Agricultural land use change and regional climate

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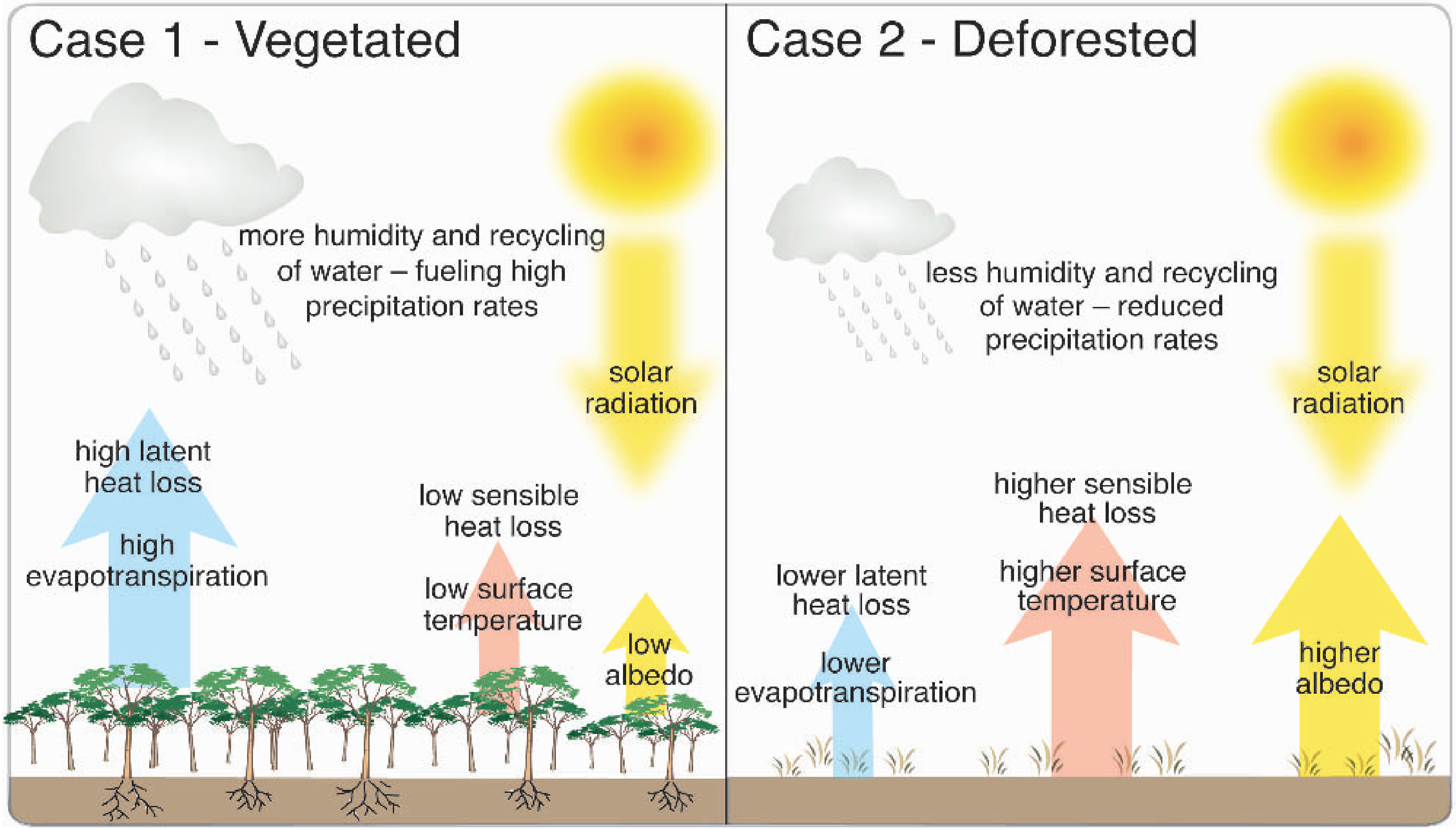
photo: Trevor Keyler

Local climate regulation by ecosystems



Foley et al. 2003, Frontiers in Ecology & Env.

Outline

1. “Local” scale: Assessing the impacts of recent land cover change using MODIS
   - Collaborators: Bill Smith, Tyler Lark, Holly Gibbs, Missy Holbrook, and Peter Huybers
2. Regional scale: Centennial trends in extreme temperatures and agricultural land use
   - Collaborators: Ethan Butler, Karen McKinnon, Andrew Rhines, Martin Tingley, Missy Holbrook, and Peter Huybers
3. Global scale: Ag. land use and extreme temperatures across major temperate cropping systems
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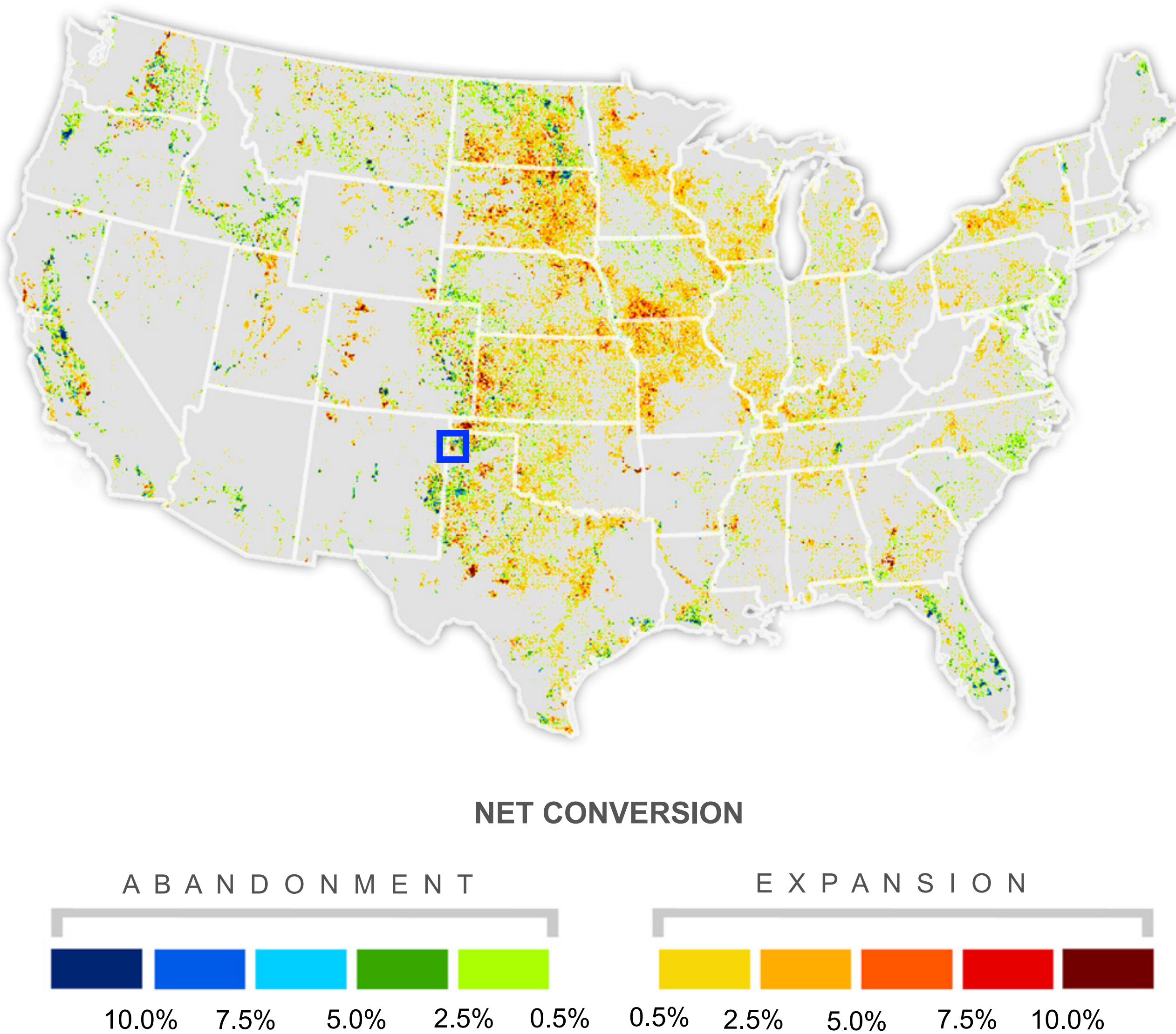
4. Implications for pest management under climate change

