National Aeronautics and Space Administration

HyspIRI and the Land–Atmosphere Water Flux

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EVAPOTRANSPIRATION
why do we care?
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IPCC AR5

‘Hydrological acceleration’

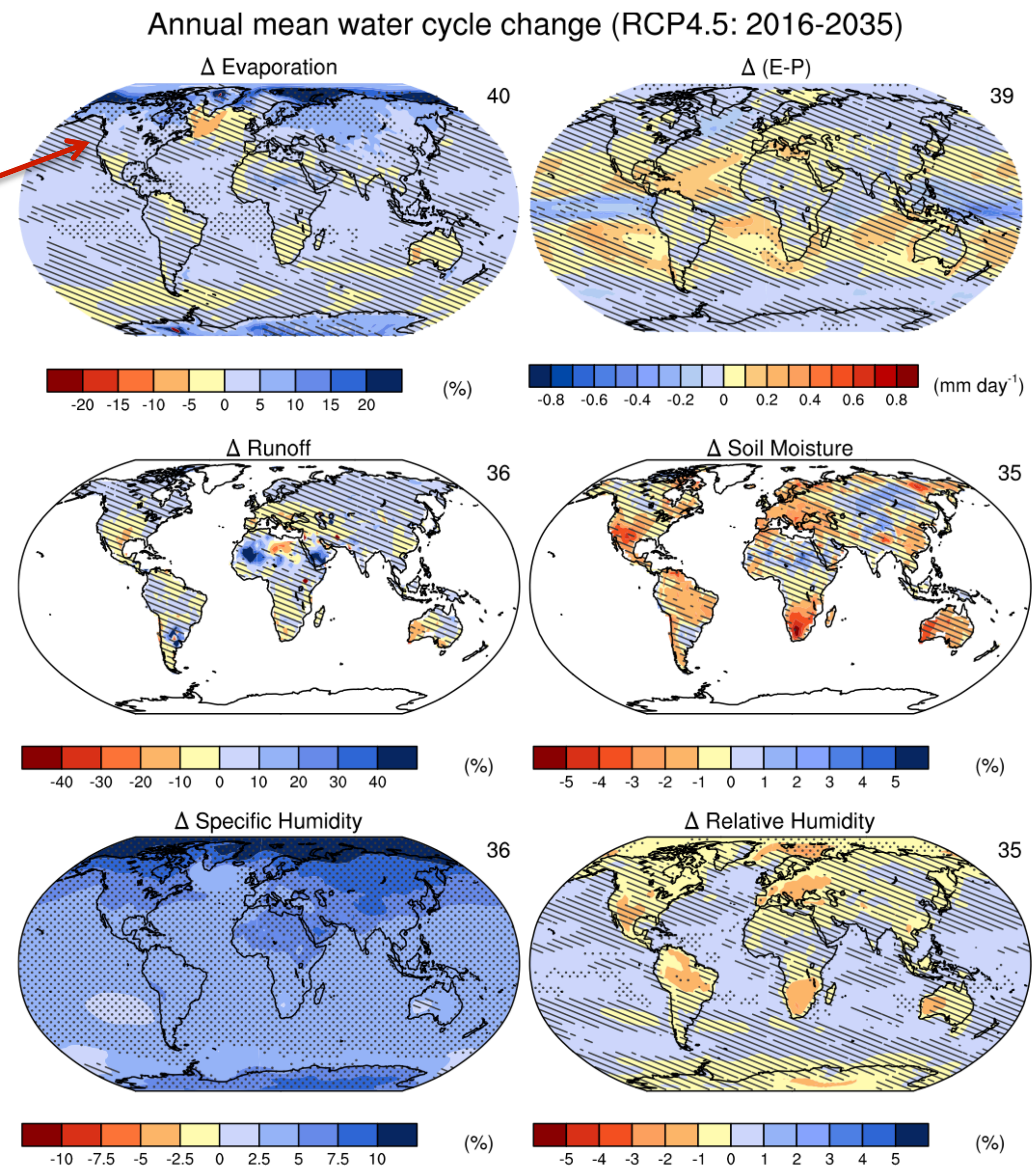


Figure 11.14: CMIP5 multi-model annual mean projected changes for the period 2016–2035 relative to 1986–2005 under RCP4.5 for: (a) evaporation (%), (b) evaporation minus precipitation (E-P, mm day^{-1}), (c) total runoff (%), (d) soil moisture in the top 10 cm (%), (e) relative change in specific humidity (%), and (f) absolute change in relative humidity (%). The number of CMIP5 models used is indicated in the upper-right corner of each panel. Hatching and stippling as in Figure 11.10.

IPCC AR5

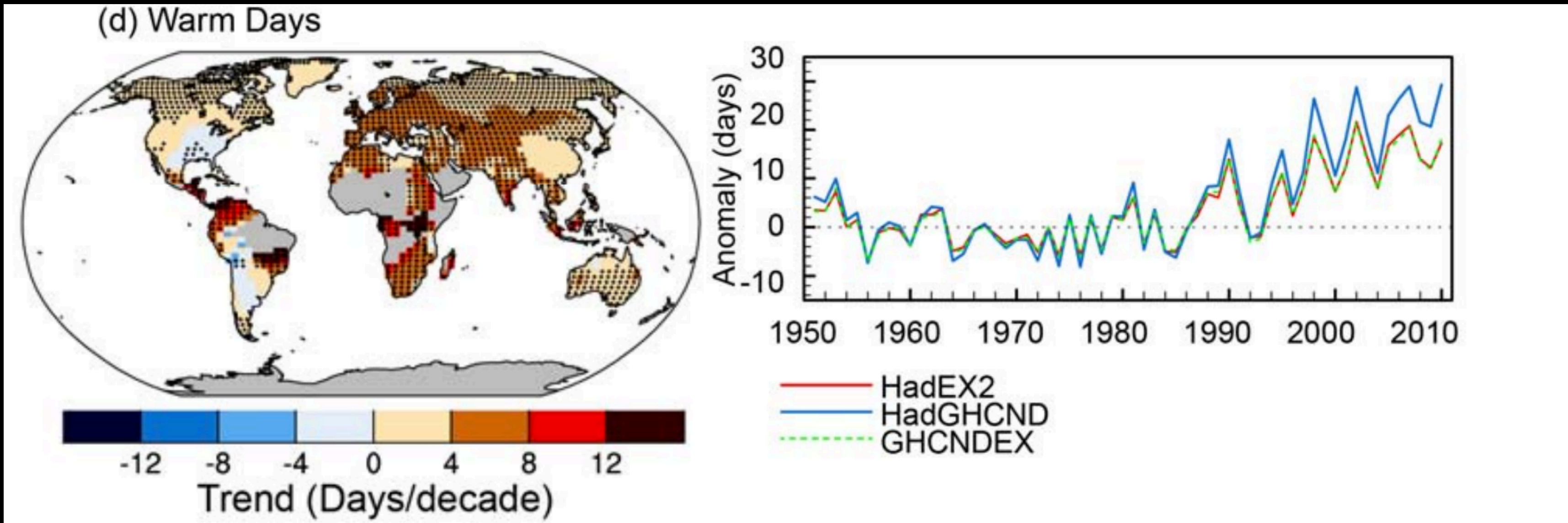
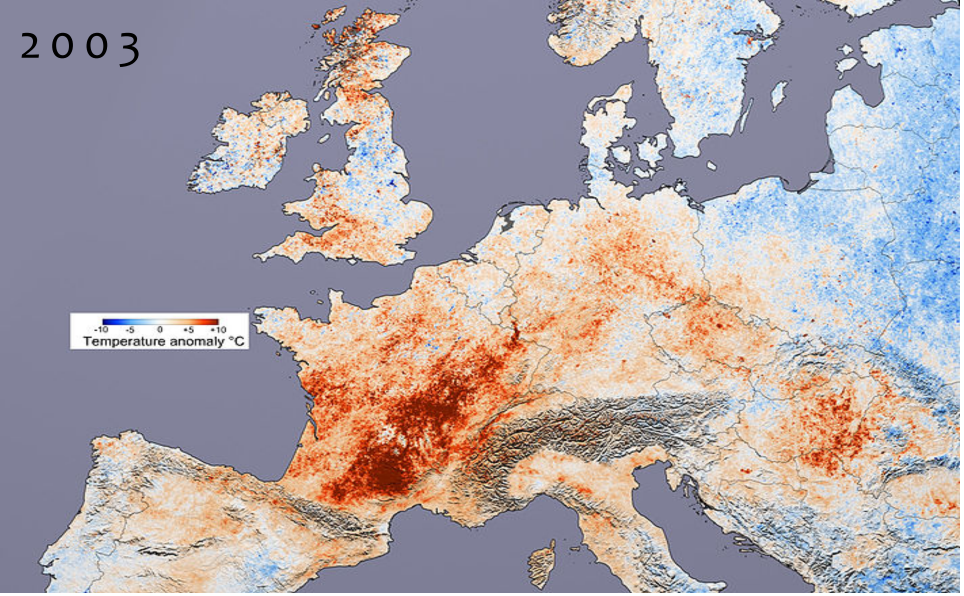
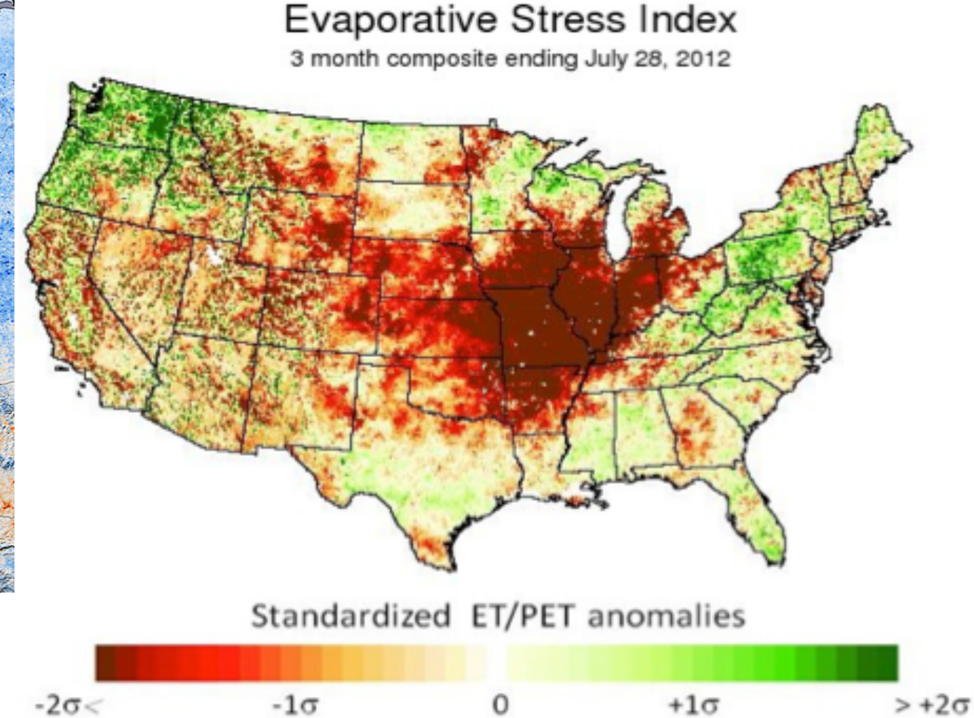


