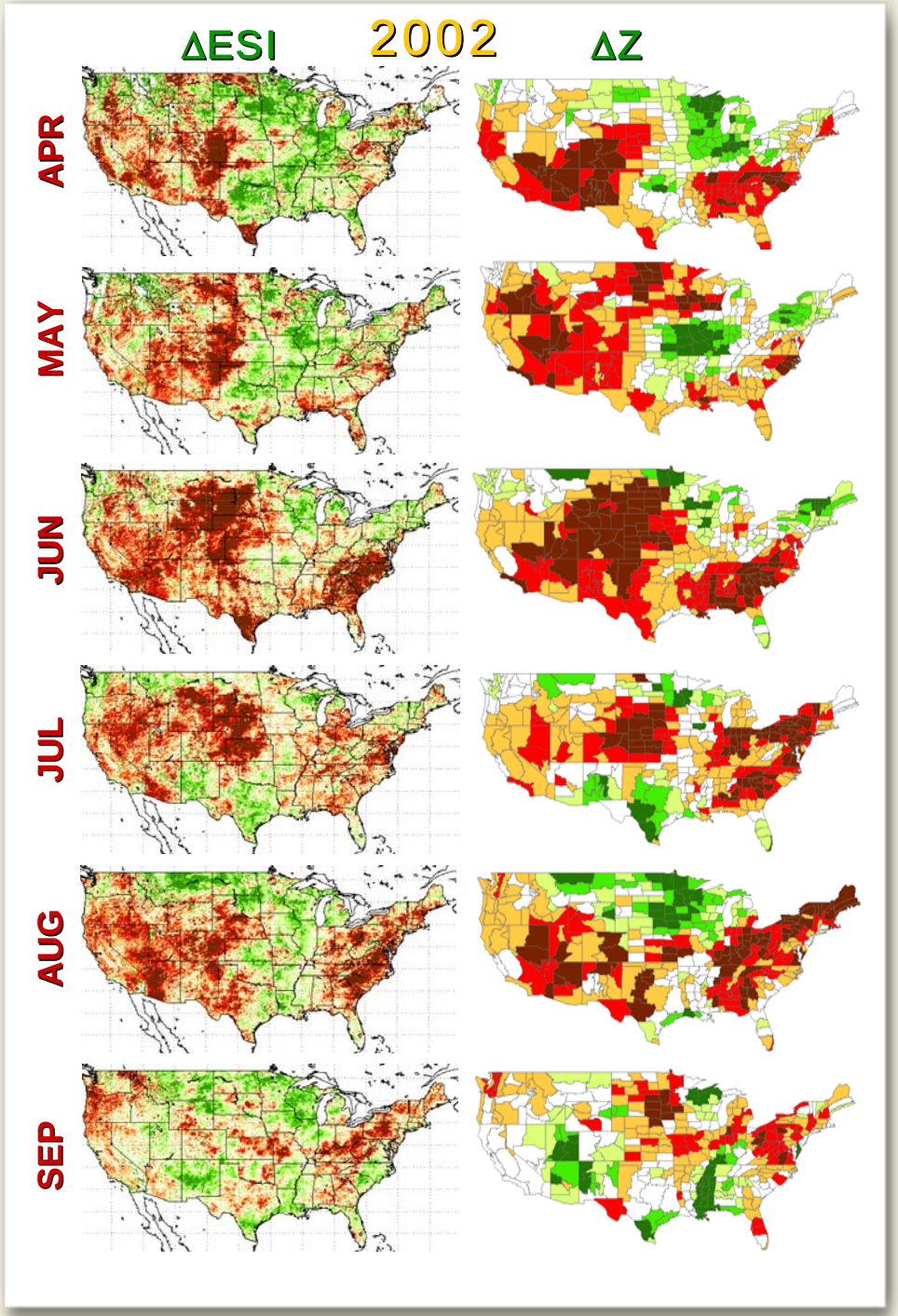

APPLICATIONS
... drought & stress monitoring
ESI = 1 – AET/PET
Evaporative Stress Index

Climatological Study: 2002-2005



- 2002: extreme-severe drought conditions covering 40% of the US in July
- 2003: some improvement (10-25% extreme-severe drought coverage)
- 2004: extreme drought coverage falls < 5% due to increased late rainfall
- 2005: wetter than average in western US, drought in east