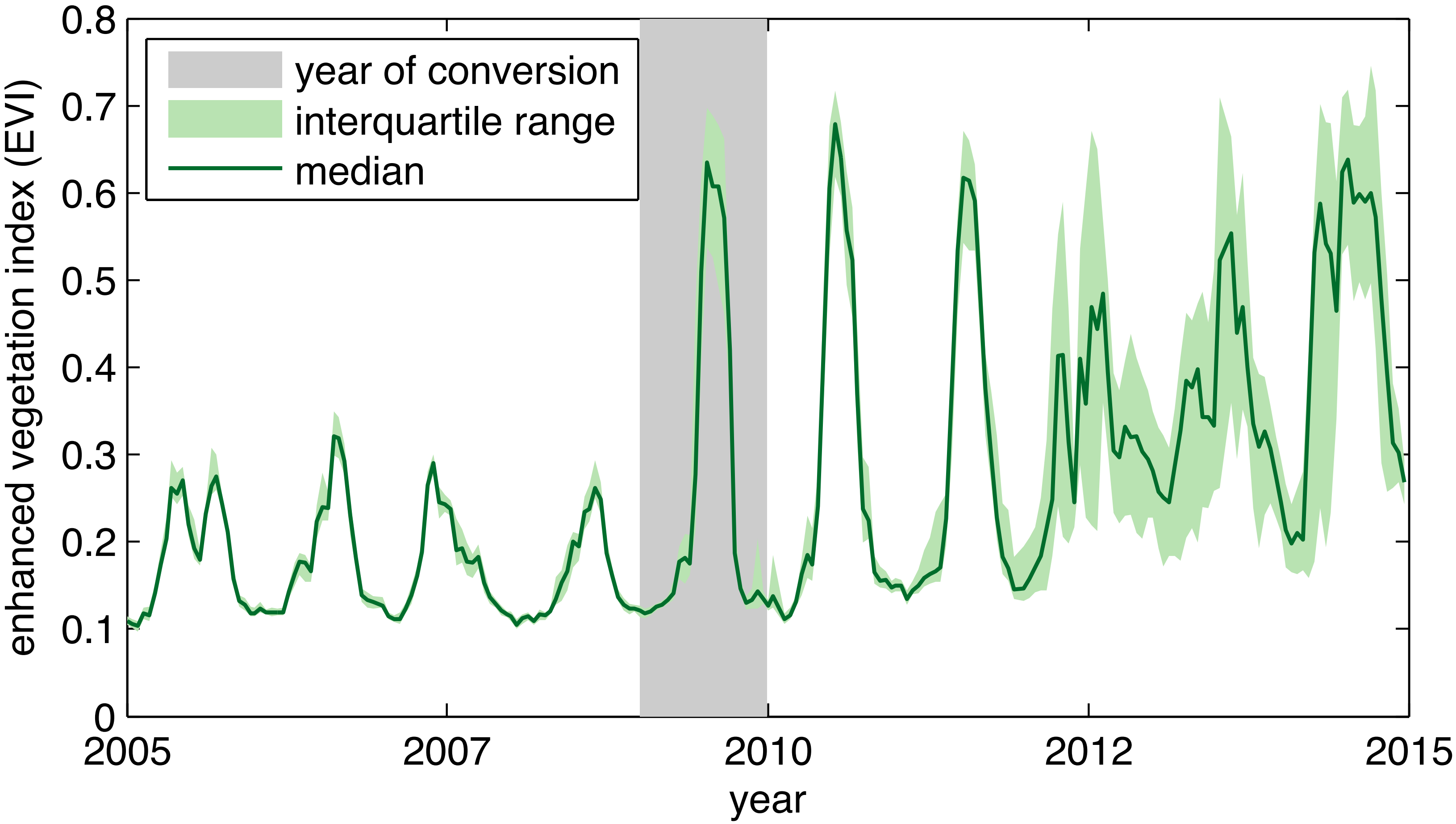
Recent cropland expansion: 2008–2012



Lark et al. 2015 ERL

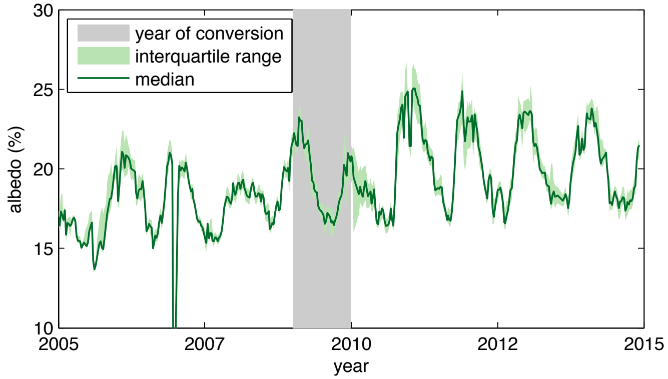
- Net conversion of 3 million acres into cropland
- Based on USDA cropland data layer
- High commodity prices

Texas Panhandle EVI: 2009 conversion of grass to maize

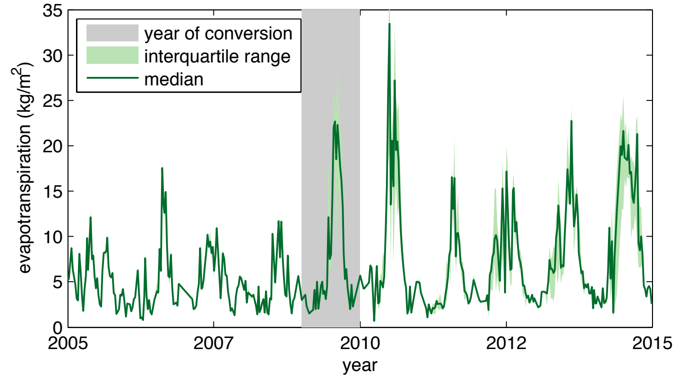


Mueller et al. in prep

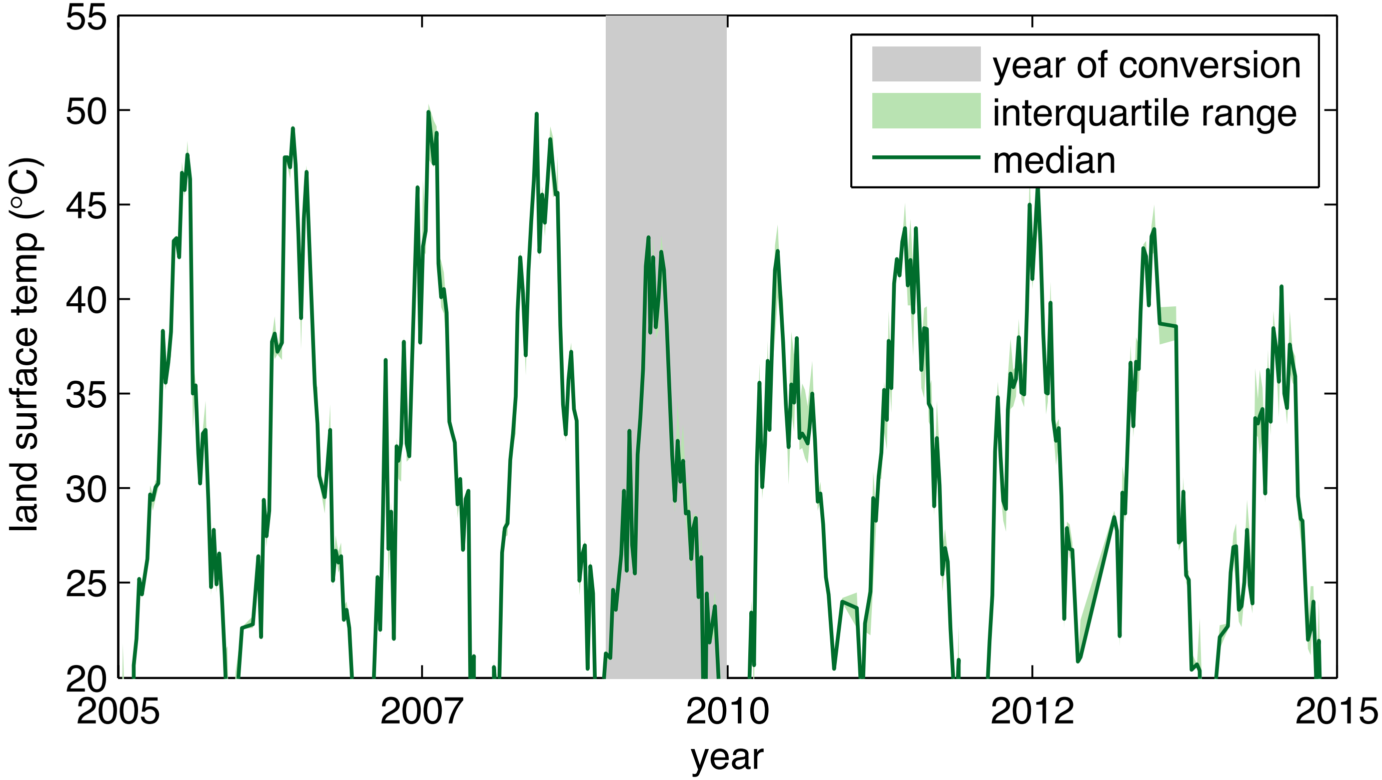
albedo



evapotranspiration (ET)



land surface temperature (LST)



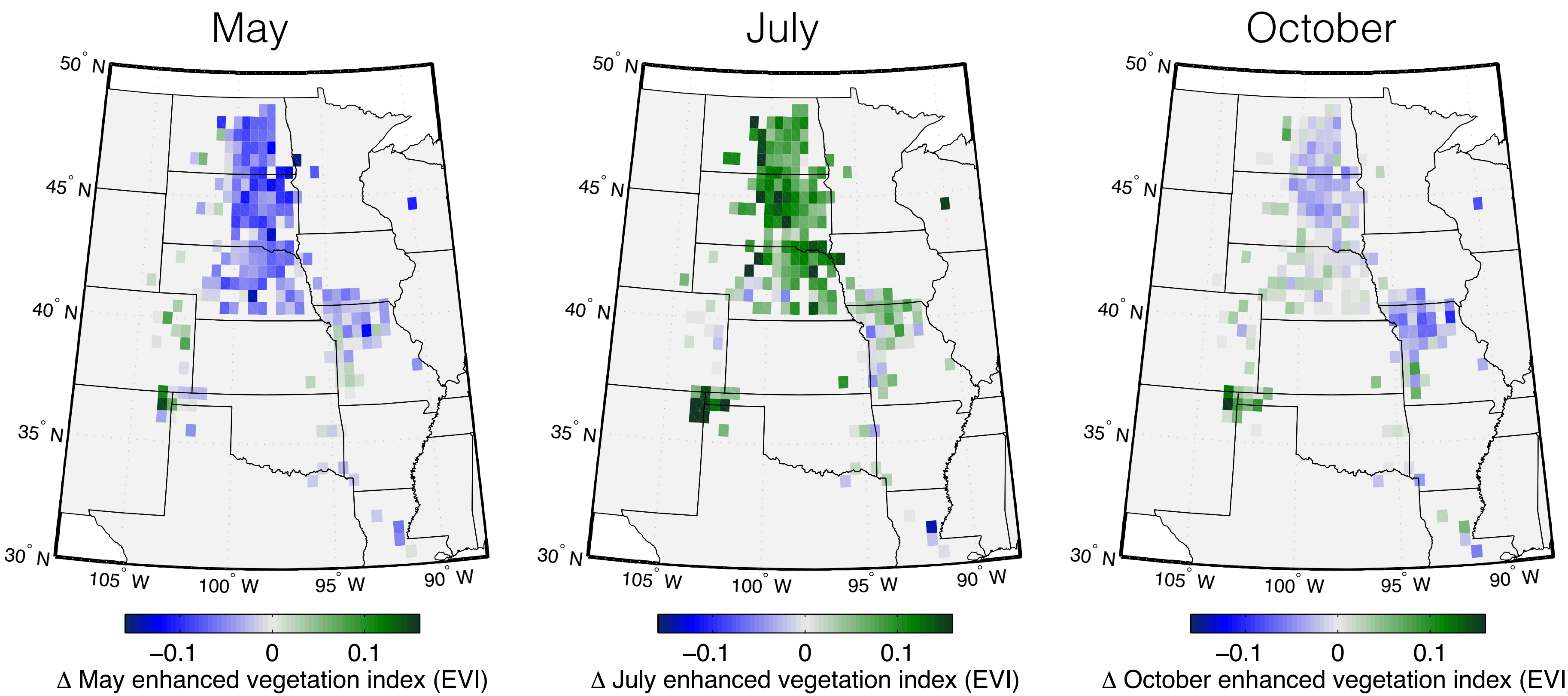
Texas Panhandle:

conversion of grass to maize

estimated ET from MODIS ET algorithm (Mu et al. 2011)