Figure 2.32: Trends in annual frequency of extreme temperatures over the period 1951–2010, for: (a) cold nights (TN10p), (b) cold days (TX10p), (c) warm nights (TN90p) and (d) warm days (TX90p) (Box 2.4, Table 1). Trends were calculated only for grid boxes that had at least 40 years of data during this period and where data ended no earlier than 2003. Grey areas indicate incomplete or missing data. Black plus signs (+) indicate grid boxes where trends are significant (i.e., a trend of zero lies outside the 90% confidence interval). The data source for trend maps is HadEX2 (Donat et al., 2013c) updated to include the latest version of the European Climate Assessment dataset (Klok and Tank, 2009). Beside each map are the near-global time series of annual anomalies of these indices with respect to 1961–1990 for three global indices datasets: HadEX2 (red); HadGHCND (Caesar et al., 2006; blue) and updated to 2010 and GHCNDEX (Donat et al., 2013a; green). Global averages are only calculated using grid boxes where all three datasets have at least 90% of data over the time period. Trends are significant (i.e., a trend of zero lies outside the 90% confidence interval) for all the global indices shown.





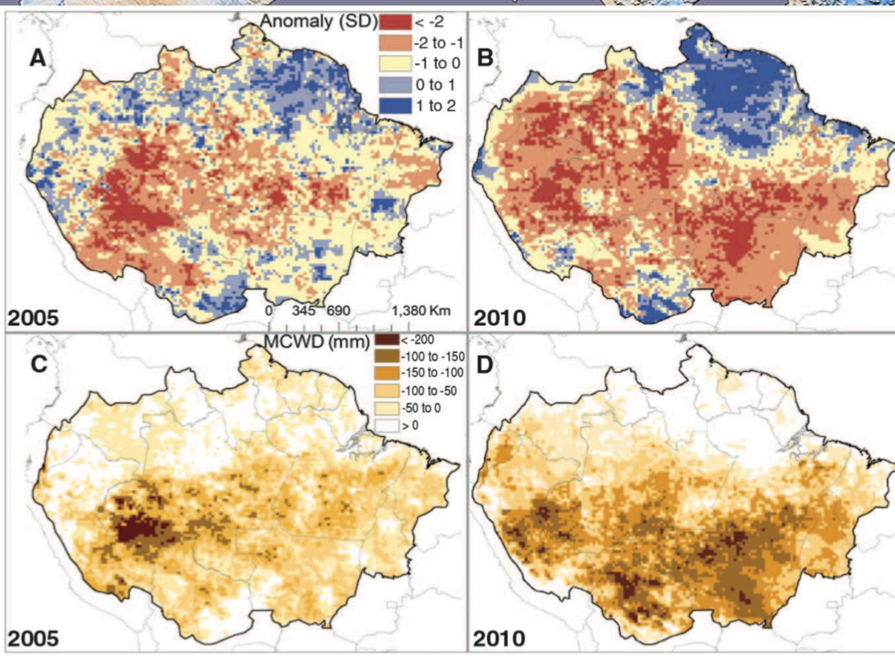
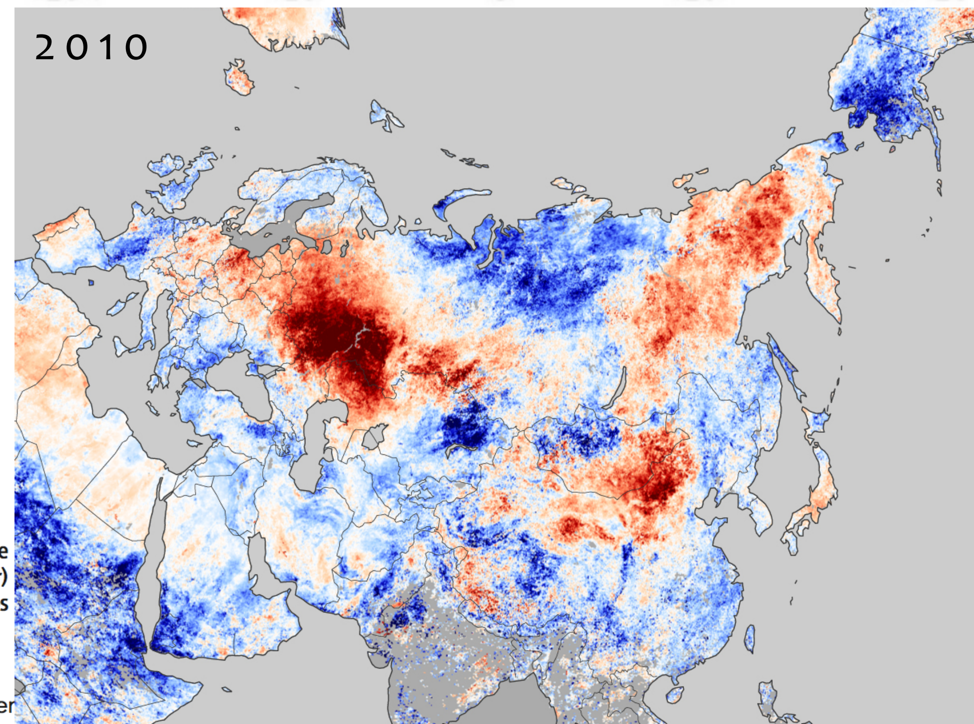
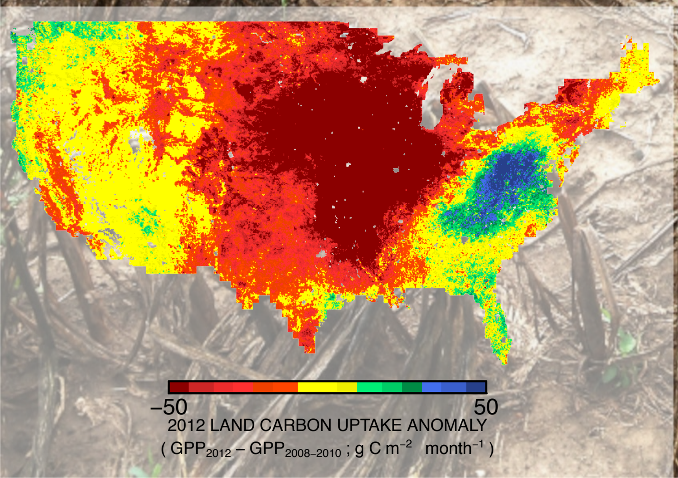


Fig. 1. (**A** and **B**) Satellite-derived standardized anomalies for dry-season rainfall for the two most extensive droughts of the 21st century in Amazonia. (**C** and **D**) The difference in the 12-month (October to September) MCWD from the decadal mean (excluding 2005 and 2010), a measure of drought intensity that correlates with tree mortality. (A) and (C) show the 2005 drought; (B) and (D) show the 2010 drought.