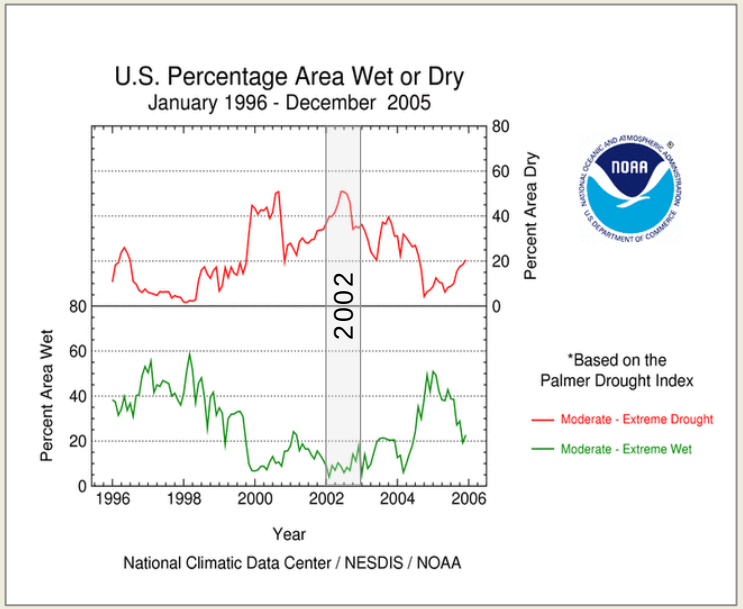

2002
2003
2004
2005
APR
MAY
JUN
JUL
AUG
SEP
MONTHLY ESI ANOMALIES
DRY
WET

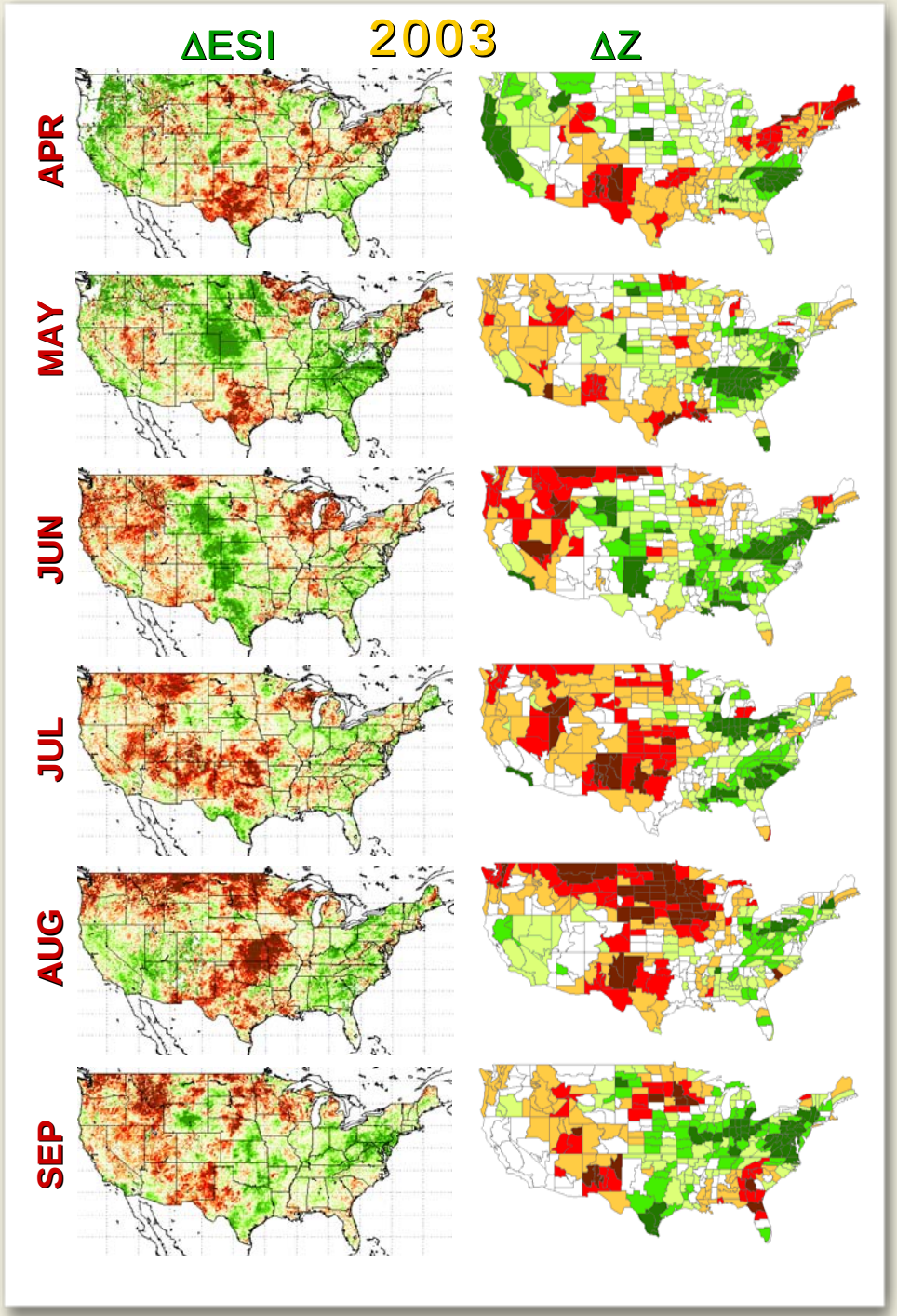


Evaporative Stress Index

2002

Dry — Wet

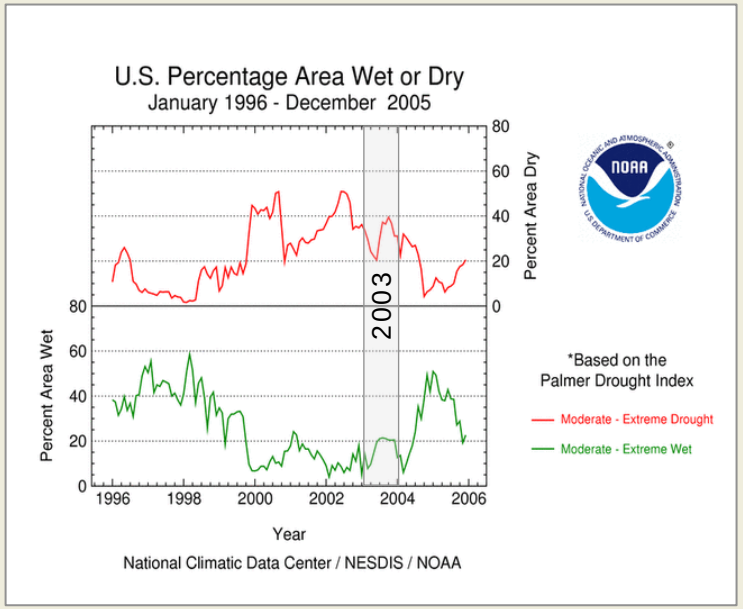


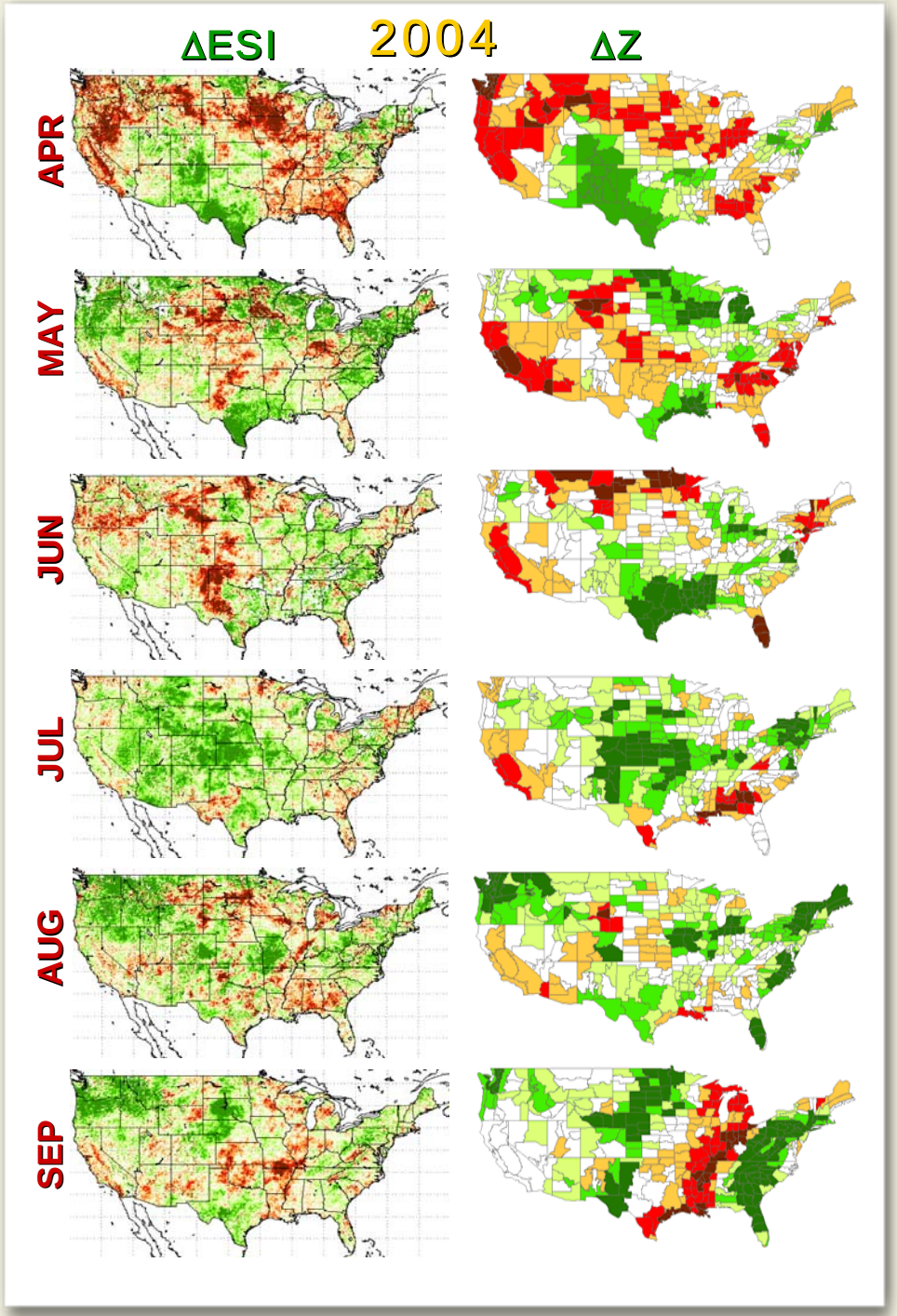