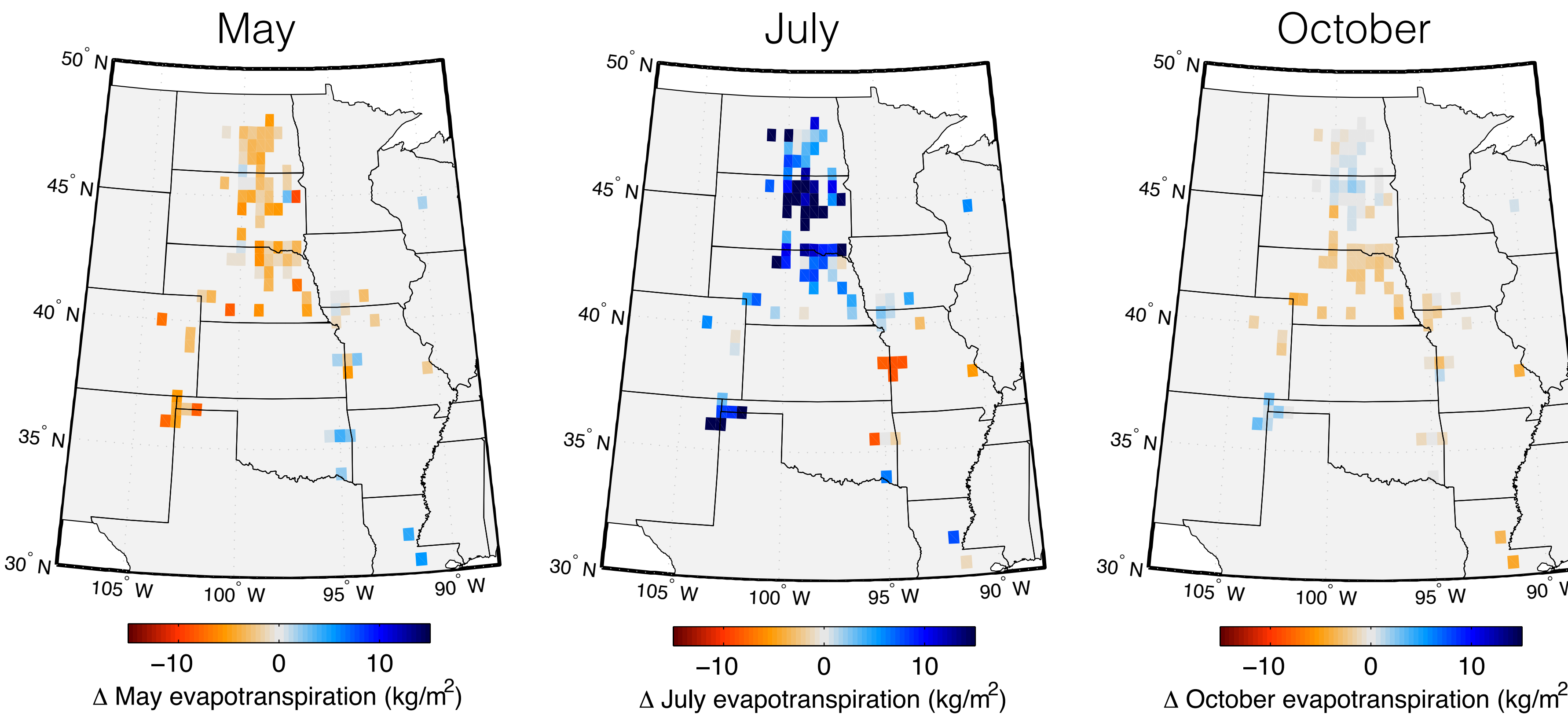
Mueller et al. in prep

Regional ΔEVI from conversion of grass to maize and soybeans



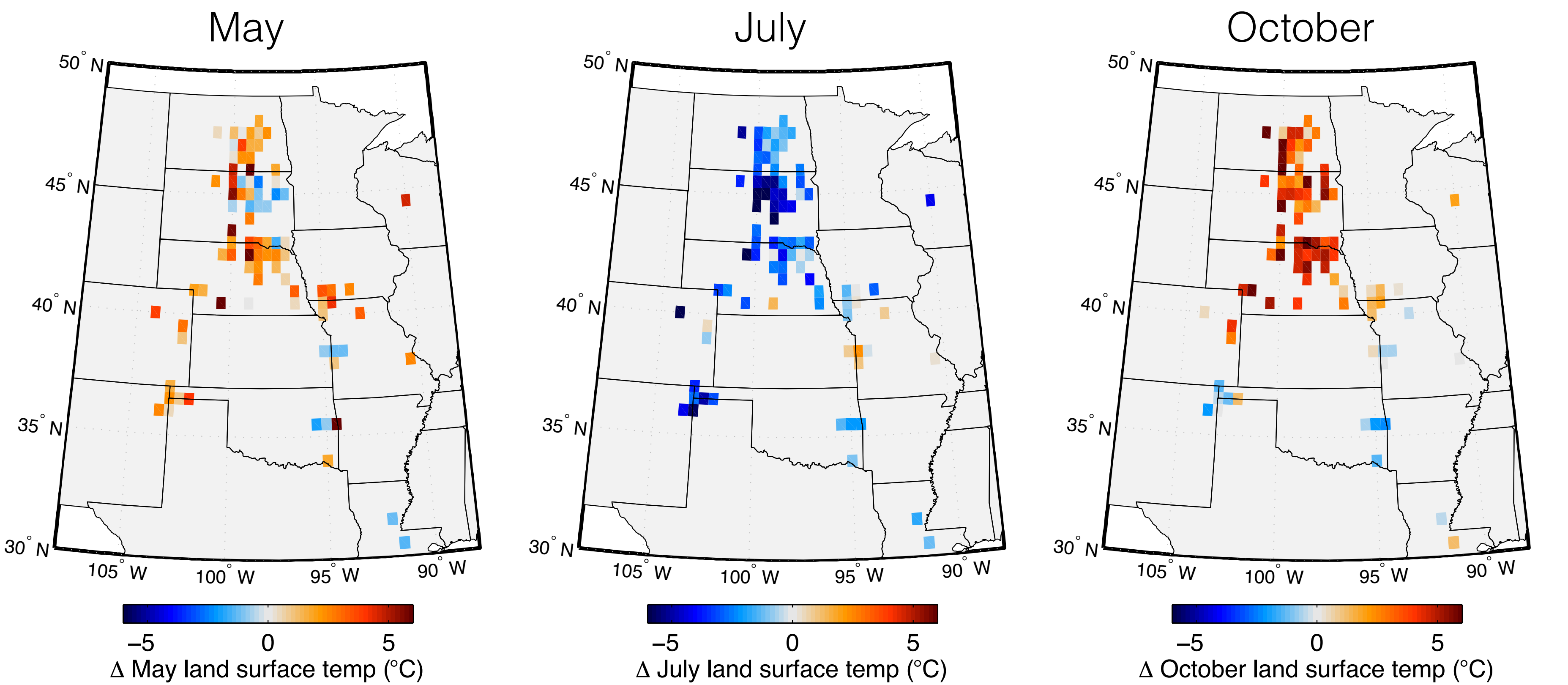
Average EVI difference post – pre-conversion from MODIS pixels with >75% conversion, binned to 0.5 degree grid cells

Regional ΔET from conversion of grass to maize and soybeans



Average EVI difference post – pre-conversion from MODIS pixels with >50% conversion, binned to 0.5 degree grid cells

Regional ΔLST from conversion of grass to maize and soybeans



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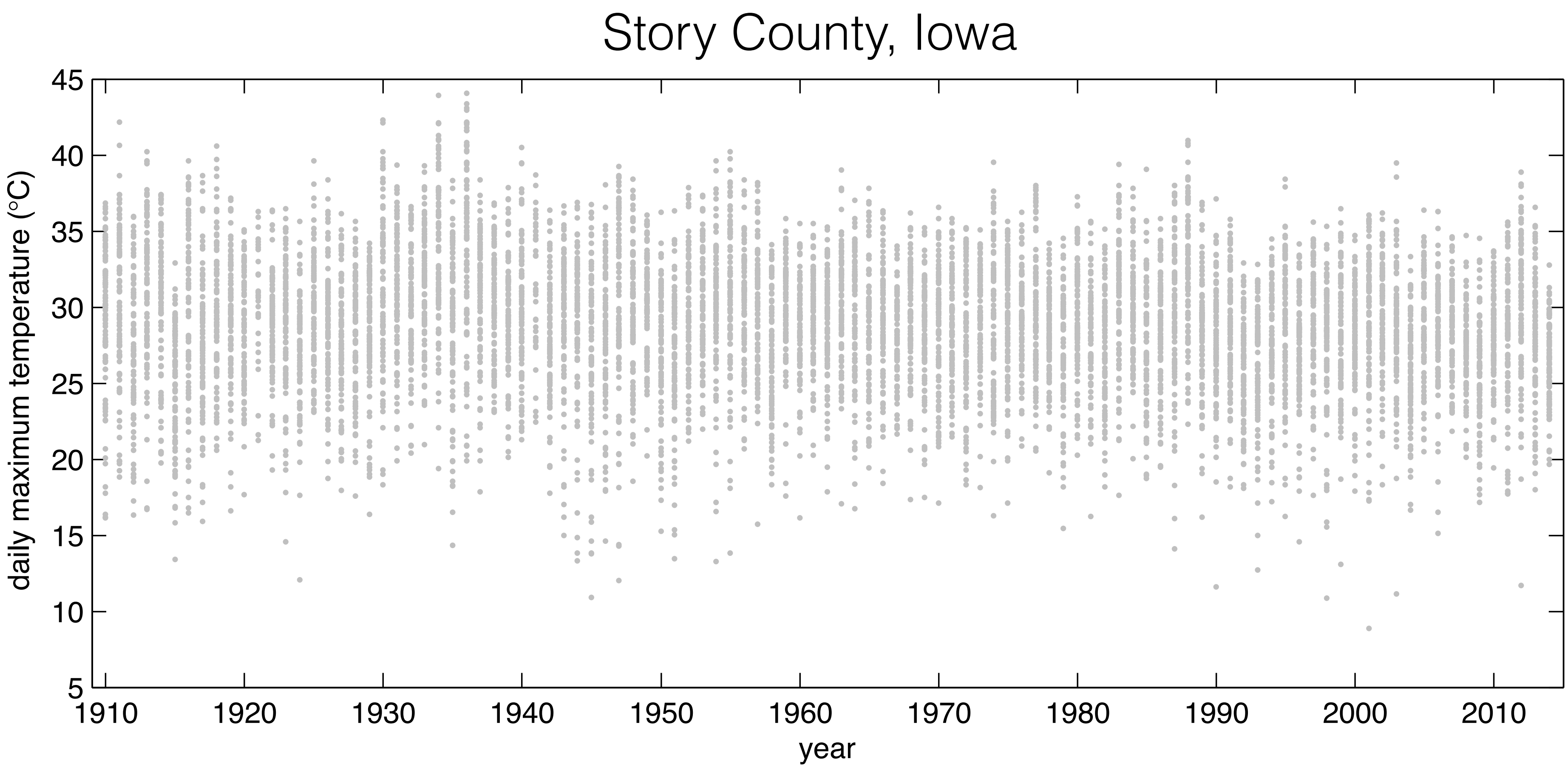
How are extremes changing?