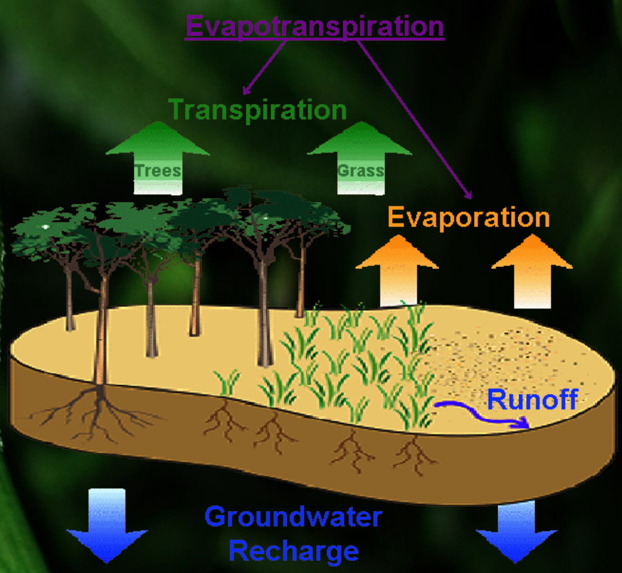
US Drought of 2011-12:

- Affected natural ecosystems
- Devastated agricultural production
- Reduced total GDP, threatened food security



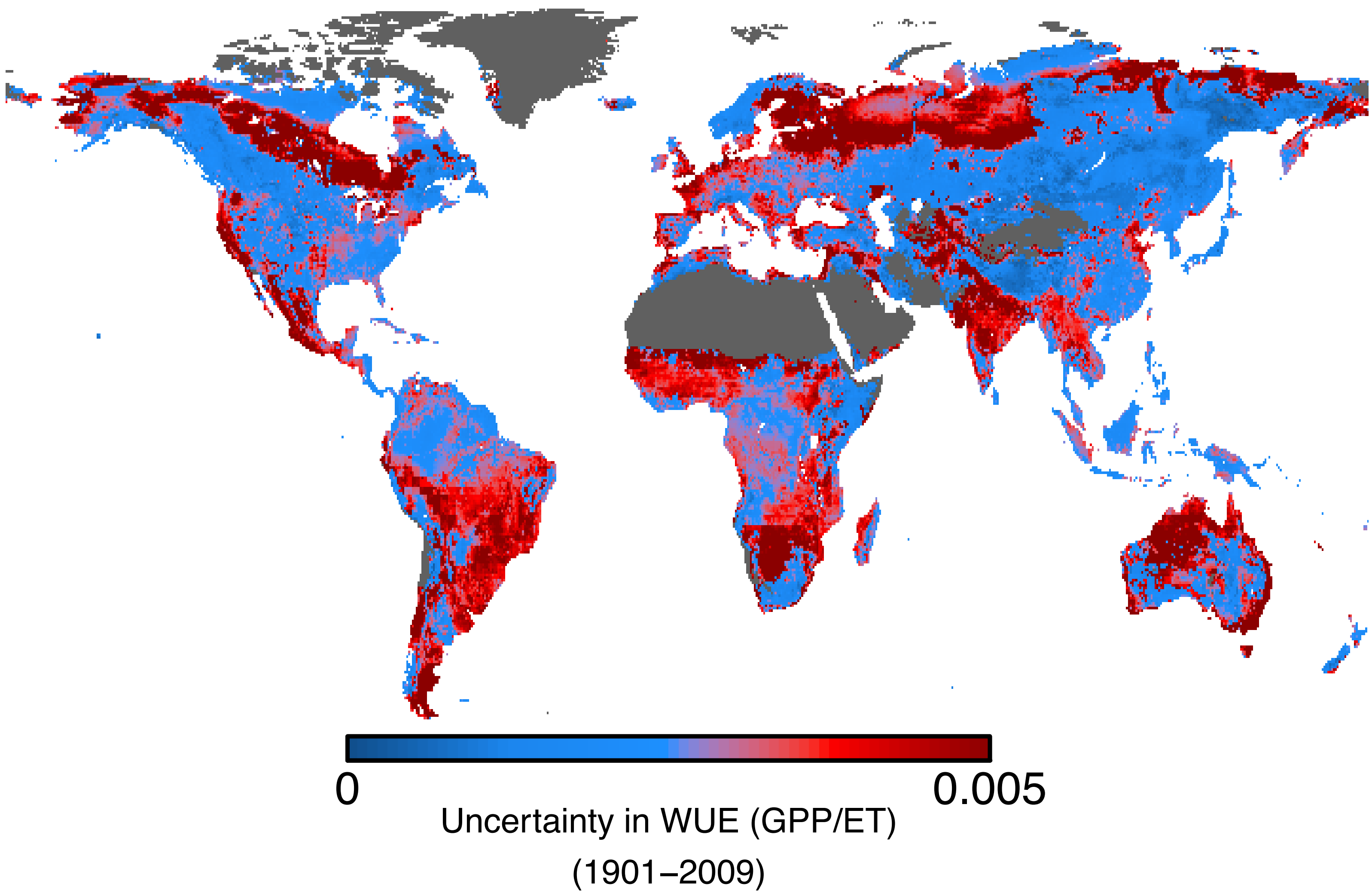
What does this all mean for Evapotranspiration (ET)?

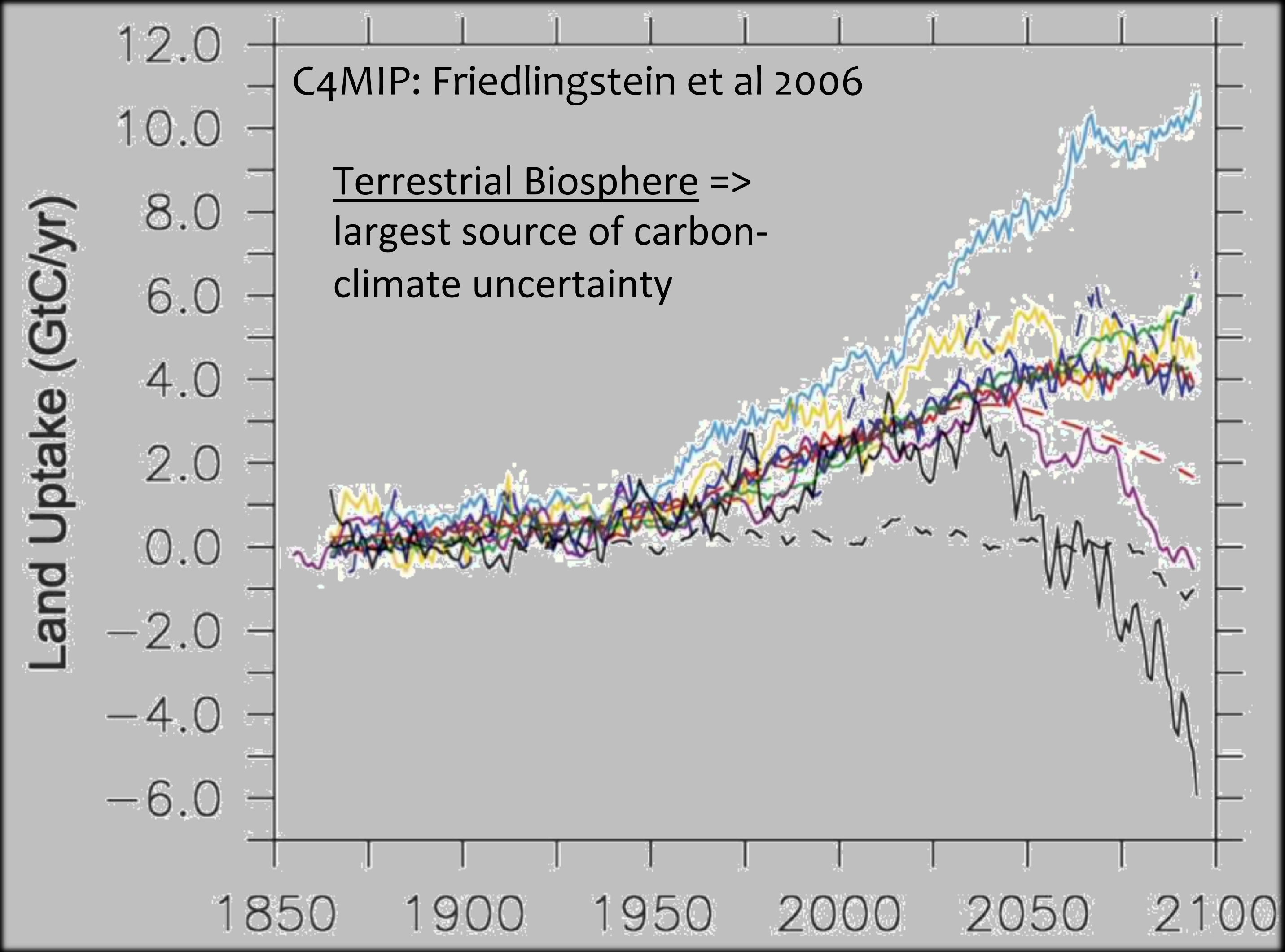
- Ecosystem response to heat stress measured with ET
- Plants regulate water loss by closing pores, but at expense of shutting off CO2
- Transpiration performs same cooling function as sweat in human body



WATER USE EFFICIENCY (WUE): UNCERTAINTY

WUE: Plant's ability to fix a large amount of carbon using little amount of water