Evaporative Stress Index

2003

Dry — Wet

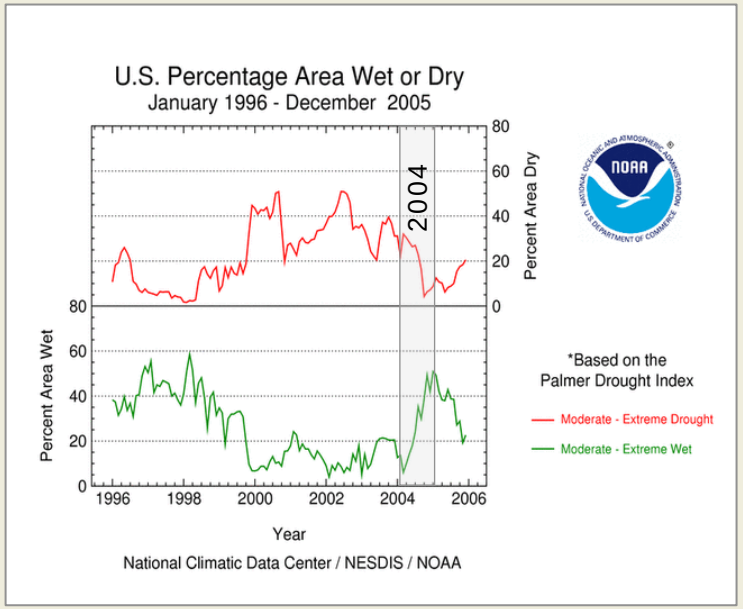


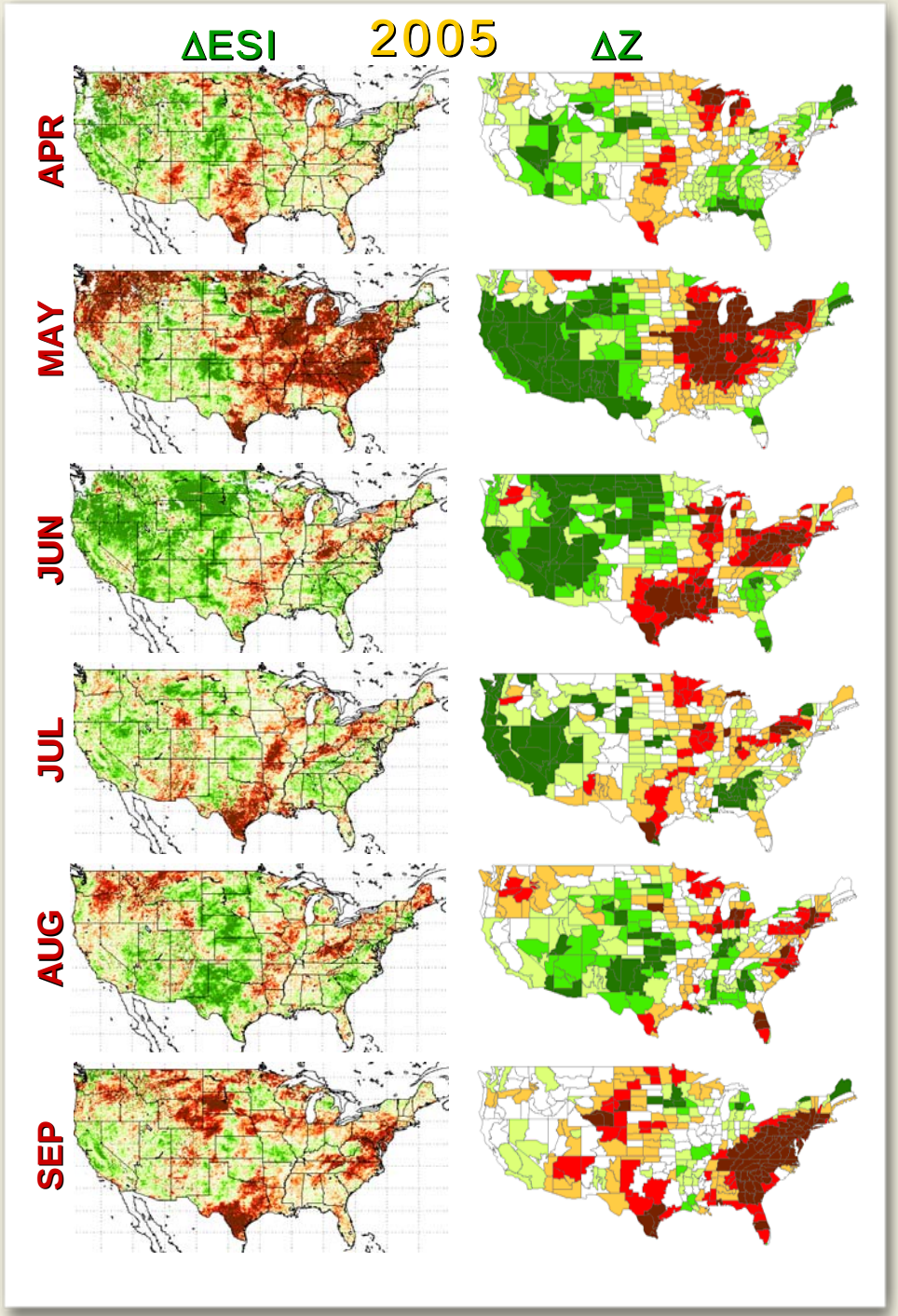


Evaporative Stress Index

2004

Dry — Wet

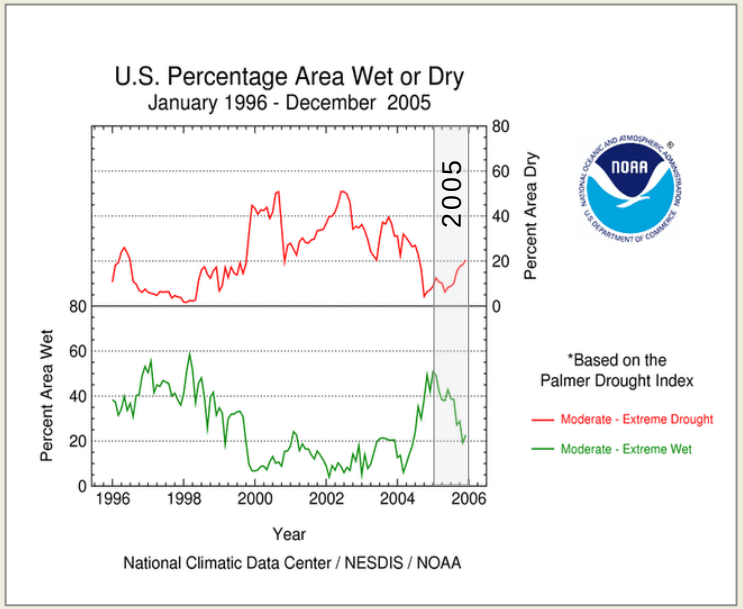




Evaporative Stress Index

2005

Dry — Wet