use quantile regression

note: temperature data must be corrected for rounding artifacts (Rhines et al. 2015)

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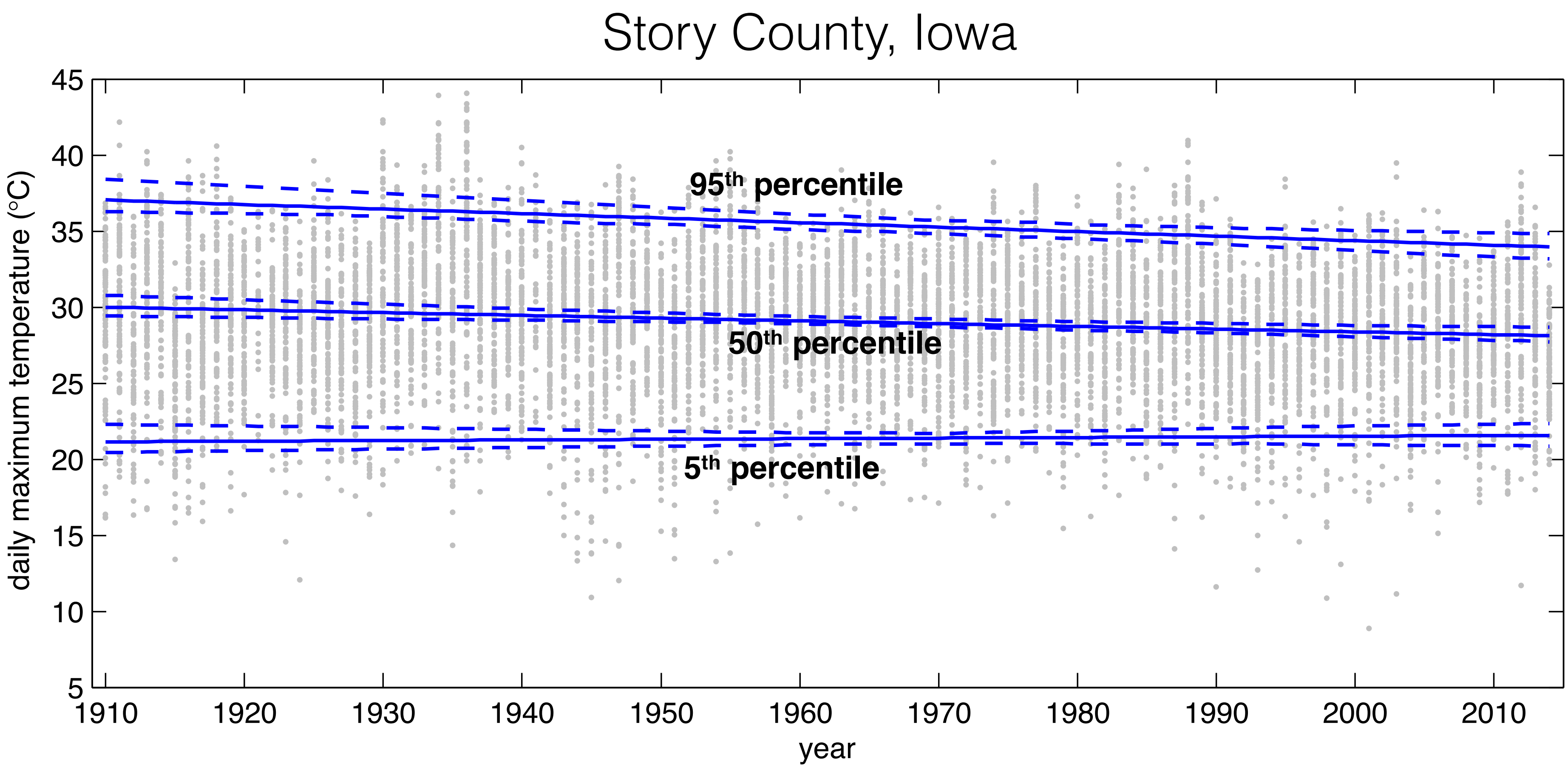

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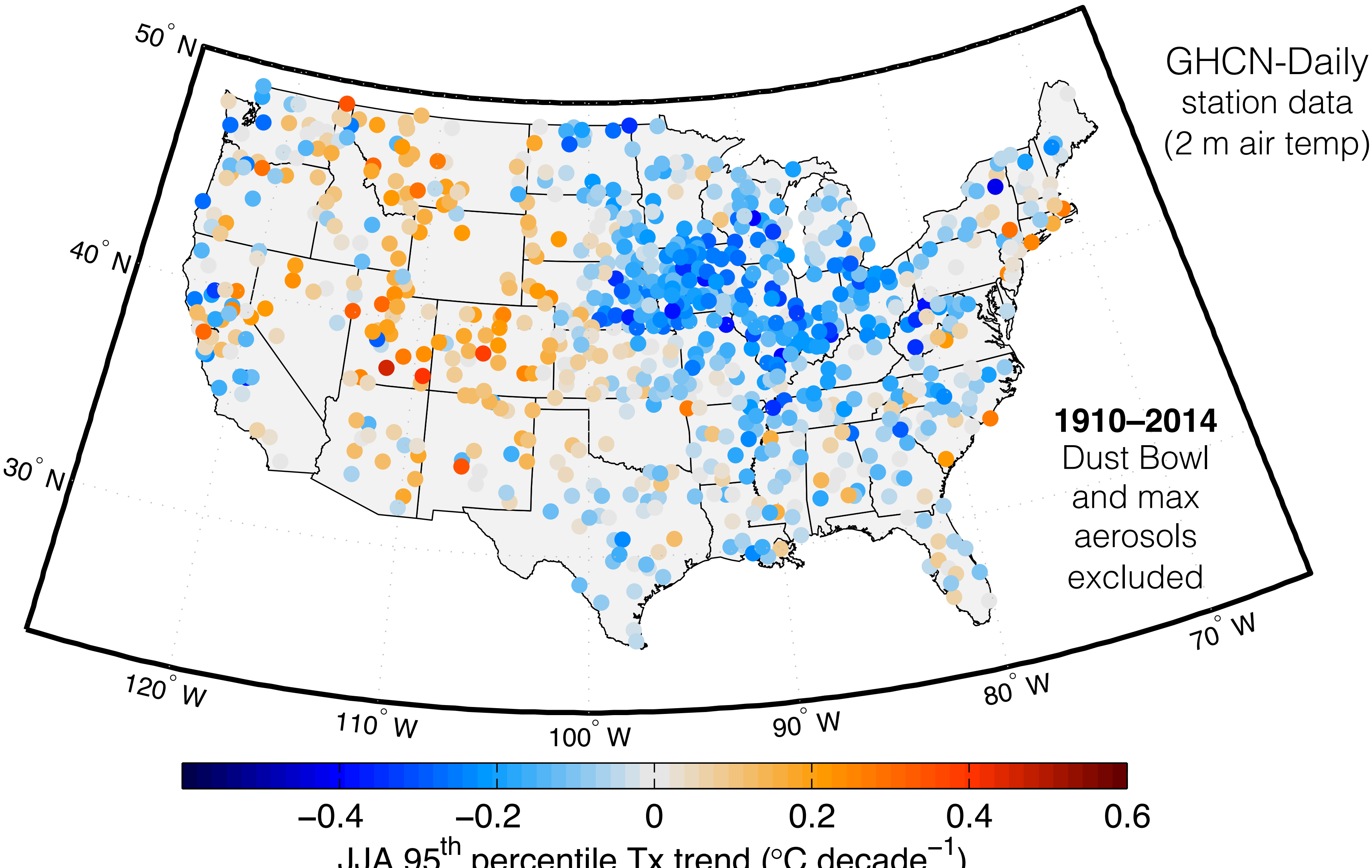
Cooler extreme summer temperatures in US