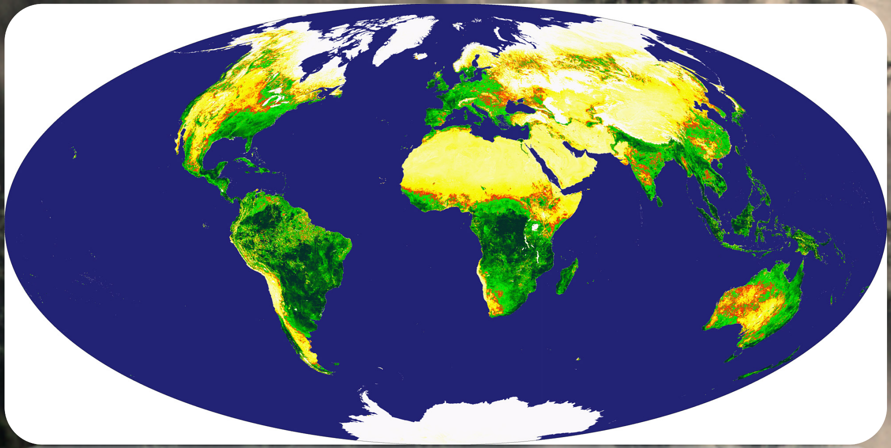


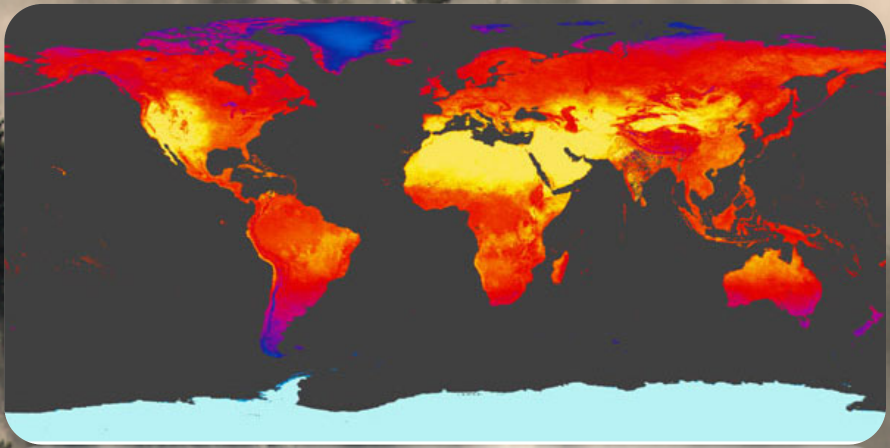


C4MIP: Friedlingstein et al 2006
Terrestrial Biosphere => largest source of carbon-climate uncertainty
Land Uptake (GtC/yr)
12.0
10.0
8.0
6.0
4.0
2.0
0.0
−2.0
−4.0
−6.0
1850
1900
1950
2000
2050
2100

EVAPOTRANSPIRATION
how do we get it?

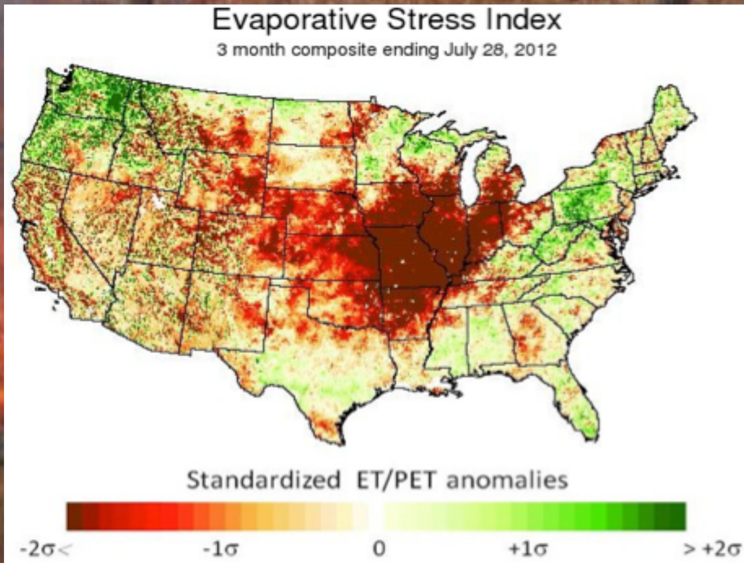
- Ground – eddy covariance sites (FLUXNET)
- Remote sensing – latent heat flux (energy variable)
- Calculated using VSWIR (phenology) and TIR (water cycle)

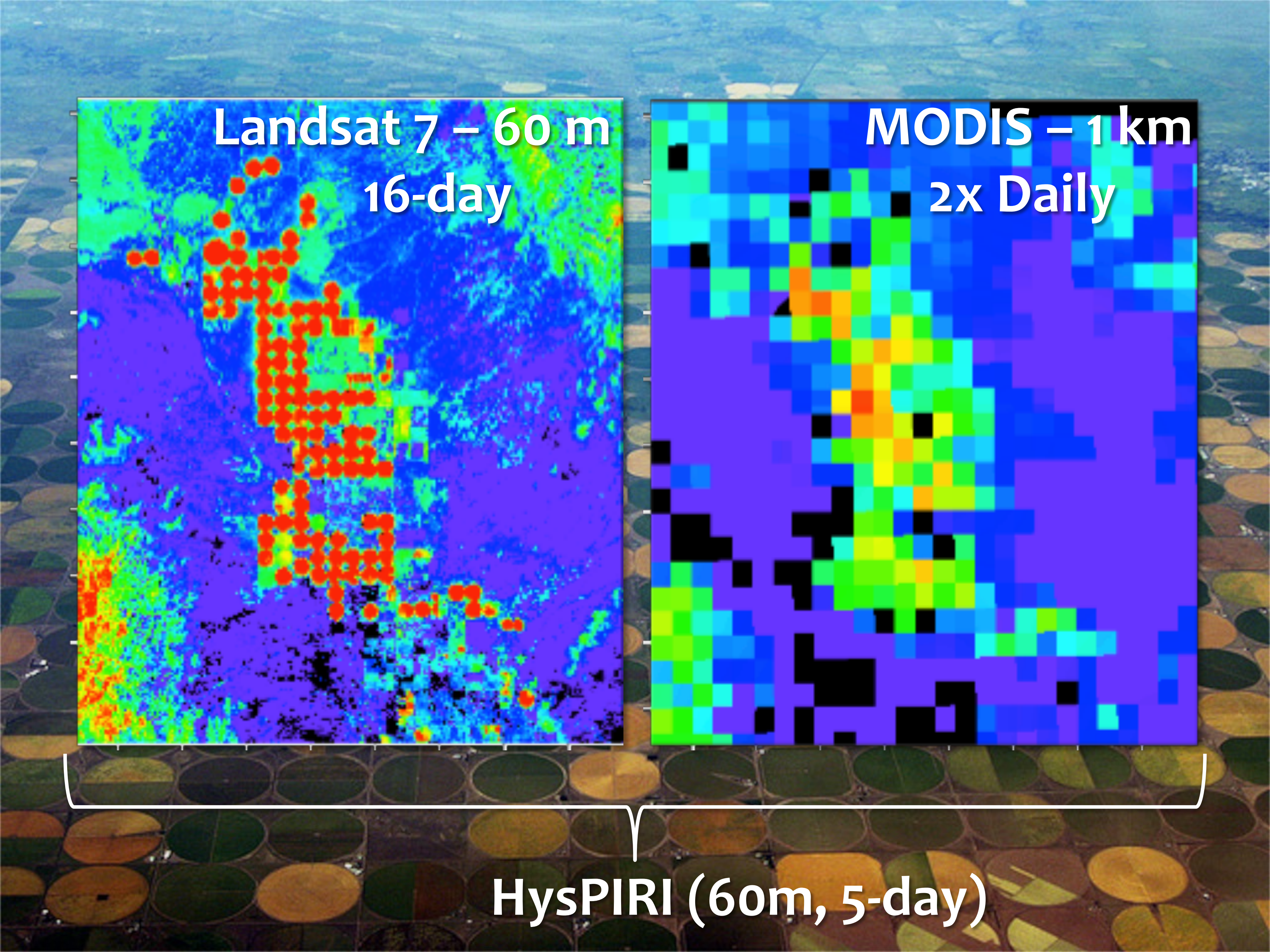




When ET is ↑, LST is ↓; and vice versa.