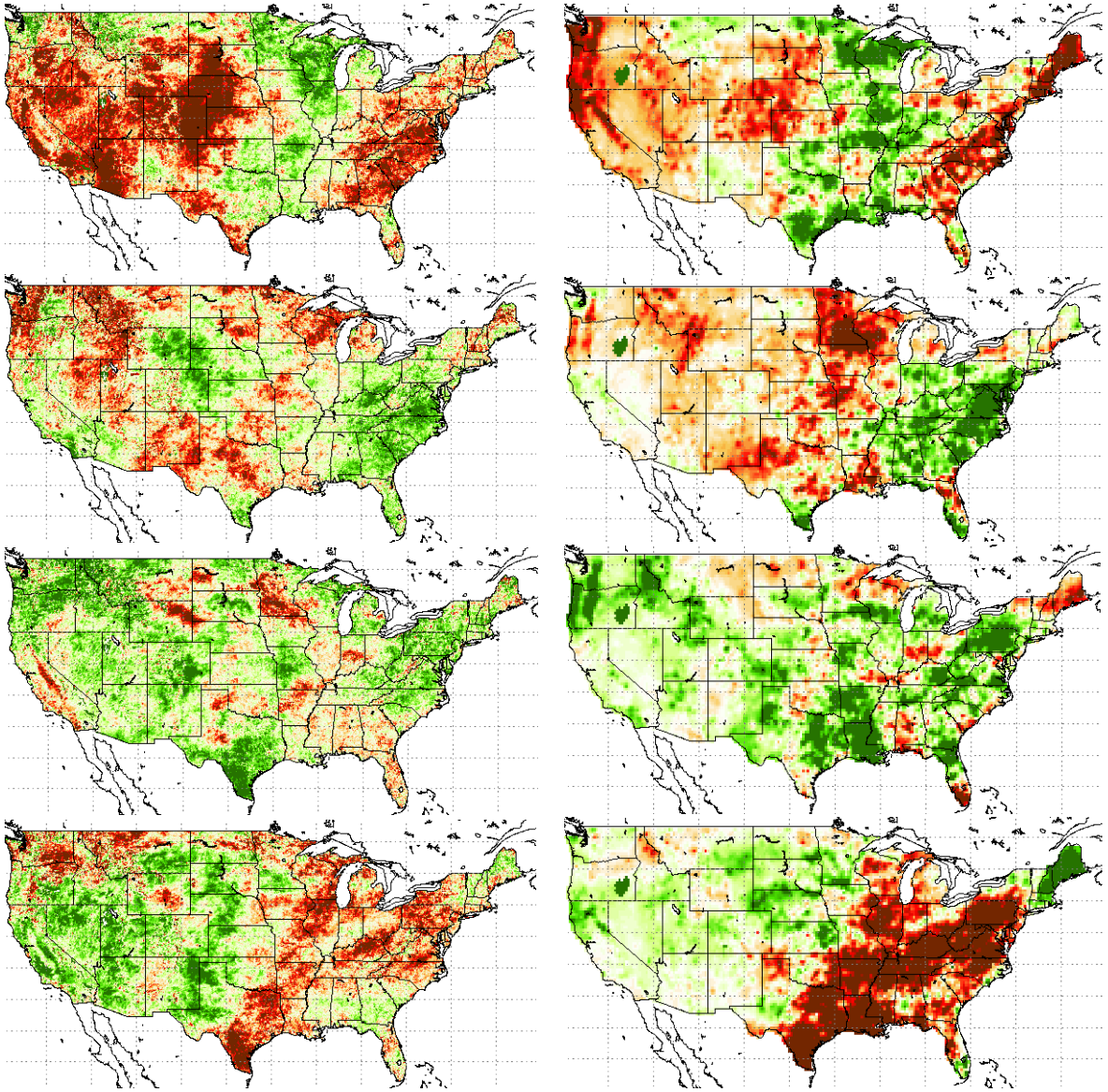
ALEXI Precipitation

2002

2003

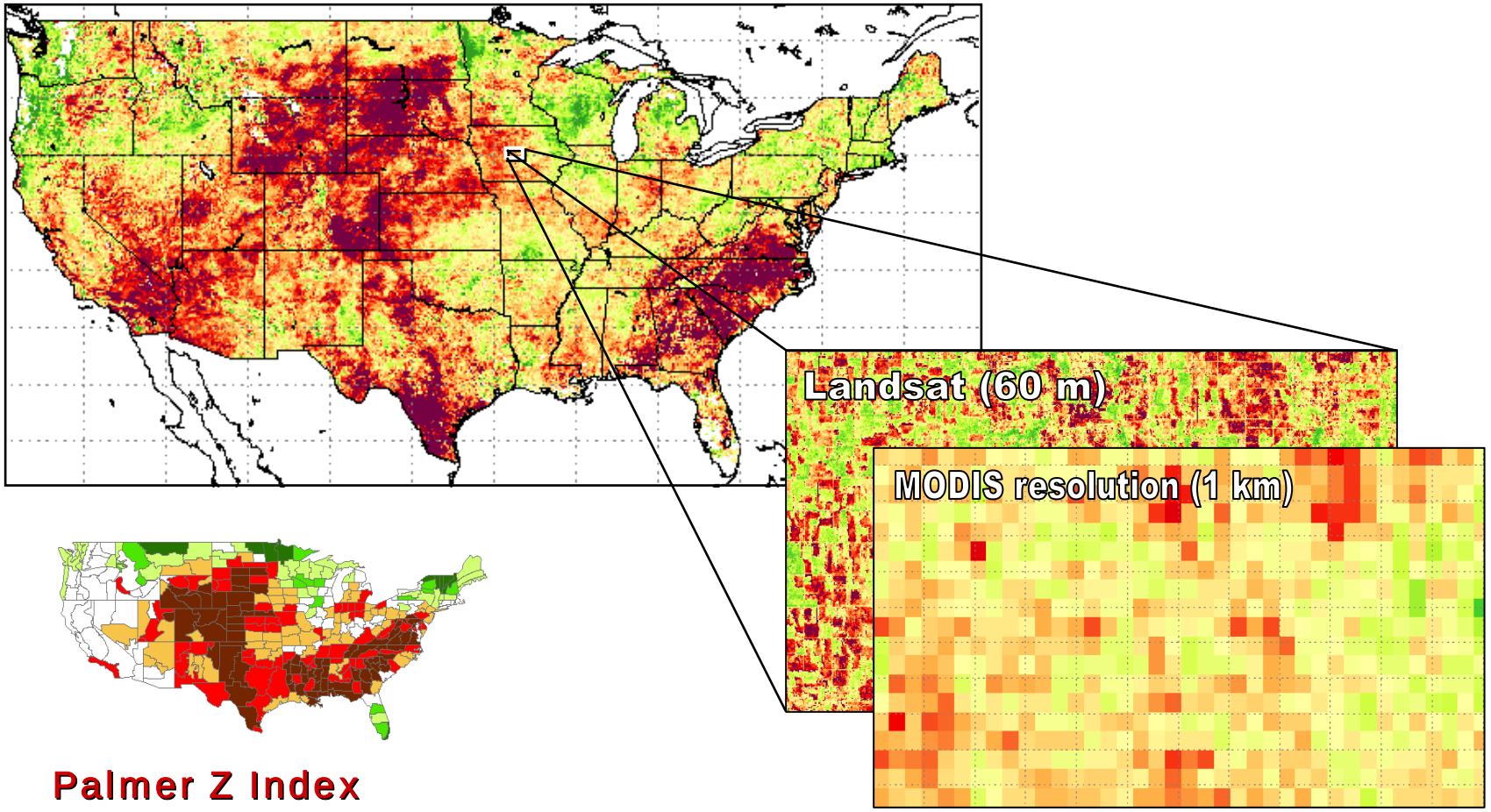
2004

2005



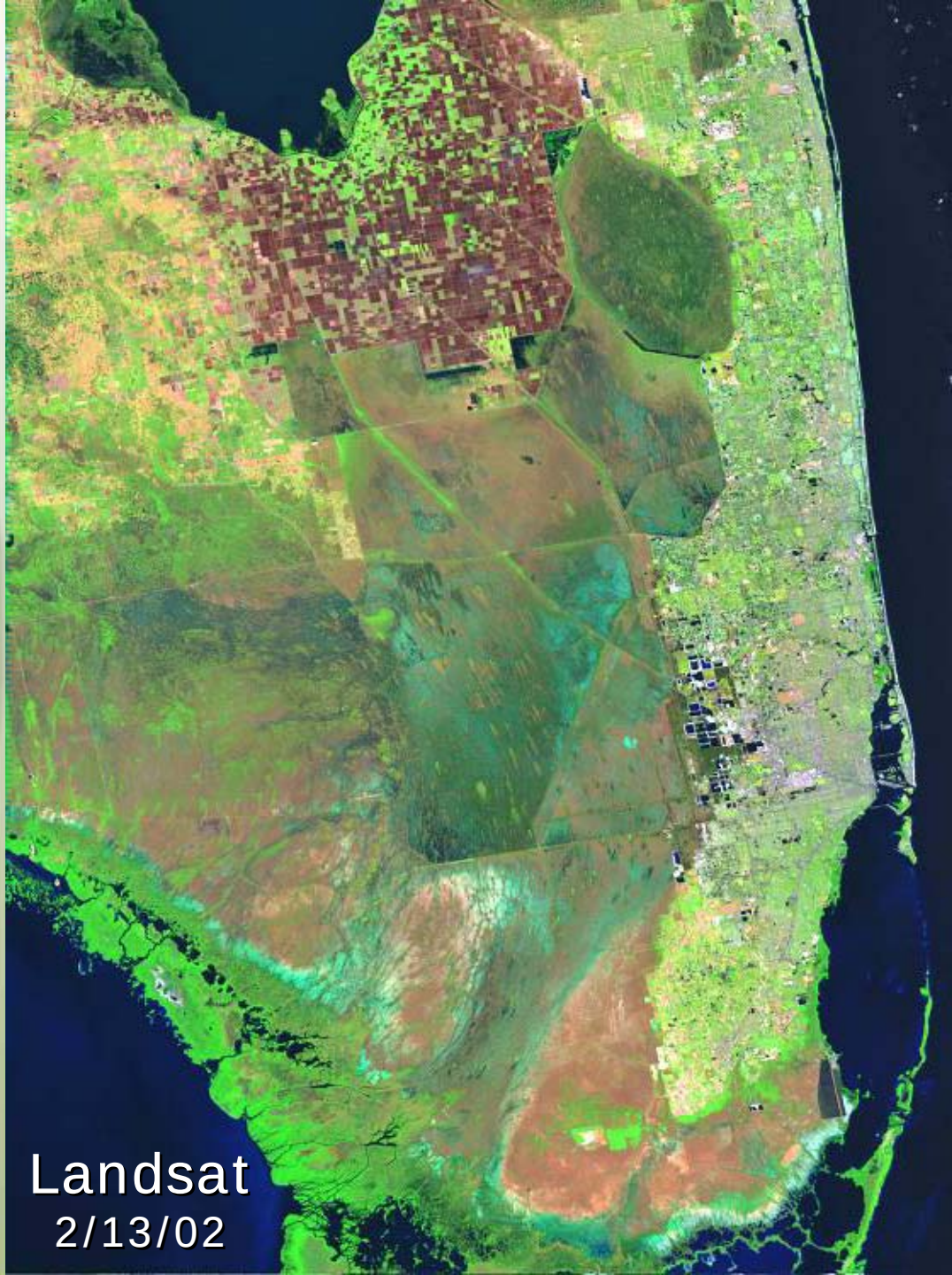
Multi-scale Drought Monitoring

GOES Evaporative Stress Index JUNE 2002



Palmer Z Index Anomaly

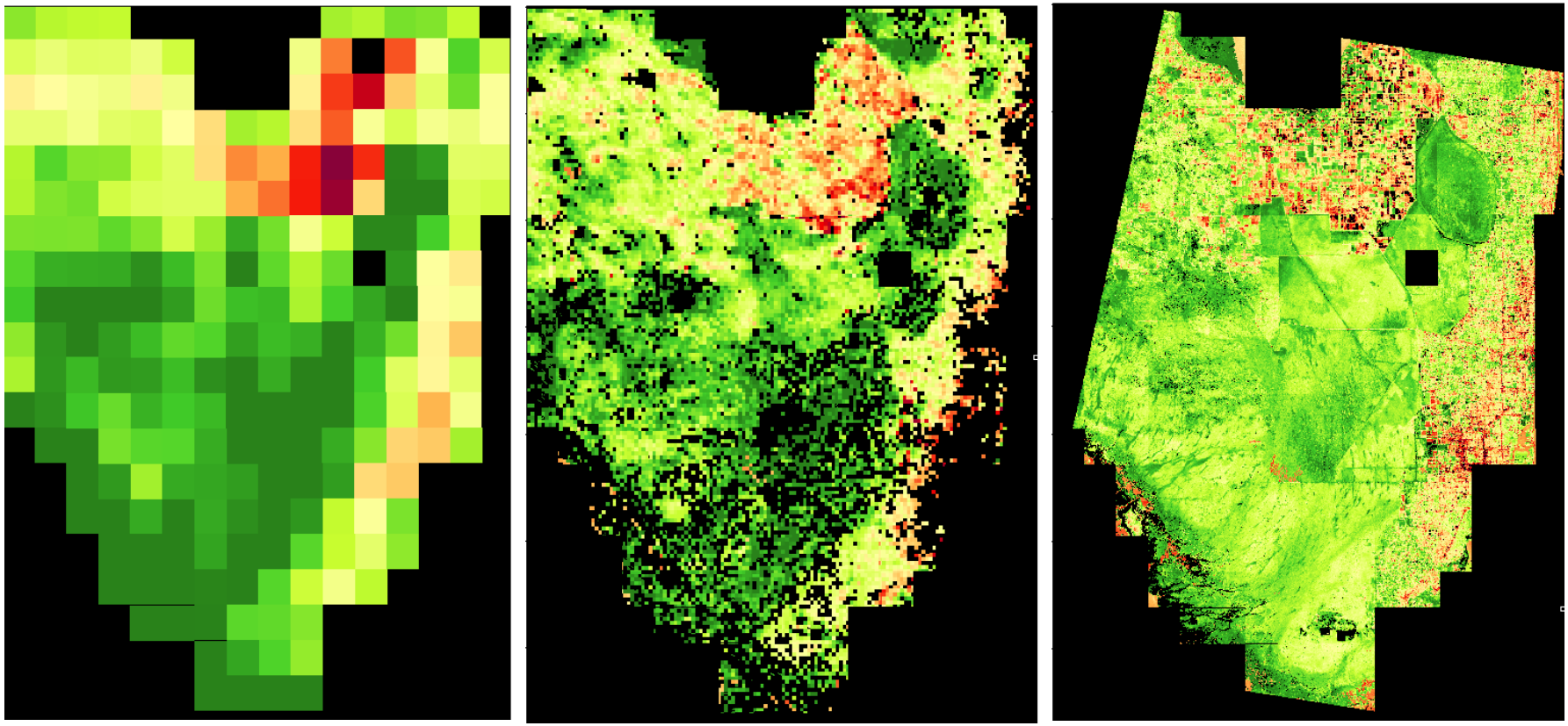
Lake
Kissimmee
SFWMD Boundary
Lake
Okeechobee
Caloosahatchee
River
Everglades
Agricultural
Area
Water
Conservation Areas
N
W
E
S
Everglades
National
Park
LEGEND
Everglades Protection Area
Water Conservation Area Boundary
Everglades National Park
Florida Bay