Mueller et al. 2016 NCC

DEPARTMENT OF COMMERCE

Herbert Hoover, Secretary

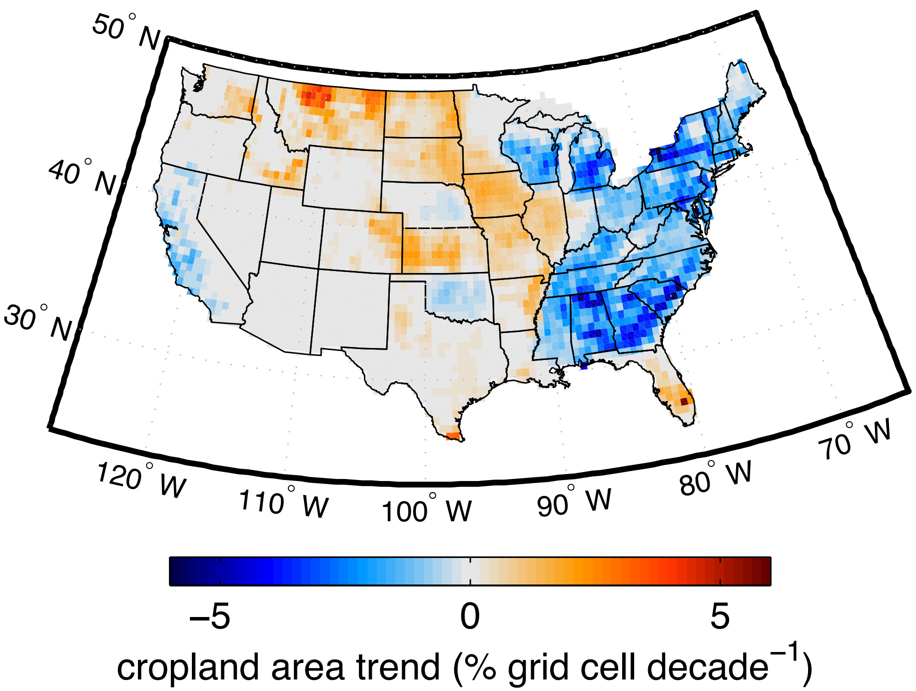
BUREAU OF THE CENSUS

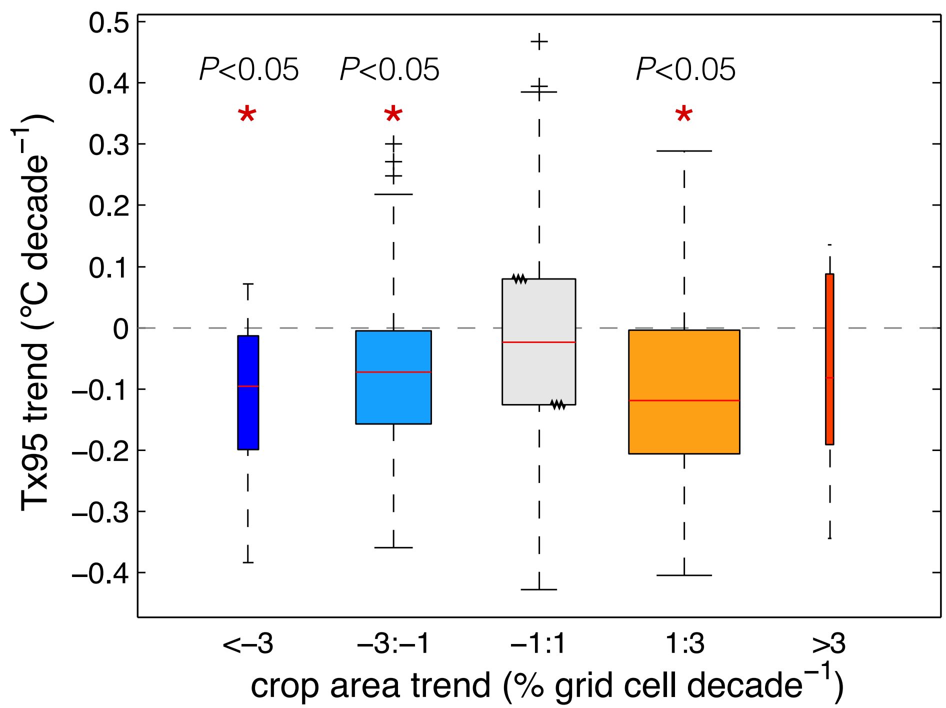
W. M. Steuart, Director

UNITED STATES CENSUS OF AGRICULTURE 1925

Cooling from cropland expansion?

No consistent relationship



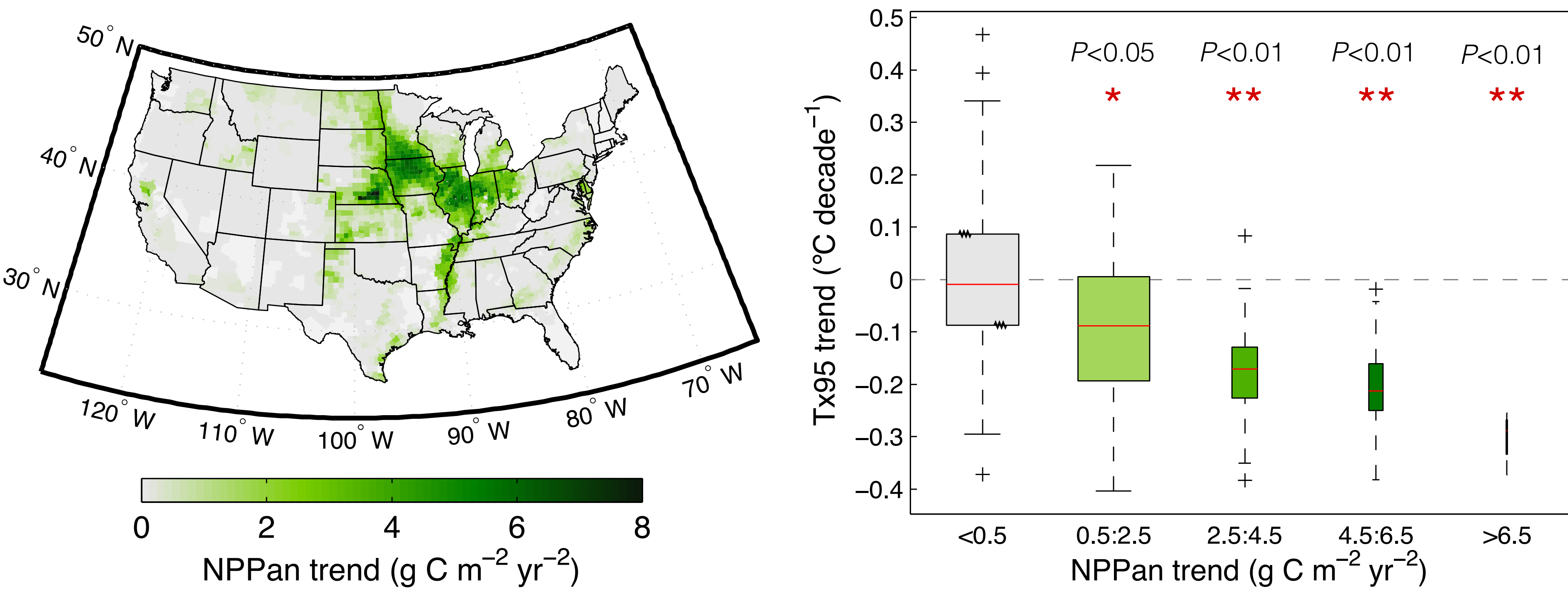


Mueller et al. 2016 NCC

Much greater rates of land conversion in the late 1800s

Other variables examined: precipitation, irrigation

Cropland intensification is associated with cooler extreme temperatures

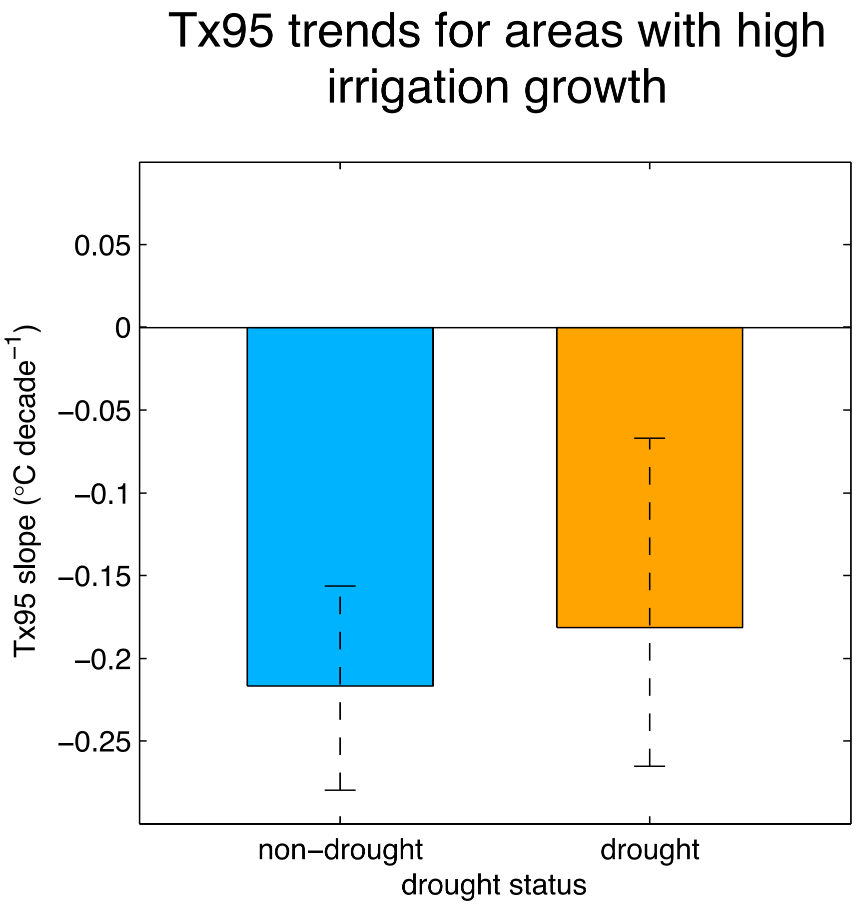


Mueller et al. 2016 NCC

Intensification → greater productivity → greater PET → cooler temperature extremes

Cooling is only sustained when soil moisture is sufficient for rainfed areas

Testing the interaction with drought



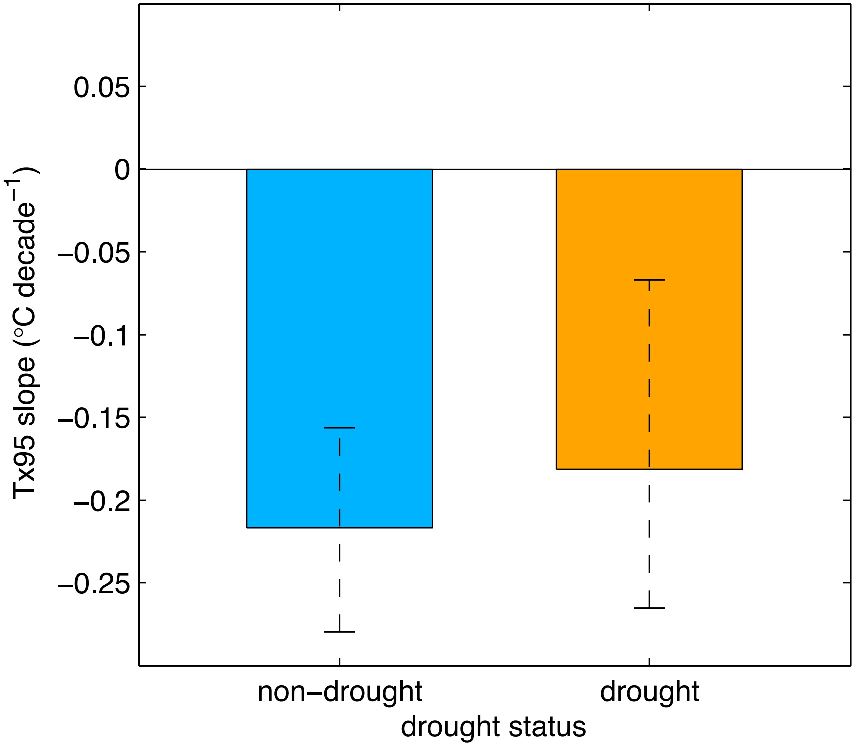
cooling persists regardless of drought status

Drought threshold: 10th percentile of sc-pm-PDSI from Dai et al. 2011. Dust bowl removed.