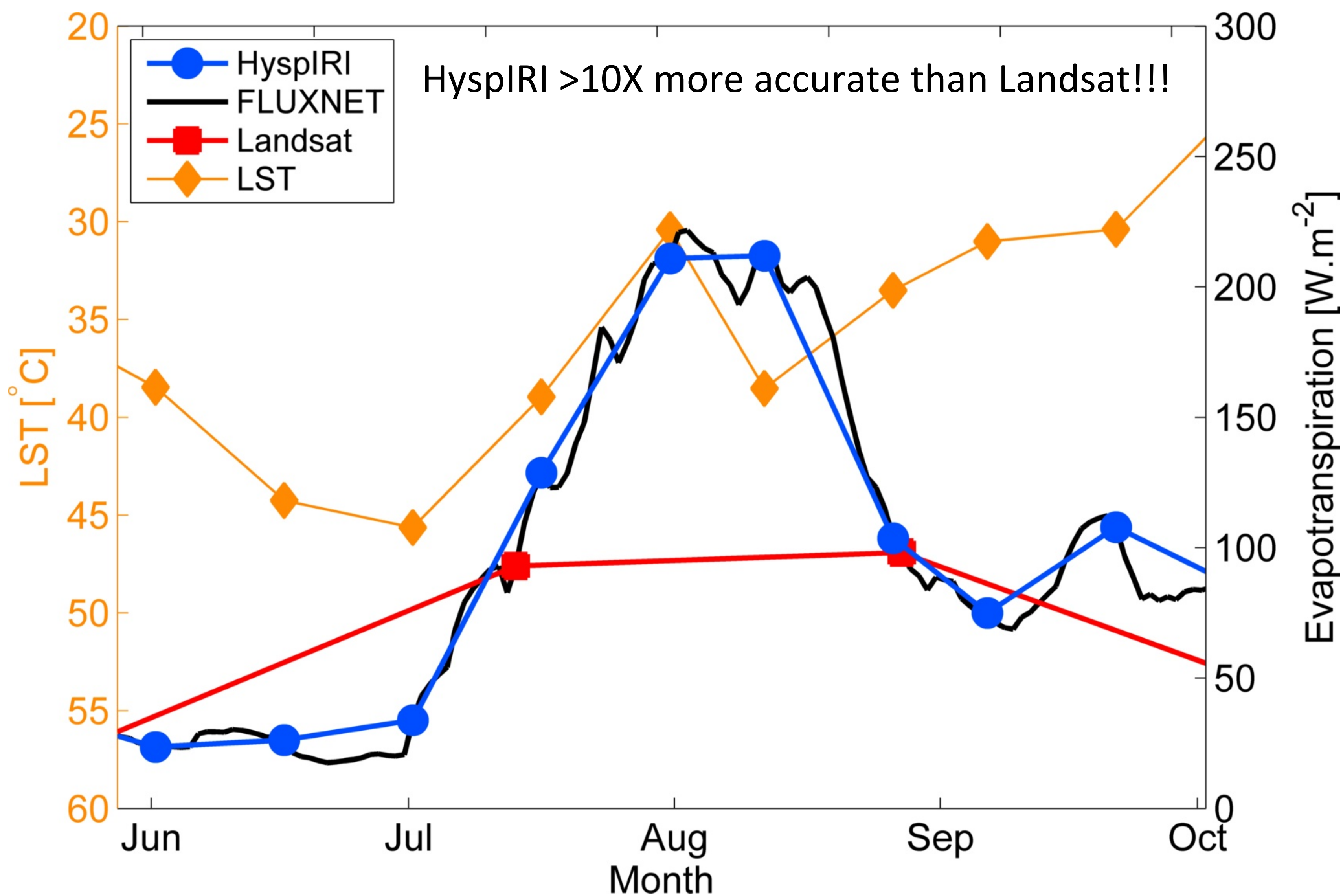
Water stress = ET/PET<1



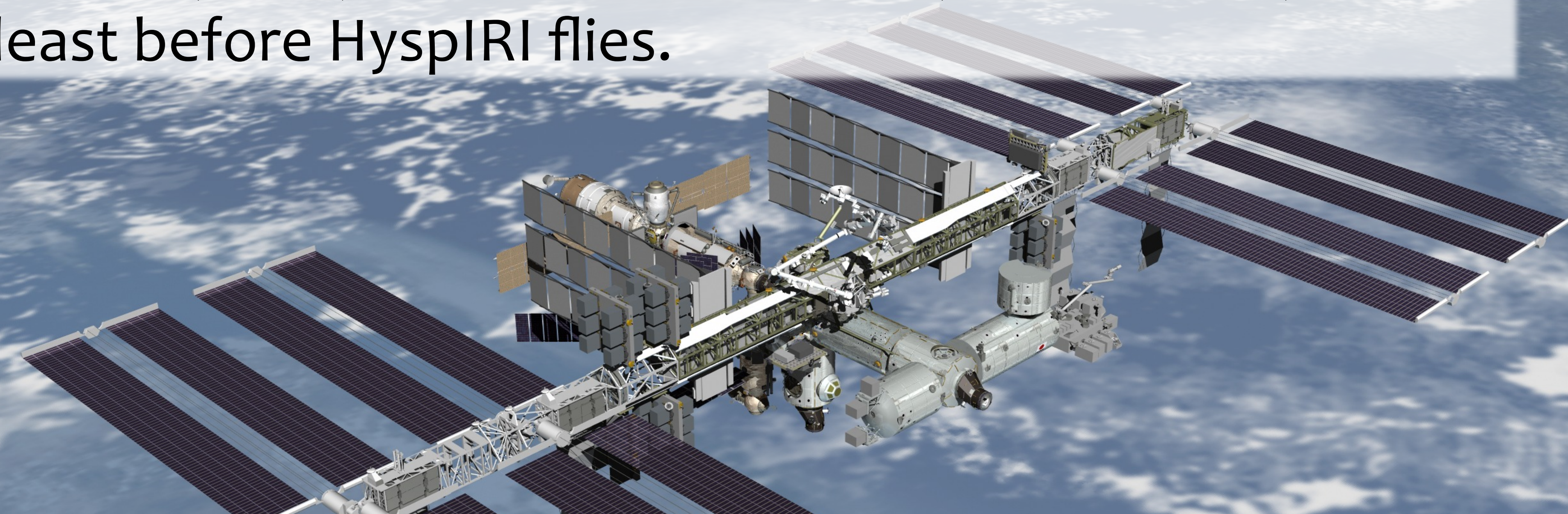

Landsat 7 – 60 m
16-day
MODIS – 1 km
2x Daily
HysPIRI (60m, 5-day)

Simulated HyspIRI ET over a Seasonal Cycle

- Santa Rita FLUXNET site data (Tuscon, AZ)
- 2 out of 3 observations removed to simulate cloud exposure