Landsat
2/13/02

Multi-scale Ecosystem Health Monitoring

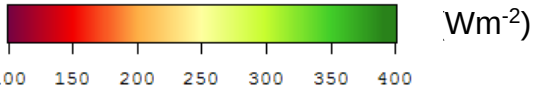
FLORIDA EVERGLADES

GOES (10km) | MODIS (1km) | L7 (60m)



(hourly) | (daily) | (monthly)

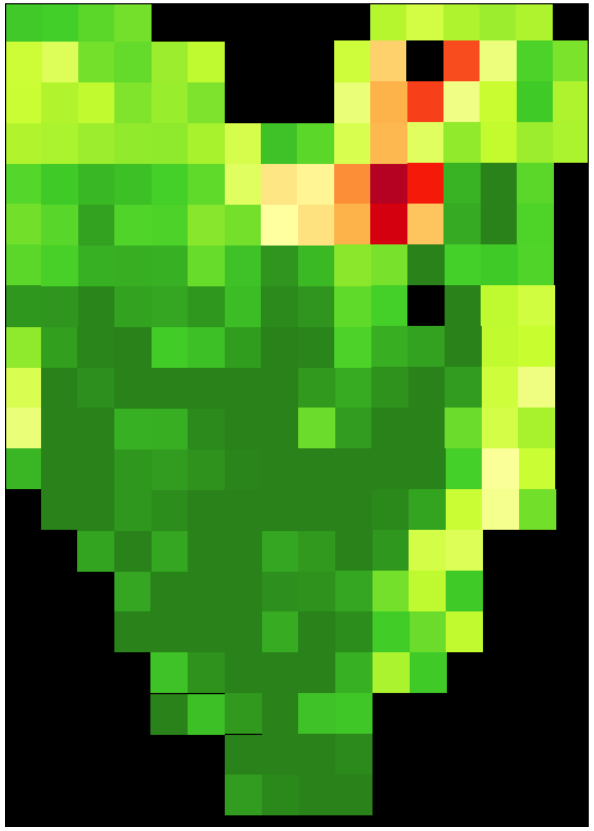
Evapotranspiration



Multi-scale Ecosystem Health Monitoring

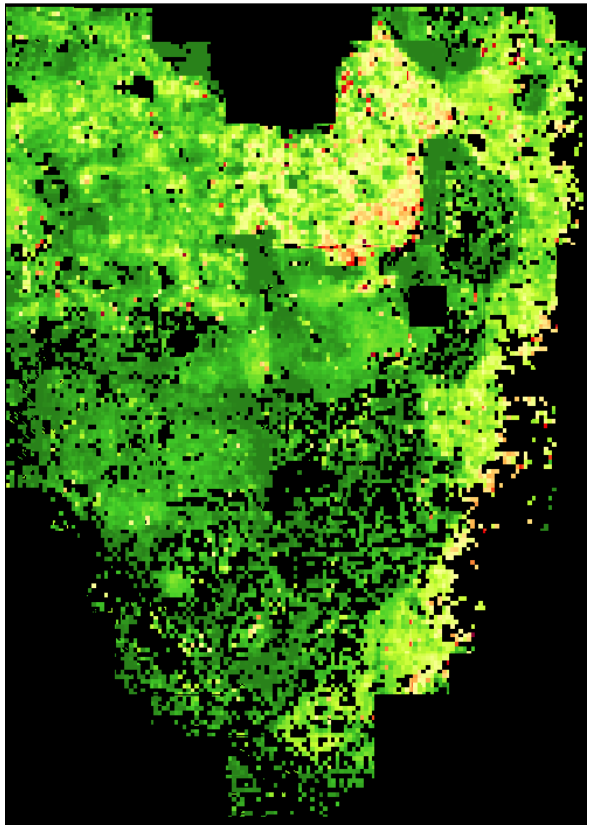
FLORIDA EVERGLADES

GOES (10km)



(hourly)

MODIS (1km)



(daily)

L7 (60m)

(monthly)

Evaporative stress

(high) (low)

Impending data gap in high-resolution TIR

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	!!

Table from S. Hook

CONCLUSIONS

- ADVANTAGES of ESI:
  - *... physically based interpretation of LST signal*
  - *... quantitatively verifiable*
  - *... thermal: early warning signal*
  - *... scalable mapping approach*

NEED TO MAINTAIN MULTI-SCALE THERMAL DATA SOURCES

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CONCLUSIONS

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

NEED TO MAINTAIN MULTI-SCALE THERMAL DATA SOURCES

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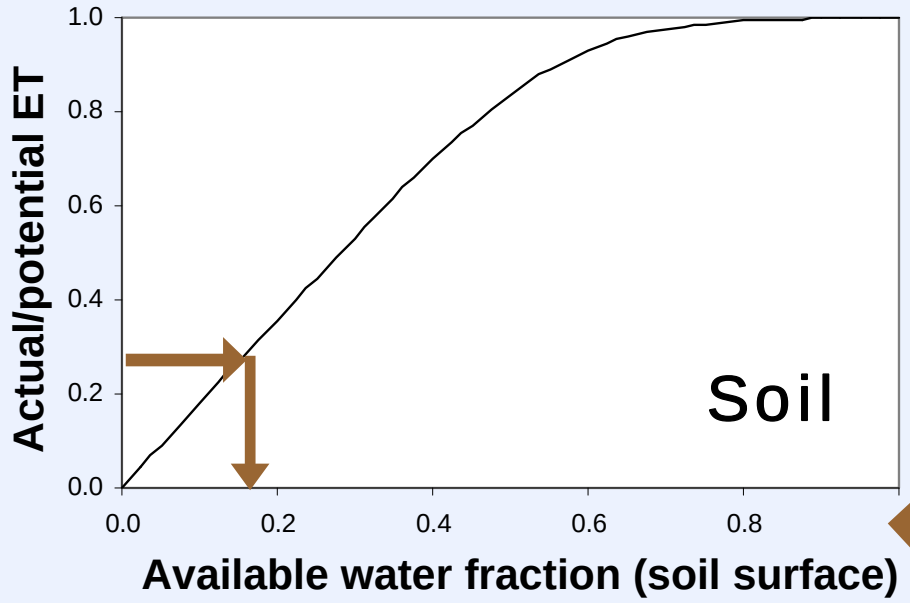
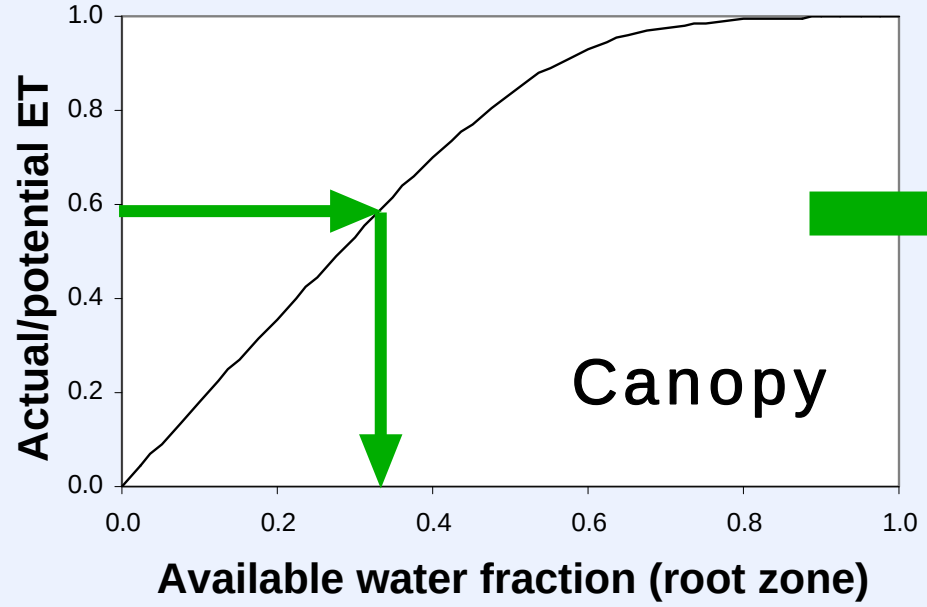
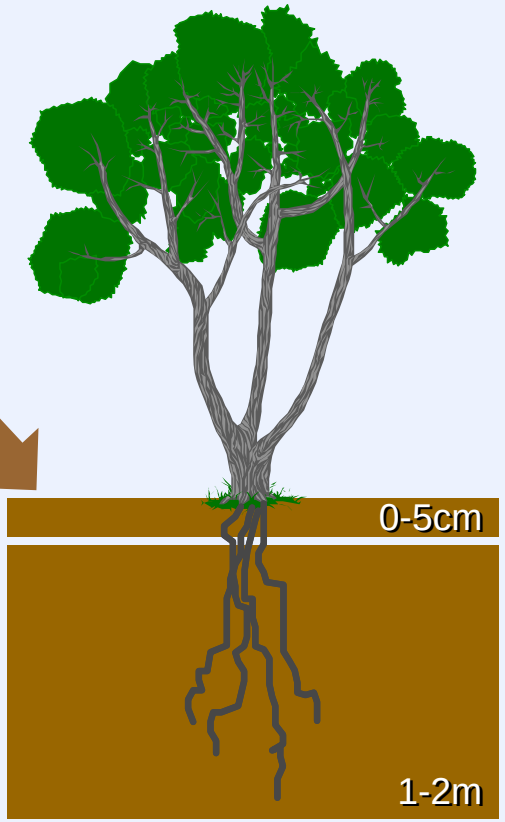
Soil evaporation