Mueller et al. 2015 NCC

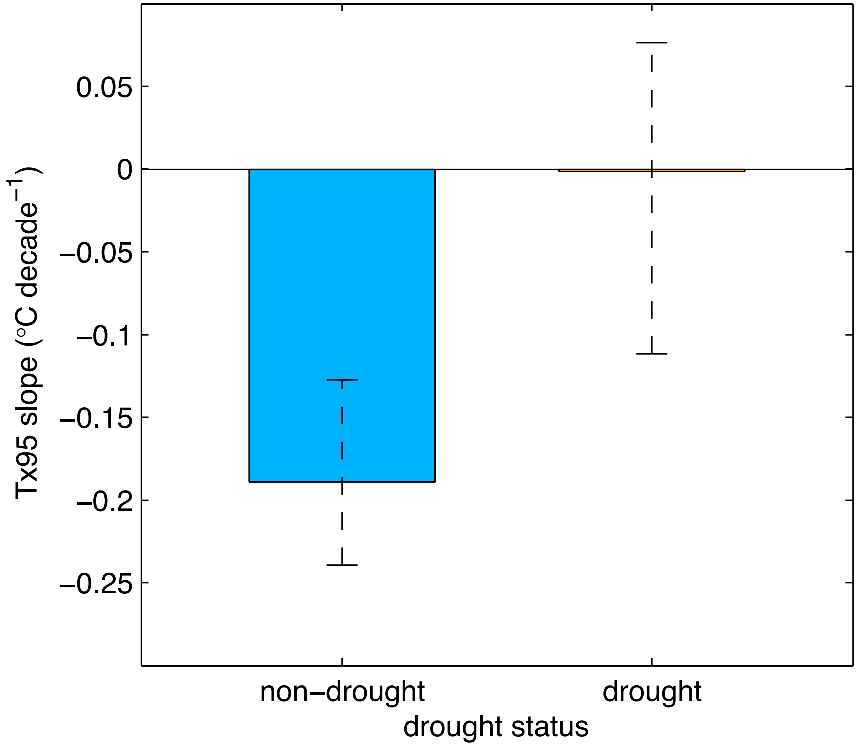
Testing the interaction with drought

Tx95 trends for areas with high irrigation growth



cooling persists regardless of drought status

Tx95 trends for rainfed areas with high NPPan growth



cooling lost during drought; increase in drought extreme T relative to normal years

Drought threshold: 10th percentile of sc-pm-PDSI from Dai et al. 2011. Dust bowl removed.

Mueller et al. 2016 NCC

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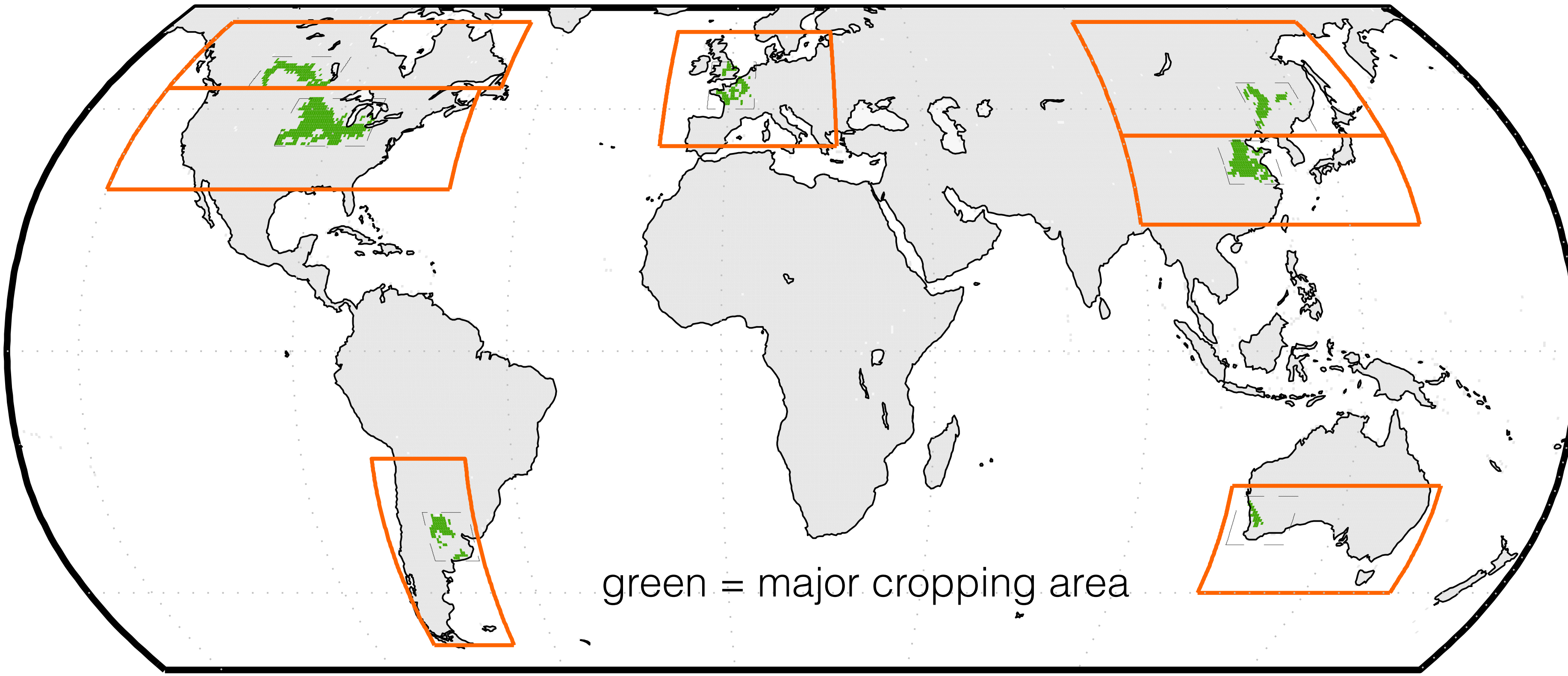
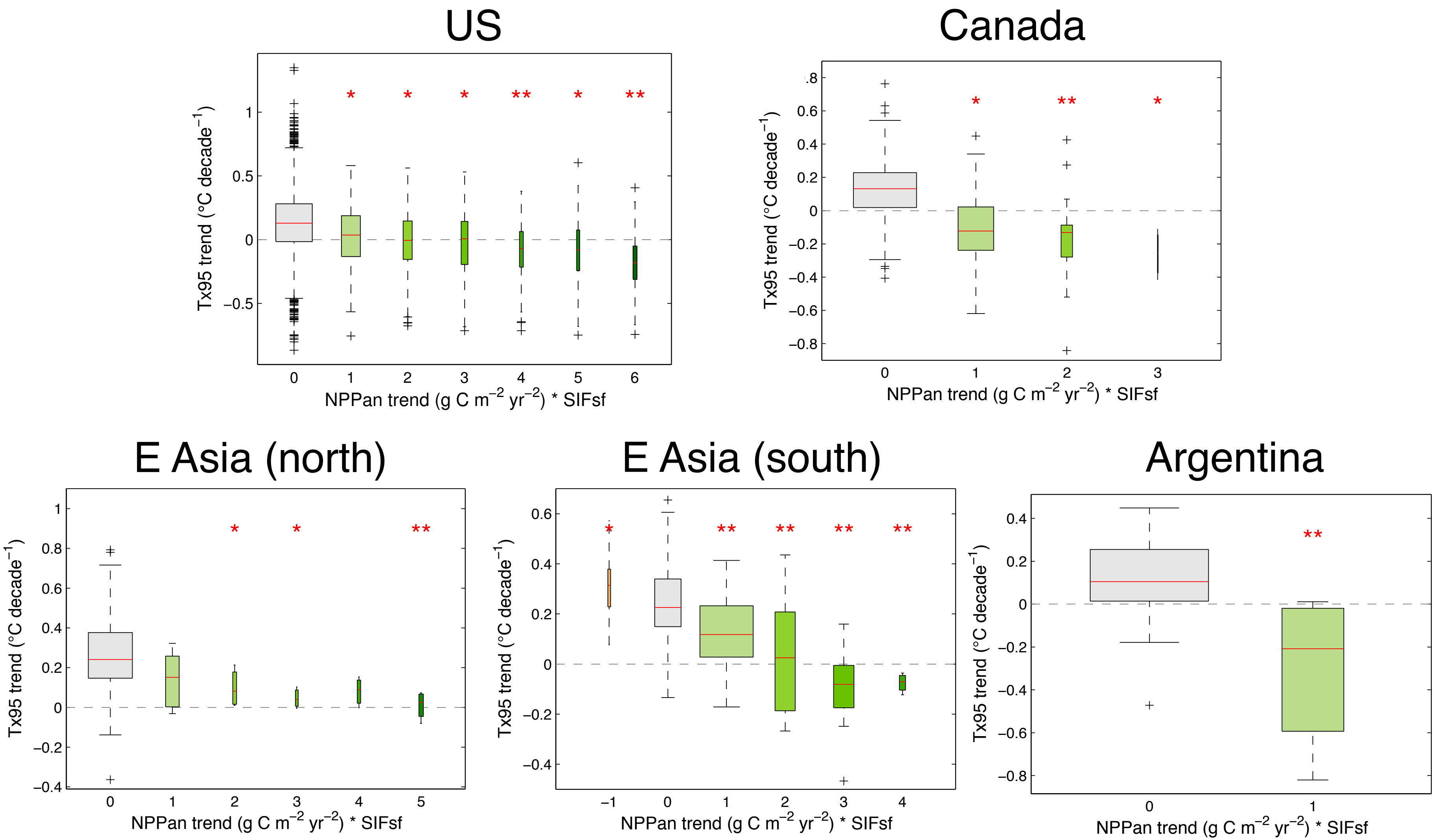
Extreme temperature and land use trends across the globe



Explanatory variables: cropland area, irrigated area, intensification

Mueller et al. 2016 in review

Consistent cooling across intensified summer cropping systems (1961–present)



Mueller et al. in review

Conclusions

1. Recent land cover change in the Great Plains leads to cooler LST mid-summer, warmer shoulder seasons

2. 100-yr trend towards cooler air temperature extremes associated with cropland intensification, greater ET – *not cropland expansion*