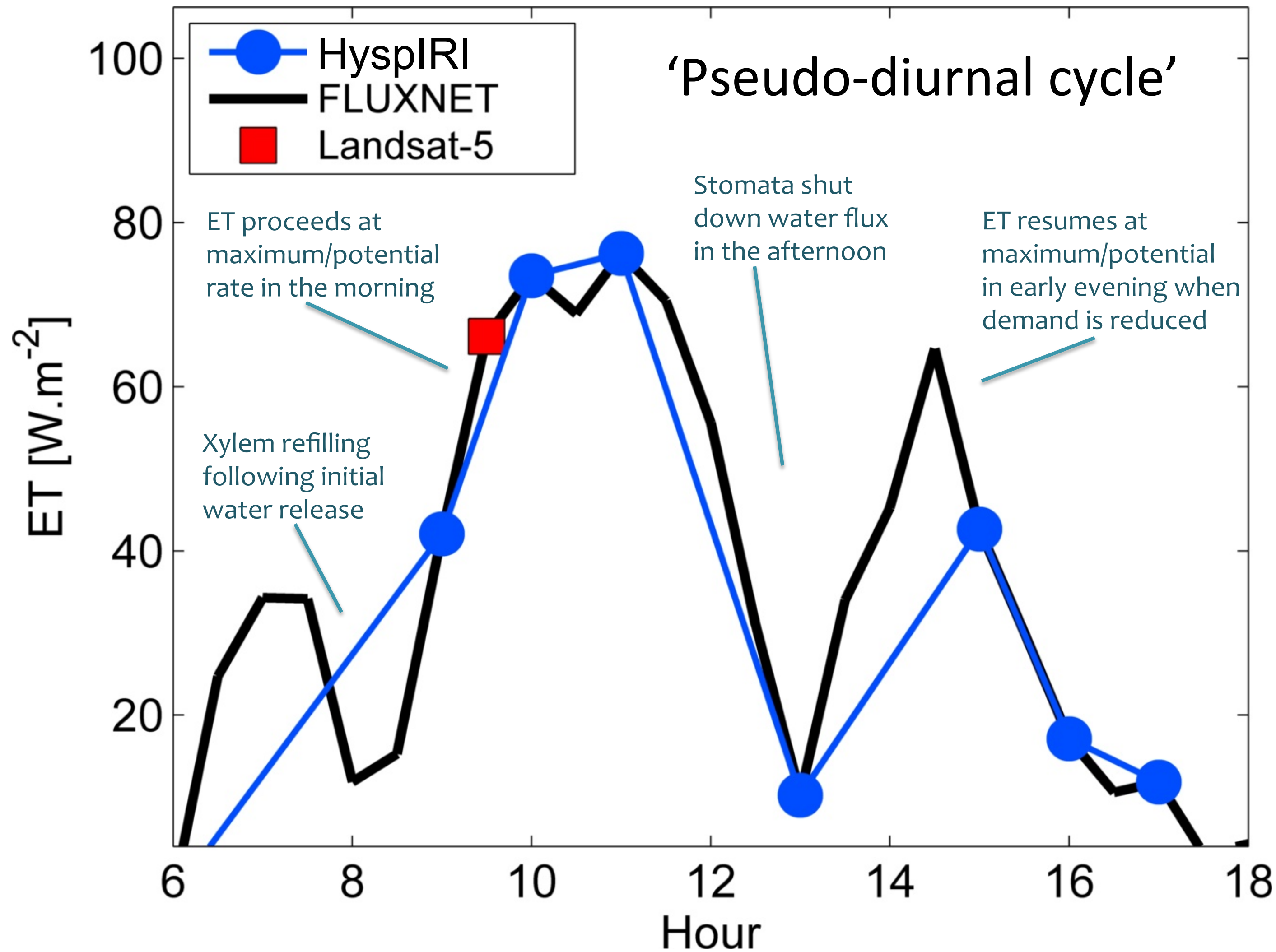


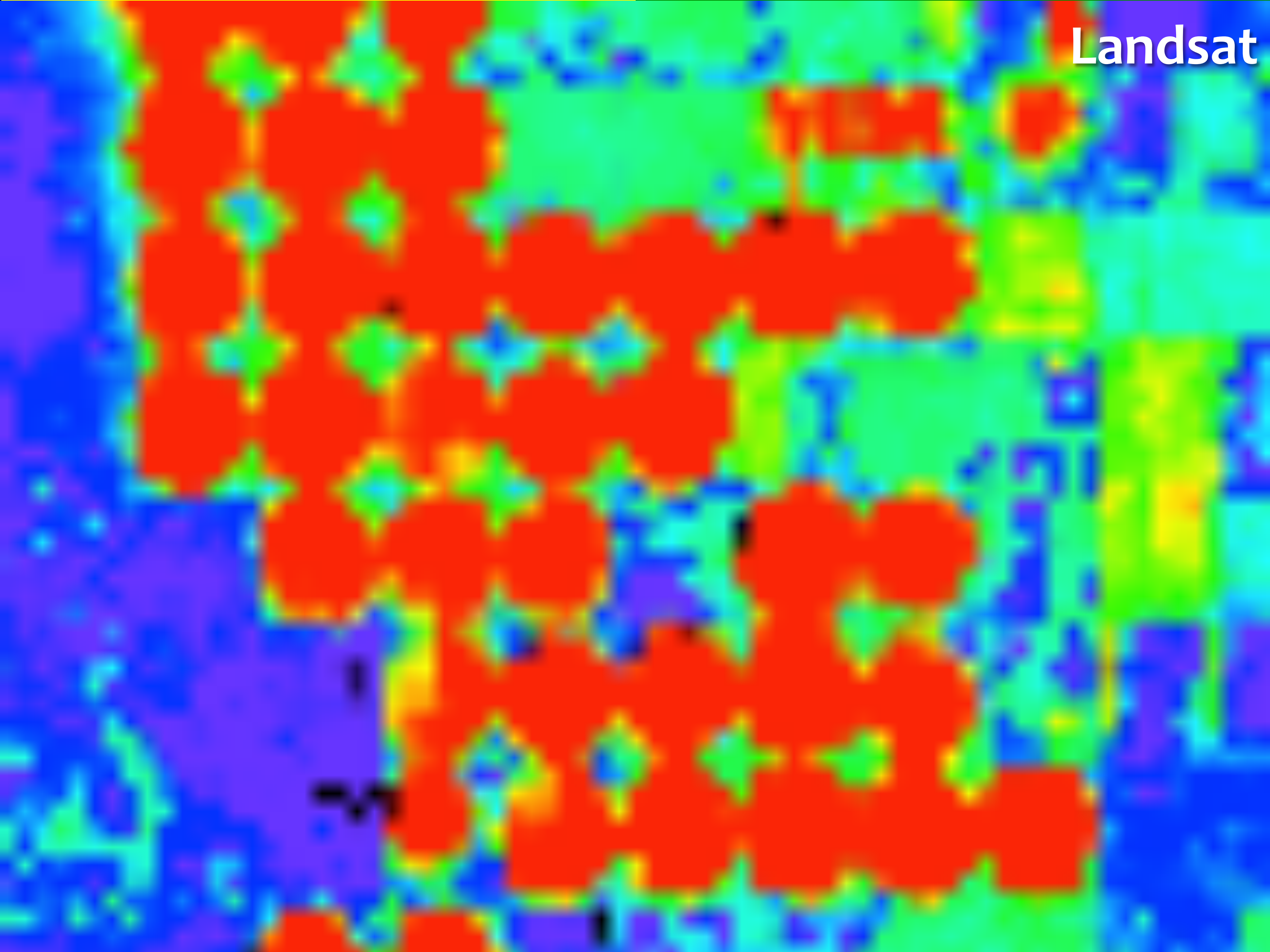
Need for HysPIRI-TIR ISS-based instrument (PHyTIR) to capture Ecosystem Stress responses at appropriate spatial (40 m) and temporal scales (diurnal cycle), at least before HyspIRI flies.



Simulated HyspIRI-TIR ET on ISS

(50° N, 1-14 September)

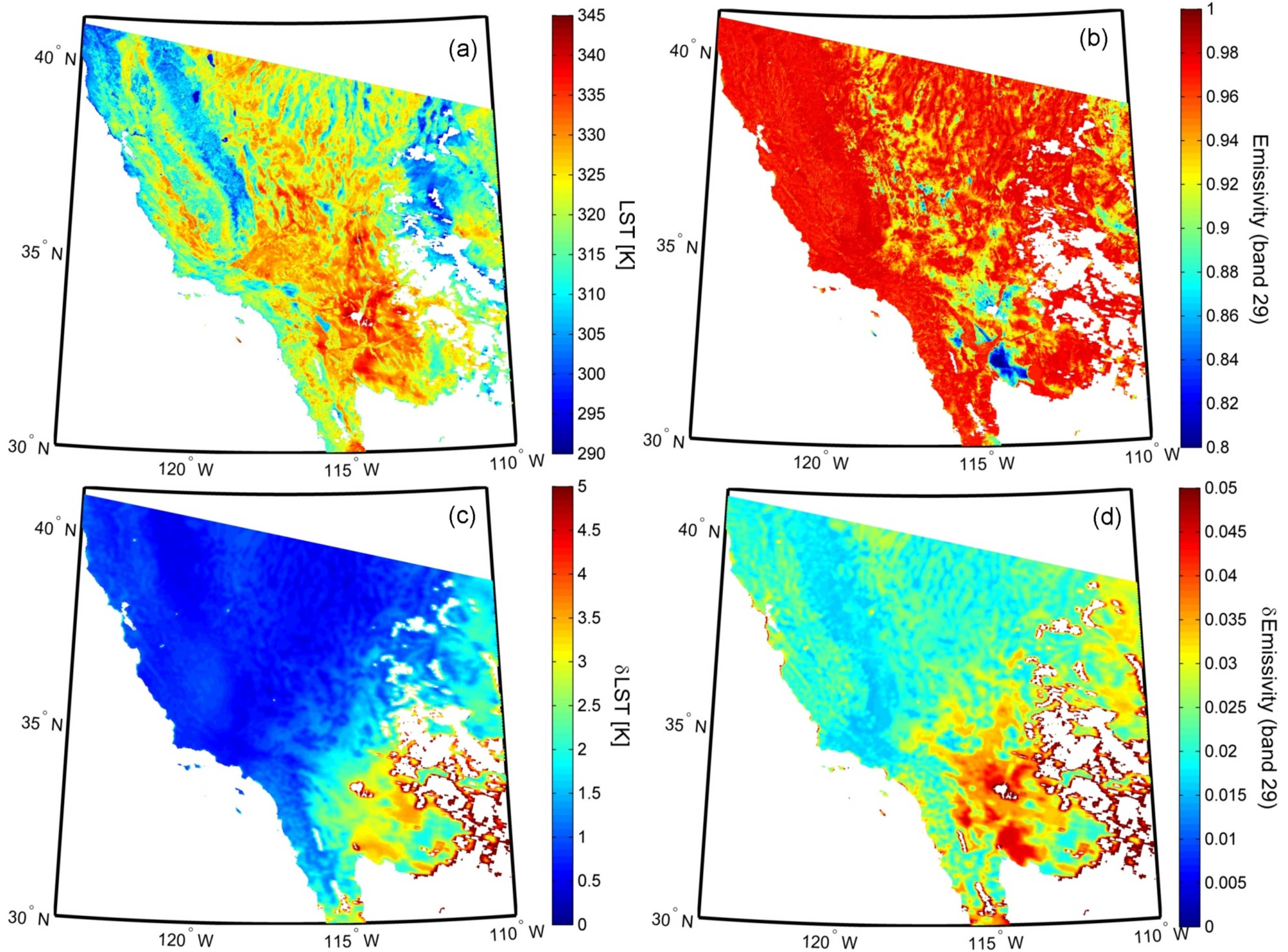



Landsat

WHAT IS THE UNCERTAINTY IN ET WHEN LST IS UNCERTAIN?

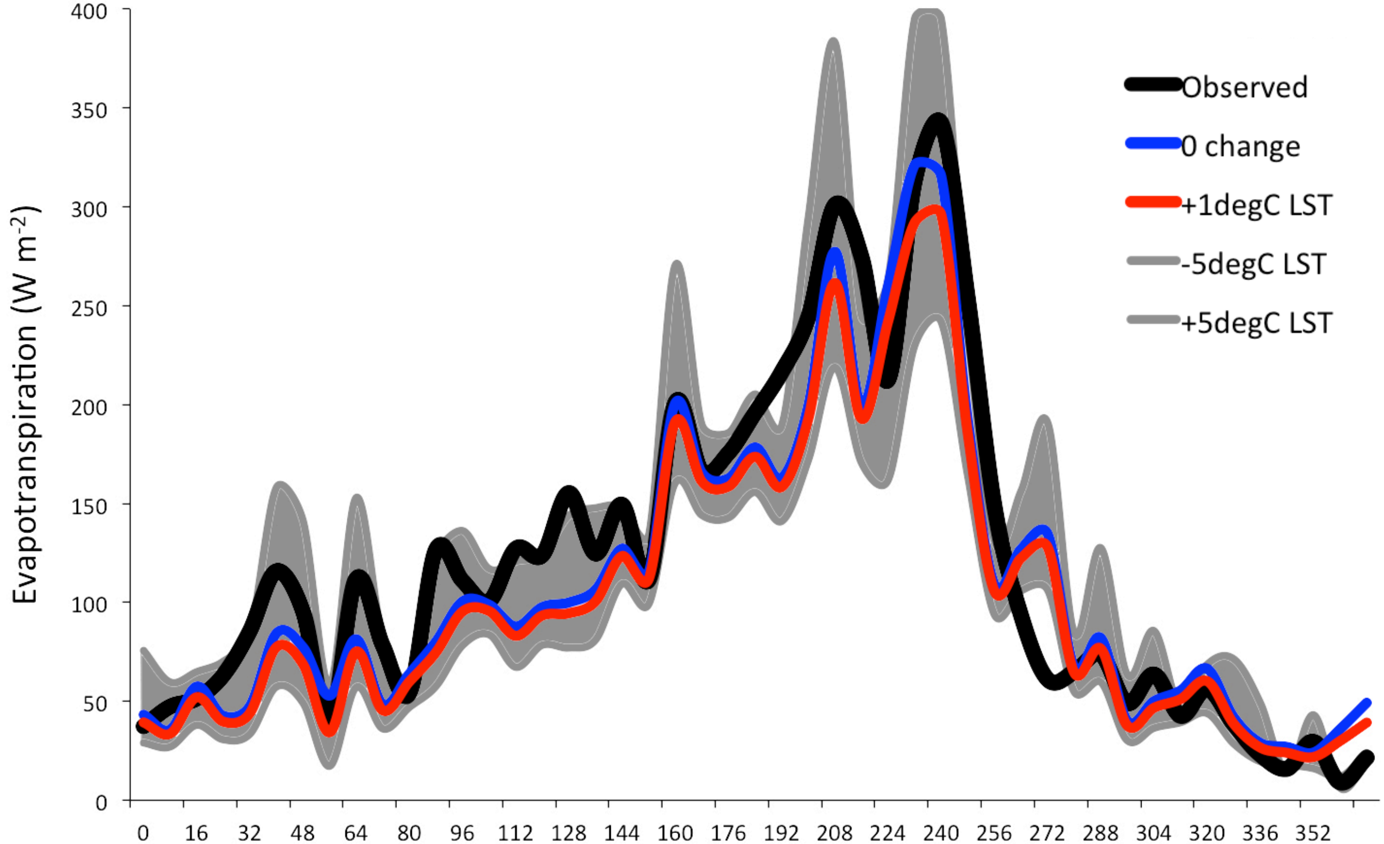
- What are requirements necessary for producing ET low enough to accurately estimate stress responses in space and time?