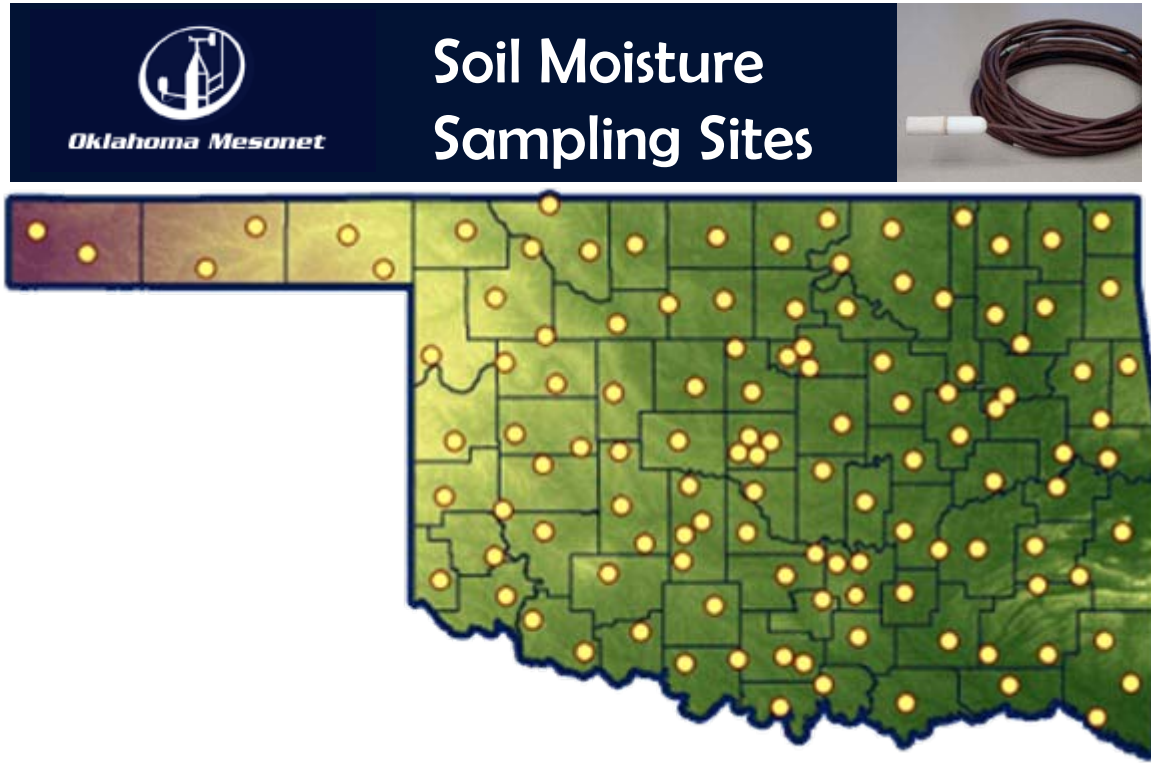


Transpiration

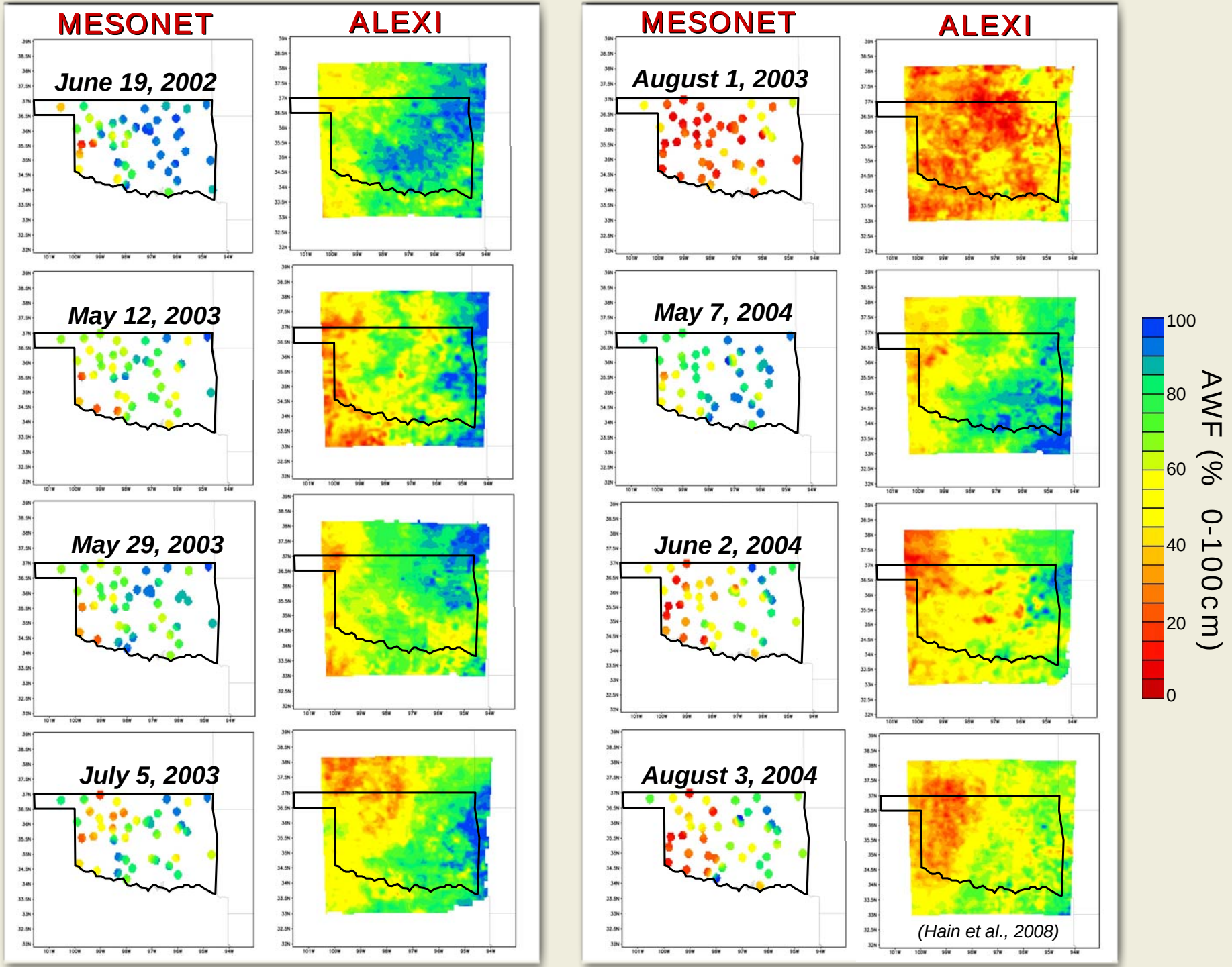




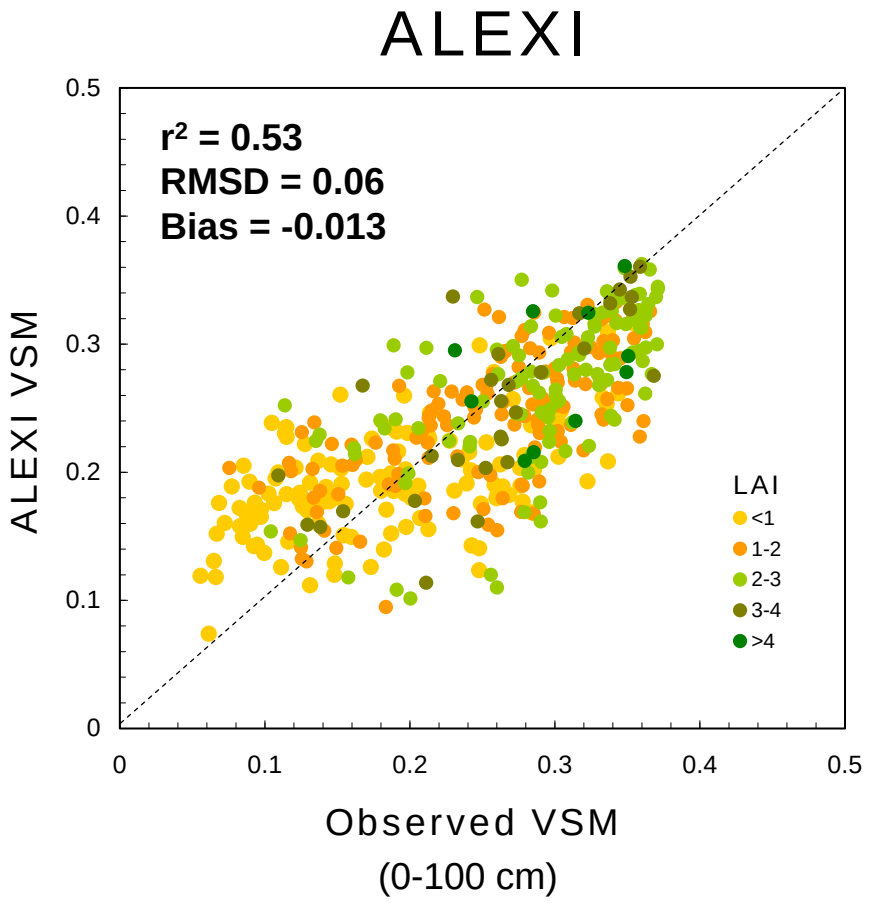
Validation – Oklahoma Mesonet



http://okmesonet.ocs.ou.edu/


MESONET
ALEXI
June 19, 2002
May 12, 2003
May 29, 2003
July 5, 2003
August 1, 2003
May 7, 2004
June 2, 2004
August 3, 2004
(Hain et al., 2008)
AWF (% 0-100cm)
100
80
60
40
20
0

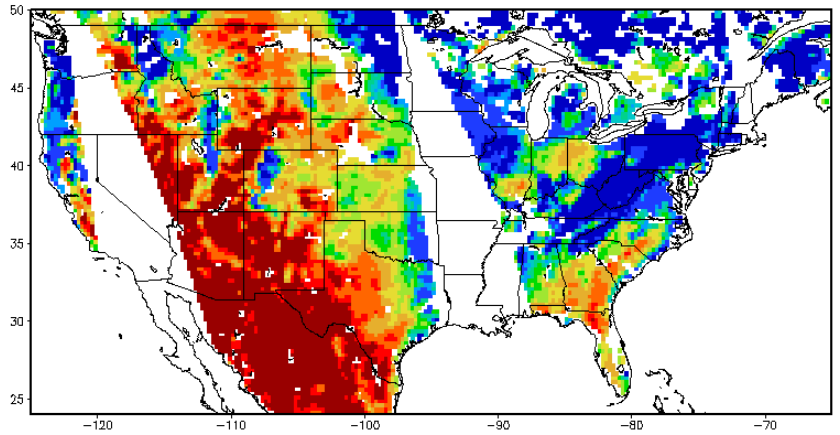
Volumetric Soil Moisture Retrievals