3. Consistent relationships between intensification and cooler extremes across the globe

Implications for pest management under climate change

1. Land use influences the climatic conditions pests experience
    - Seasonal changes
    - Distributional changes

2. Potential for feedbacks between pest infestations, crop/forest productivity, and temperatures

Potential for feedbacks

Pest
infestation

Potential for feedbacks

Pest infestation

Reductions in veg productivity

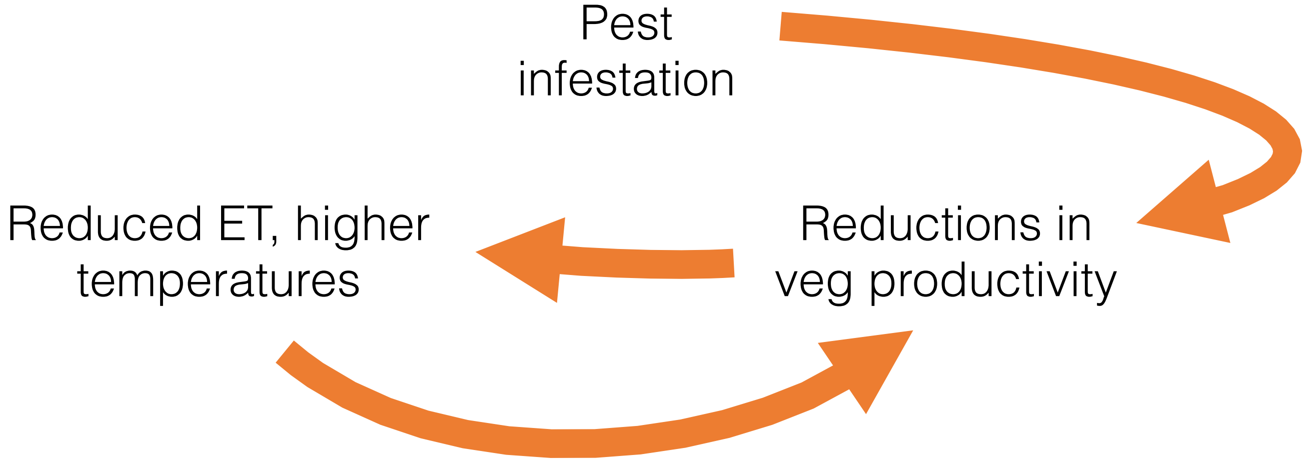
Potential for feedbacks

Pest infestation

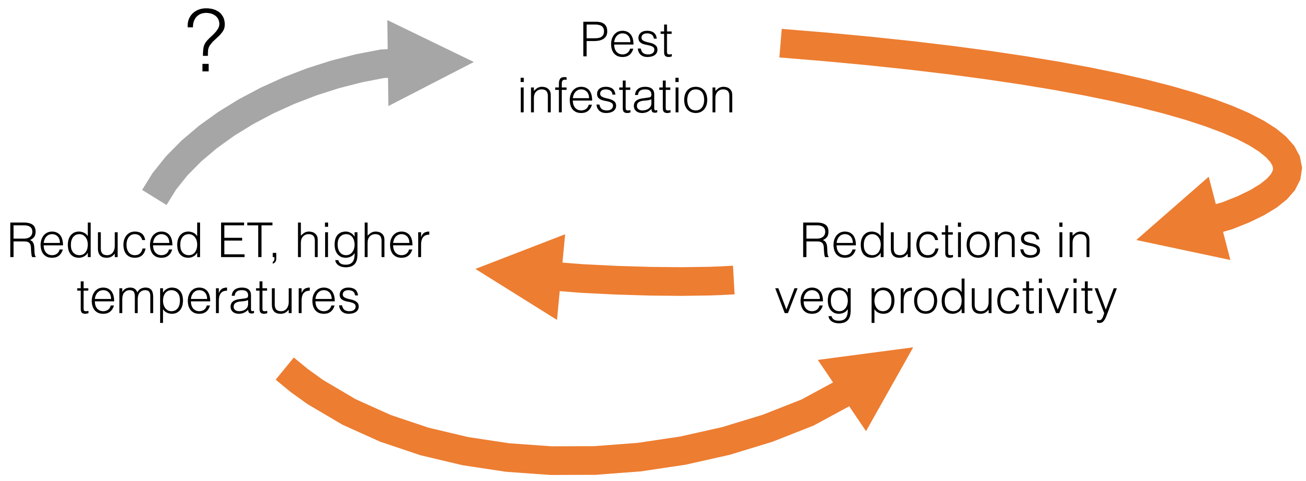
Reductions in veg productivity

Reduced ET, higher temperatures

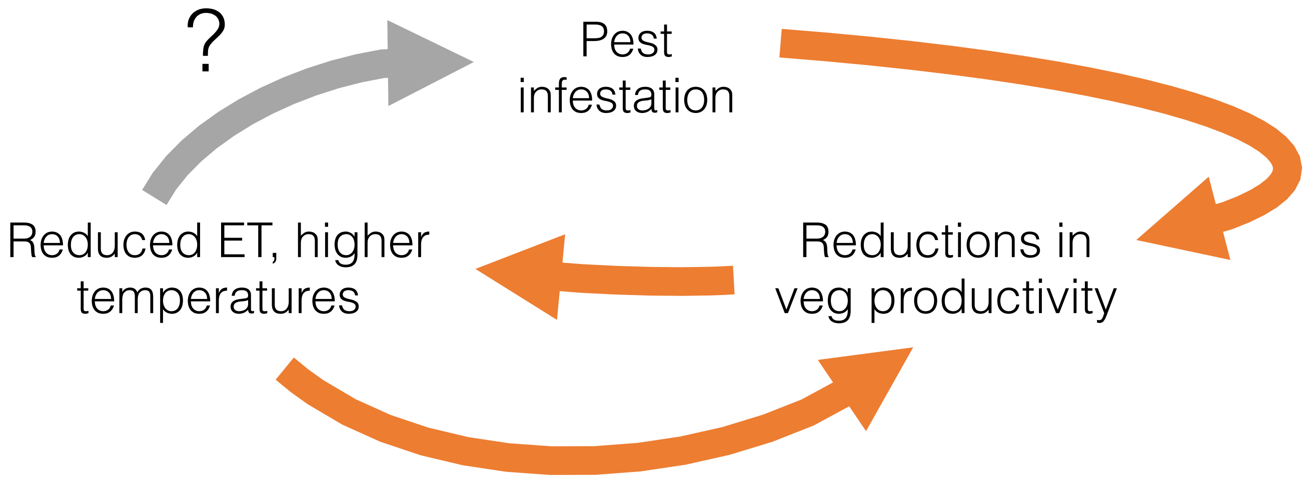
Potential for feedbacks



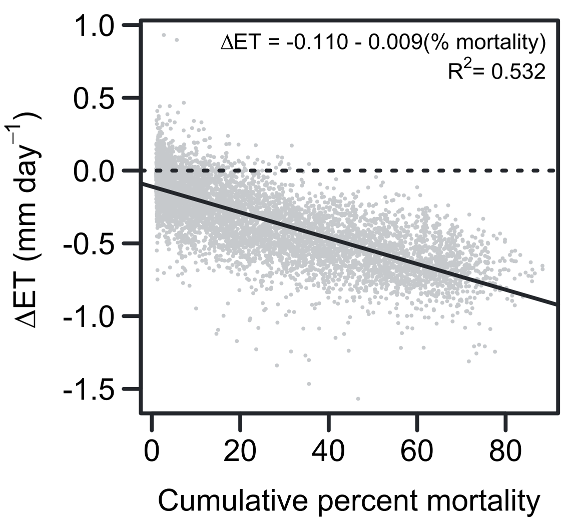
Potential for feedbacks

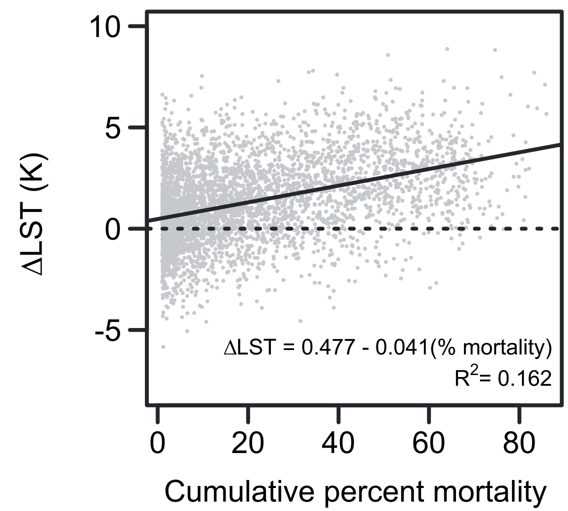


Potential for feedbacks



Bright, Hicke, and Meddens 2013 JGR:
Bark beetle tree mortality in Western US






thanks!
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USDA
NSF
Harvard University
Center for the Environment

Importance of extreme temperatures for crop yield

- High temperatures impact a host of physiological processes
  - Moisture/temperature stress can impede reproductive processes (e.g. maize silking)
  - Acceleration of development
- Dramatic yield losses projected under climate change due to extremes (e.g. nearly 80% by 2100 for US maize)
- How will the temperature distribution shift with climate change?

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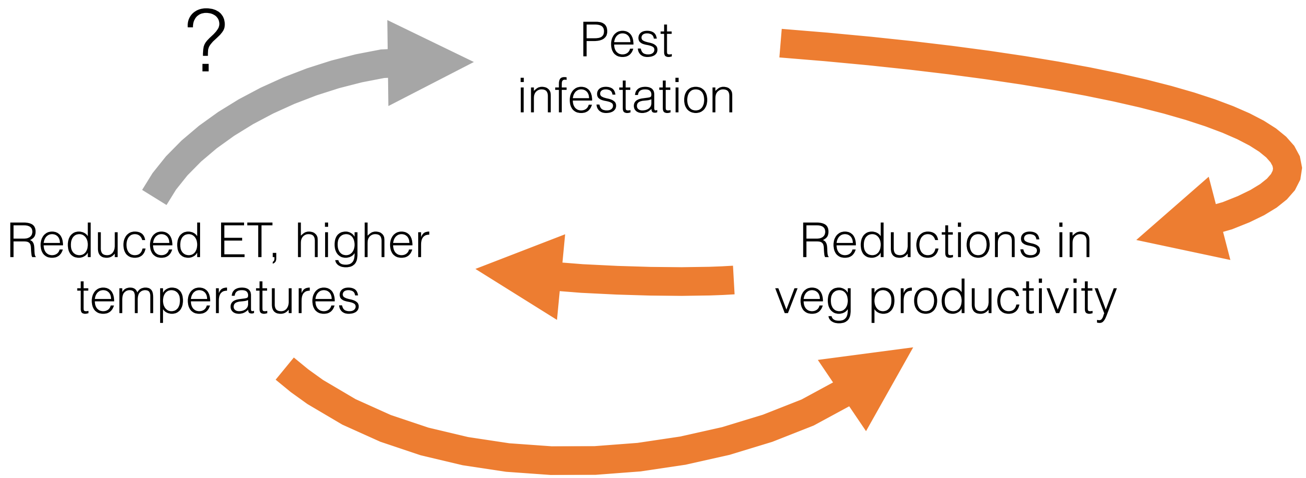
4. Implications for agricultural pests

Conclusions

1. Land use change will continue to influence climate in agricultural regions
    - Recent land cover change in the Great Plains leads to cooler LST mid-summer, warmer shoulder seasons
    - Long-term reduction in air temperature extremes associated with cropland intensification, greater ET – *not cropland expansion*
    - Consistent relationships between intensification and cooler extremes across the globe