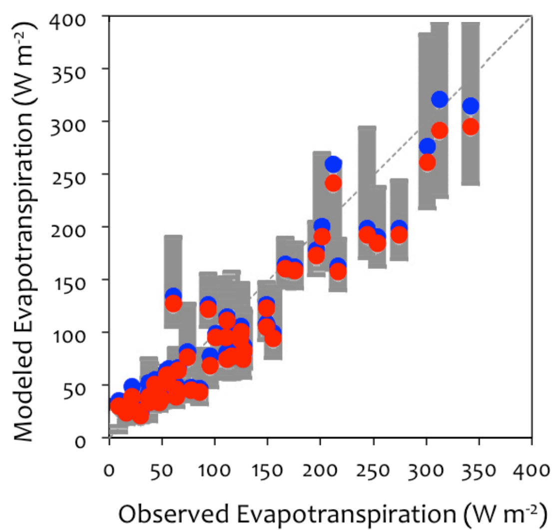
WHAT IS THE UNCERTAINTY IN LST?



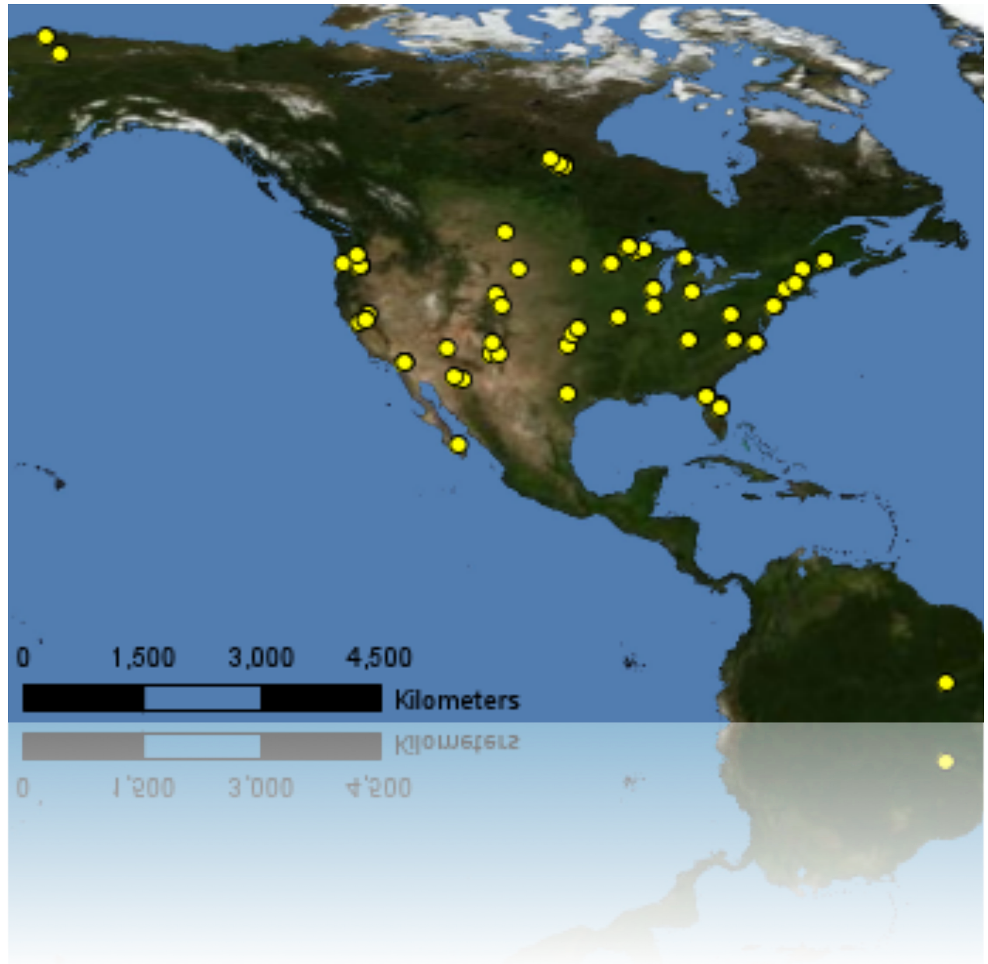
(a)
LST [K]
345
340
335
330
325
320
315
310
305
300
295
290
(b)
Emissivity (band 29)
1
0.98
0.96
0.94
0.92
0.9
0.88
0.86
0.84
0.82
0.8
(c)
δLST [K]
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
(d)
δEmissivity (band 29)
0.05
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
40° N
35° N
30° N
120° W
115° W
110° W

WHAT IS THE UNCERTAINTY IN ET WHEN LST IS UNCERTAIN?