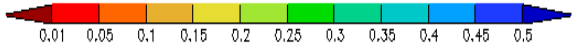


Remote Sensing of Surface Moisture

USDA AMSR-E MICROWAVE SOIL MOISTURE

1 July 2004





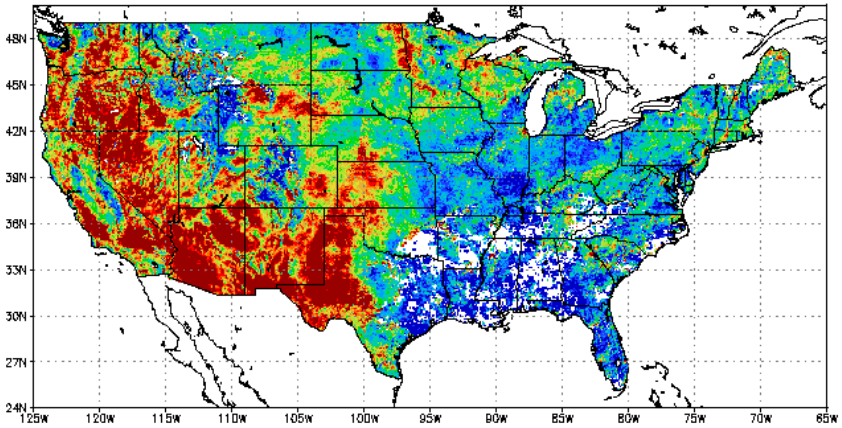
(cm^3/cm^3)

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

AMSR: Advanced Microwave Scanning Radiometer

ALEXI GOES THERMAL SOIL MOISTURE

28-day composite ending 1 July 2004



Low High

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

GOES: Geostationary Operational Environmental Satellite
L7: Landsat 7