2. Pest damages have the potential to influence local temperatures
    - Potential for feedbacks

Potential for feedbacks



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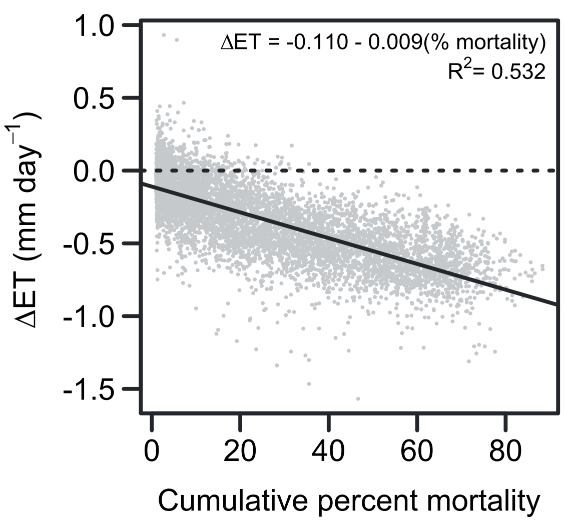
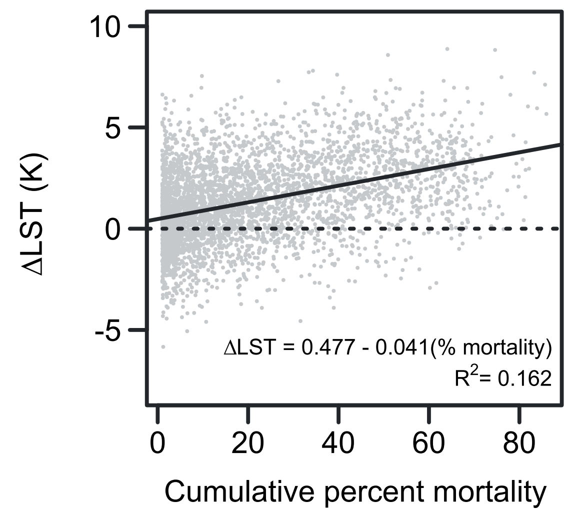
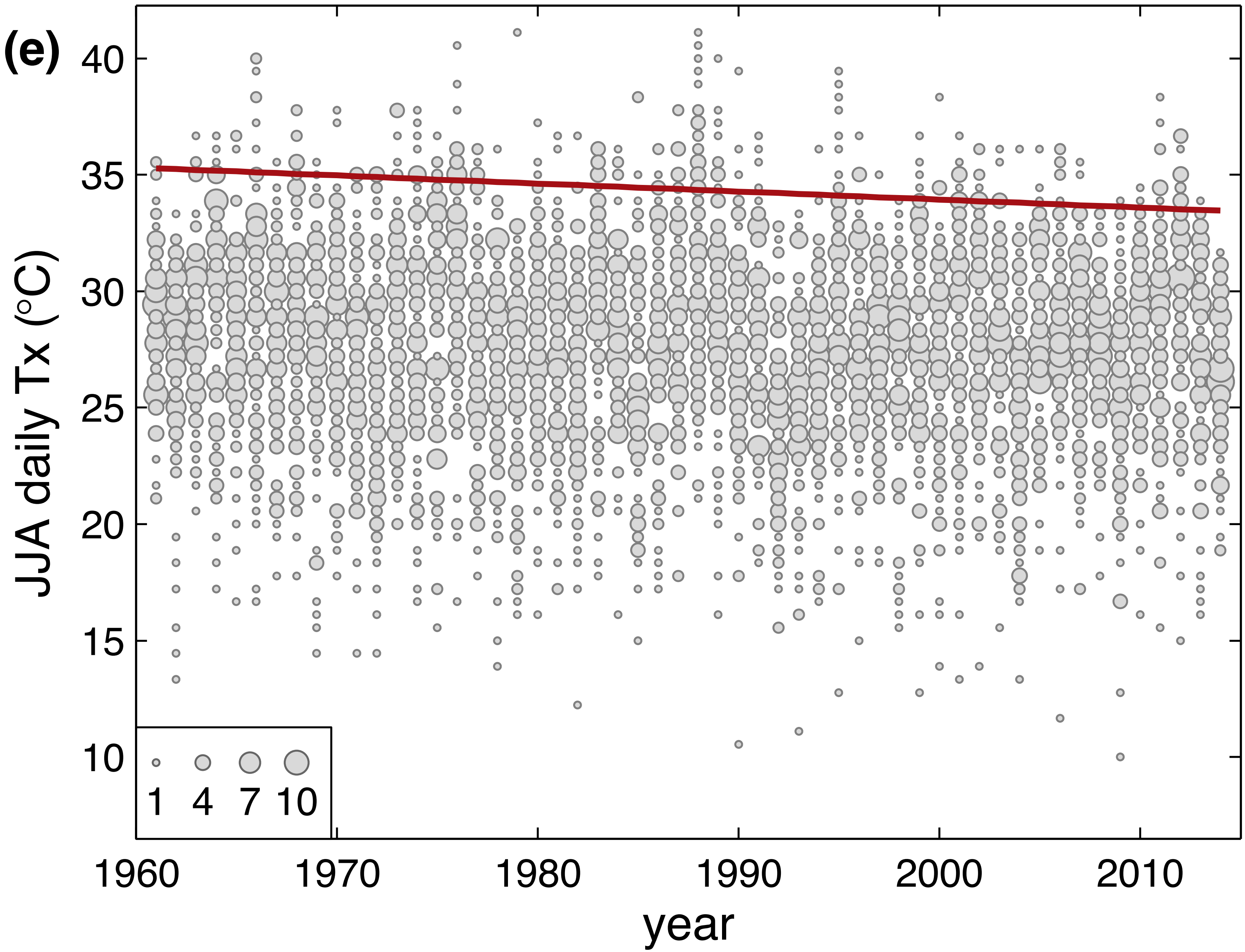
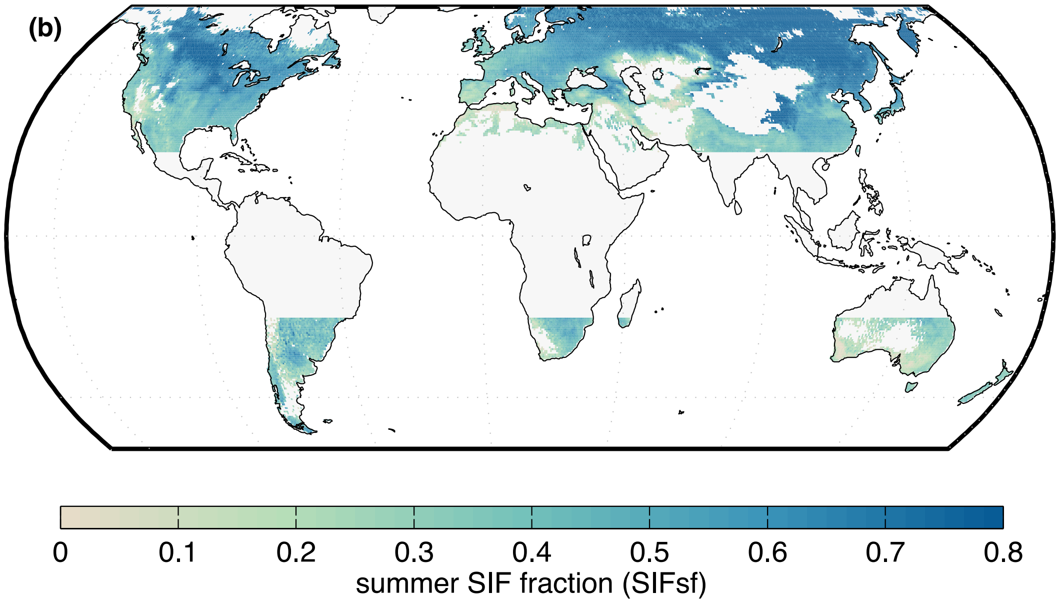
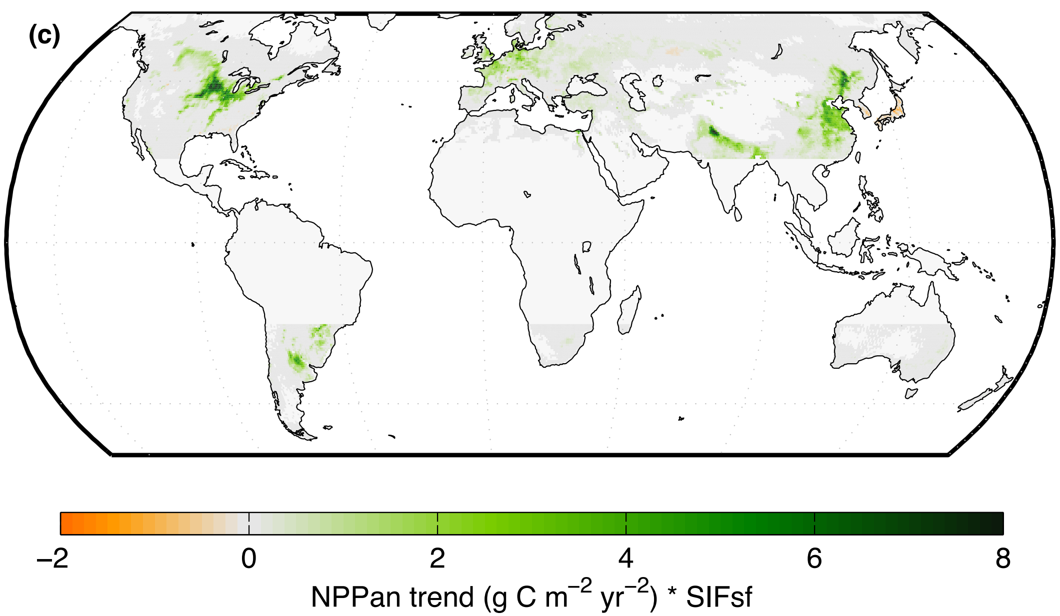





(e)
JJA daily Tx (°C)
40
35
30
25
20
15
10
1
4
7
10
1960
1970
1980
1990
2000
2010
year


(b)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
summer SIF fraction (SIFsf)


(c)
−2
0
2
4
6
8
NPPan trend (g C m−2 yr−2) * SIFsf

Surface energy balance

$$Rn = H + LE + G + S + \varepsilon$$

Rn = net radiation
H = sensible heat flux (heat energy transferred from surface to atmosphere)
LE = latent heat flux (from evapotranspiration)
    sometimes just "E" or "λE"
G = ground heat flux (fairly small)
S = heat storage in canopy (usually very small)
ε = residual errors

$$Rn - G \approx H + LE$$

Units are fluxes of energy: $W\ m^{-2}$
Reminder: Watt = Joule second^{-1}
$1\ W\ m^{-2} = 1\ J\ m^{-2}\ s^{-1}$