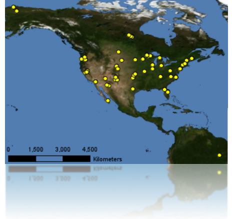


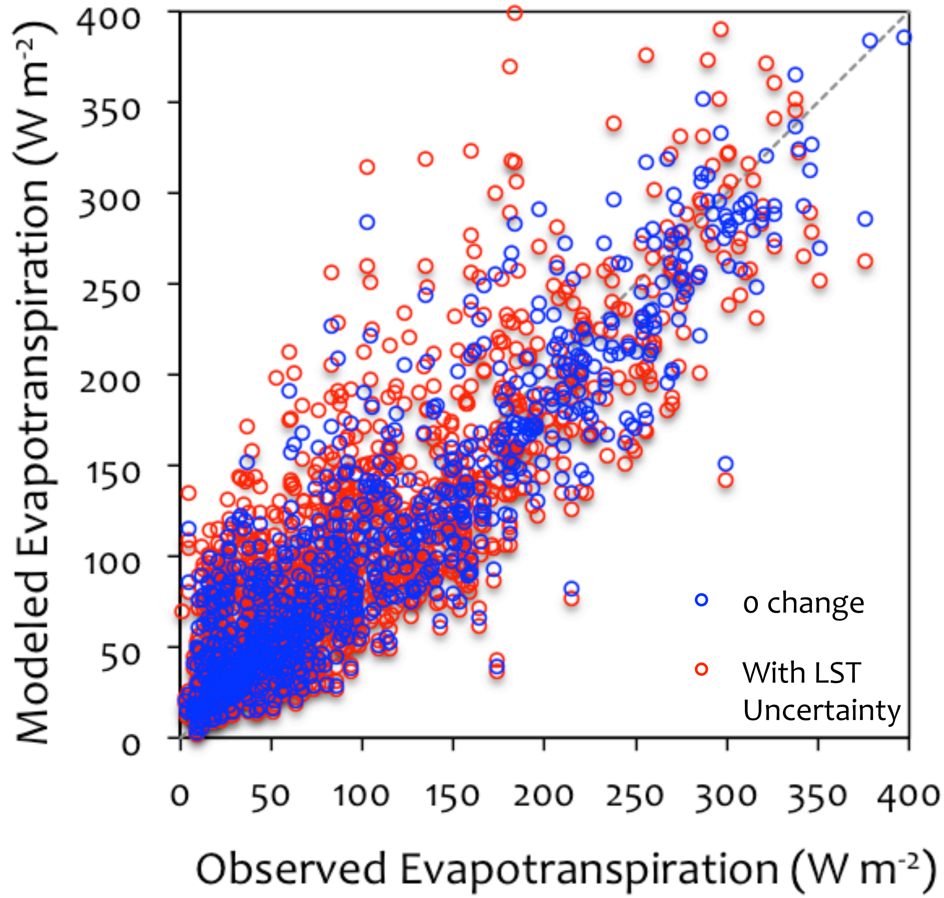


	0Δ	+1°C	±5°C
m			
r^2			
RMSE			

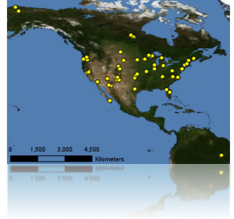

0 1,500 3,000 4,500
Kilometers

site-level ET uncertainty from LST uncertainty

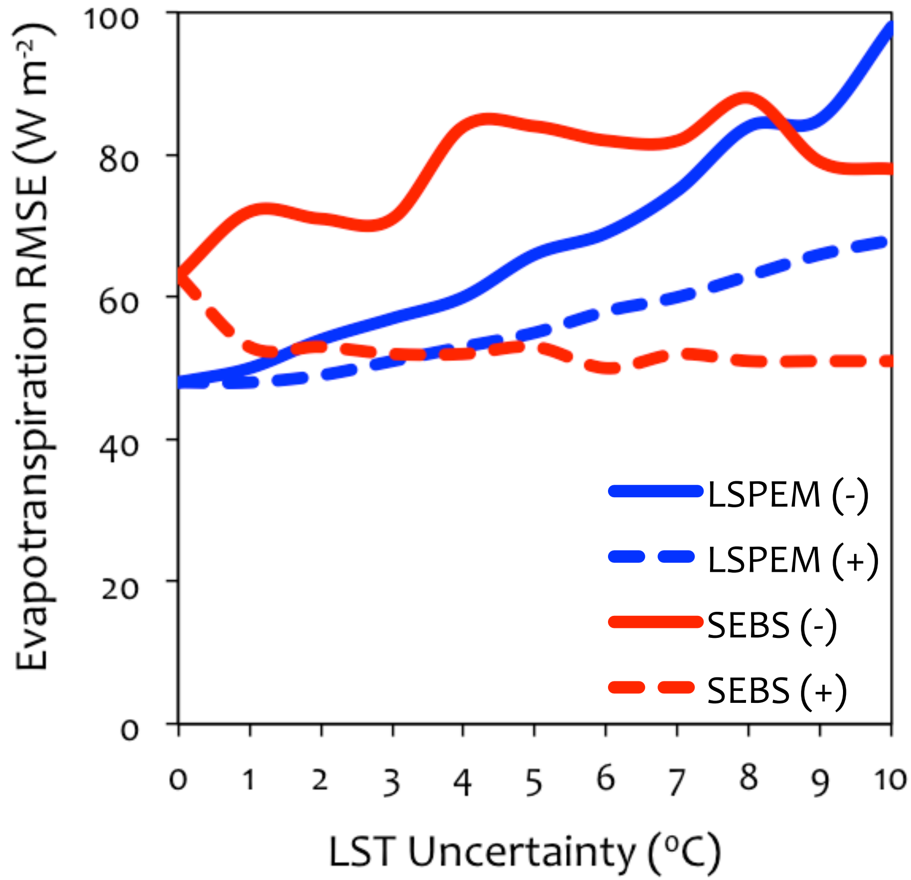


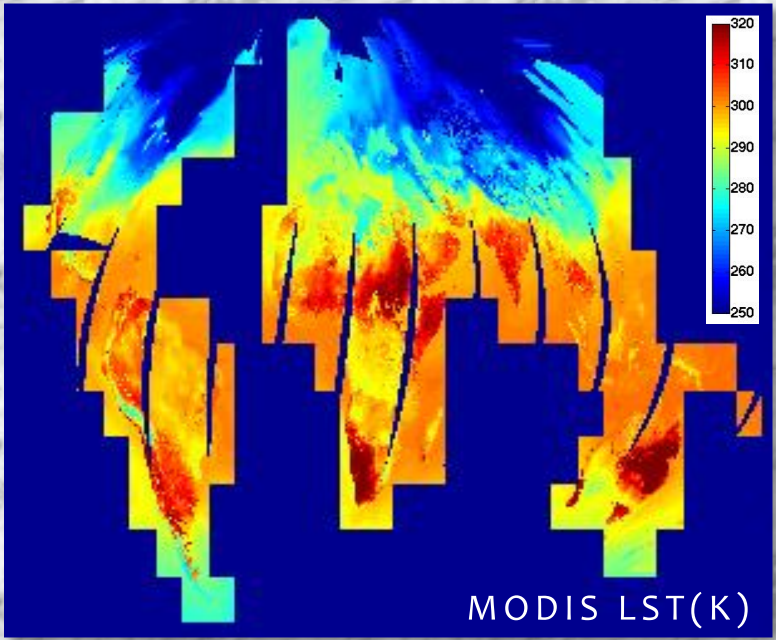


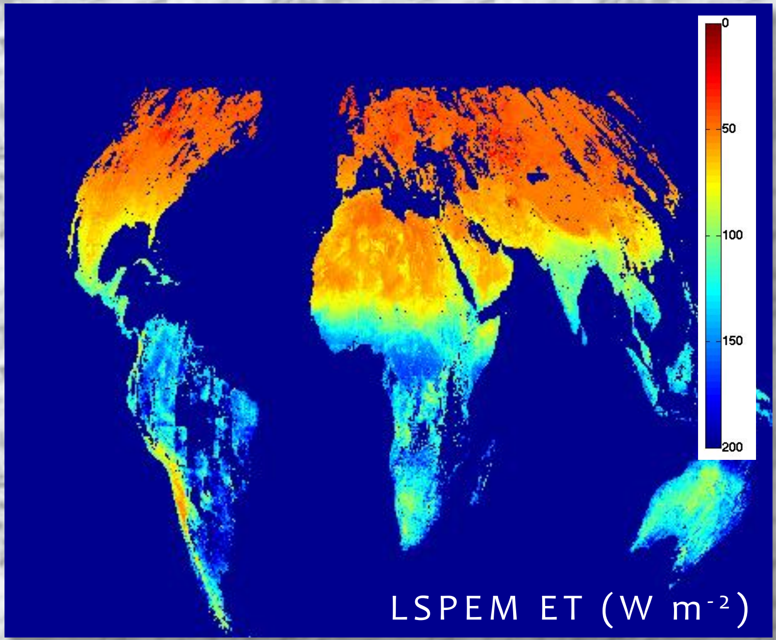
	0Δ	Δ◦C
m	0.99	
r^2	0.82	
RMSE	37.7	

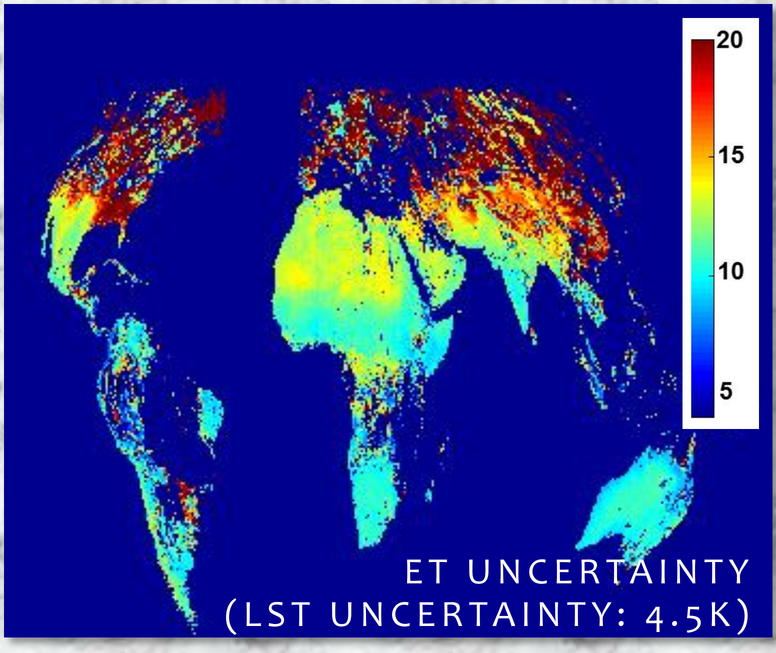


site-level ET uncertainty sensitivity from LST uncertainty









- **ET UNCERTAINTY**
  $= abs(ET^{LST0}-ET^{LST+})+abs(ET^{LST0}-ET^{LST-})$
  $= abs(50-51\ W\ m^{-2})+abs(50-58\ W\ m^{-2})$
  = **9 W m^{-2} (global mean)**

- **ET SENSITIVITY**
  $= abs(ET^{LST+}-ET^{LST-})/ET^{LST0}$
  $= abs(51-58\ W\ m^{-2})/50\ W\ m^{-2}$
  = **14% (global mean)**

CONCLUSIONS

- APPROACH
  - Uncertainty in LST was determined for MODIS (also for AIRS, ASTER, Landsat) through JPL's NASA ESDR project;
  - 2 LST-dependent ET models (LSPEM, SEBS) were tested for sensitivity and uncertainty due to LST uncertainty across all available FLUXNET sites;
    - More sites currently being included;
- RES[illegible]
  - RM[illegible]E in[illegible]ea[illegible]ed b[illegible]p[illegible] 1[illegible] W[illegible] for LSP[illegible] a[illegible] 7 [illegible] f[illegible] S[illegible]BS;
  - r^2 [illegible]crea[illegible]ed[illegible]y [illegible] 0[illegible]8 [illegible]or [illegible] LSPEM [illegible]nd [illegible];
  - LSEPM is ~linearly sensitive to uncertainty in LST, whereas SEBS uncertainty is more complex;
  - Globally, ET estimates vary by 2-14% (LSPEM) given 4.5◦C error in LST;
    - SEBS and TSEB to be included;
    - An extended time series is currently being conducted;
    - A pixel-explicit LST uncertainty is currently being generated;
- IMPLICATIONS
  - If we want ET uncertainty from LST uncertainty to be <10%, then LST uncertainty needs to be <2◦C. ➔ implications for future instruments.

Thank you!