Crops and temperature extremes

1. Adaptation of US maize to heat waves
2. Whether heat waves will get hotter
3. Medium term forecasting of heat waves

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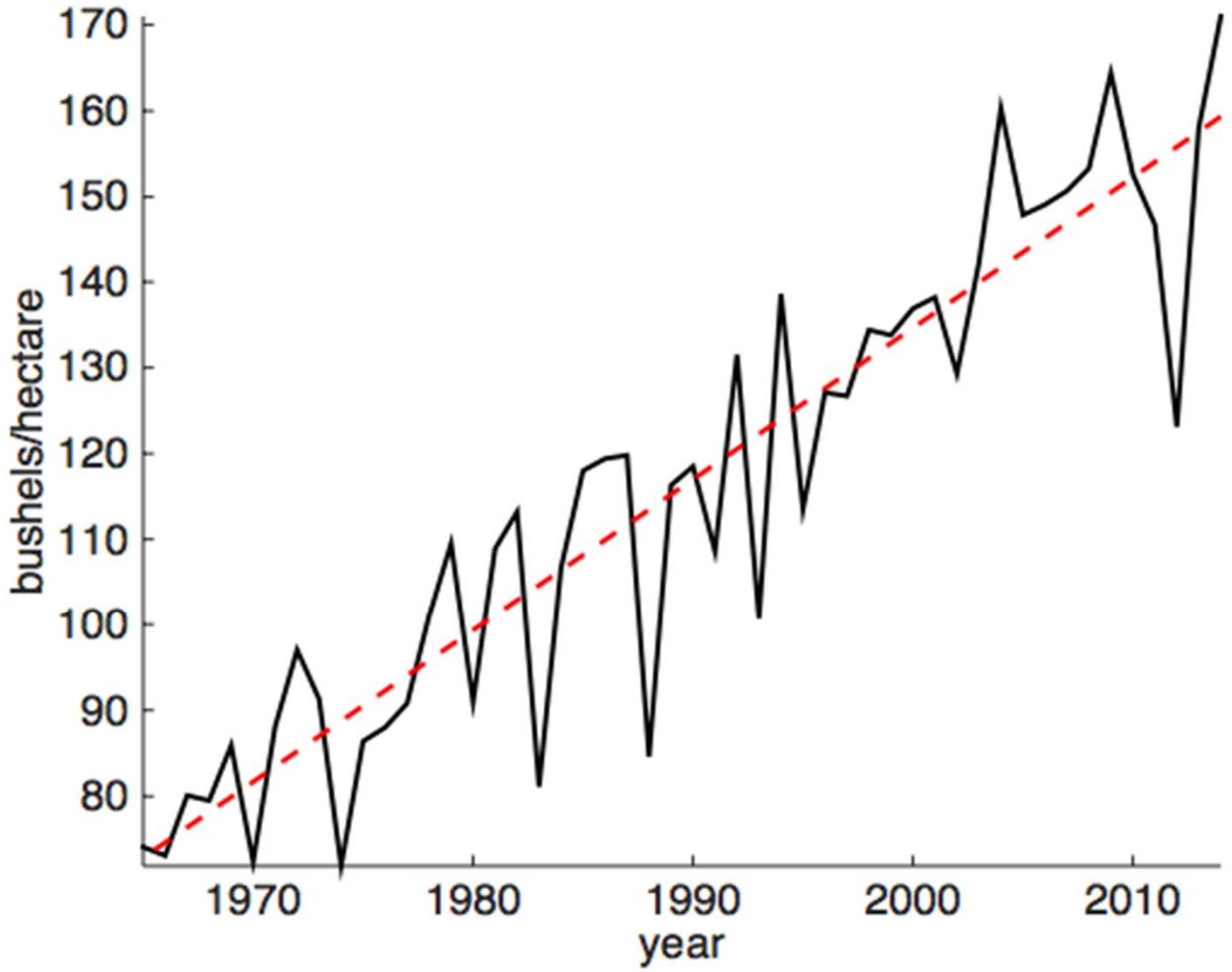
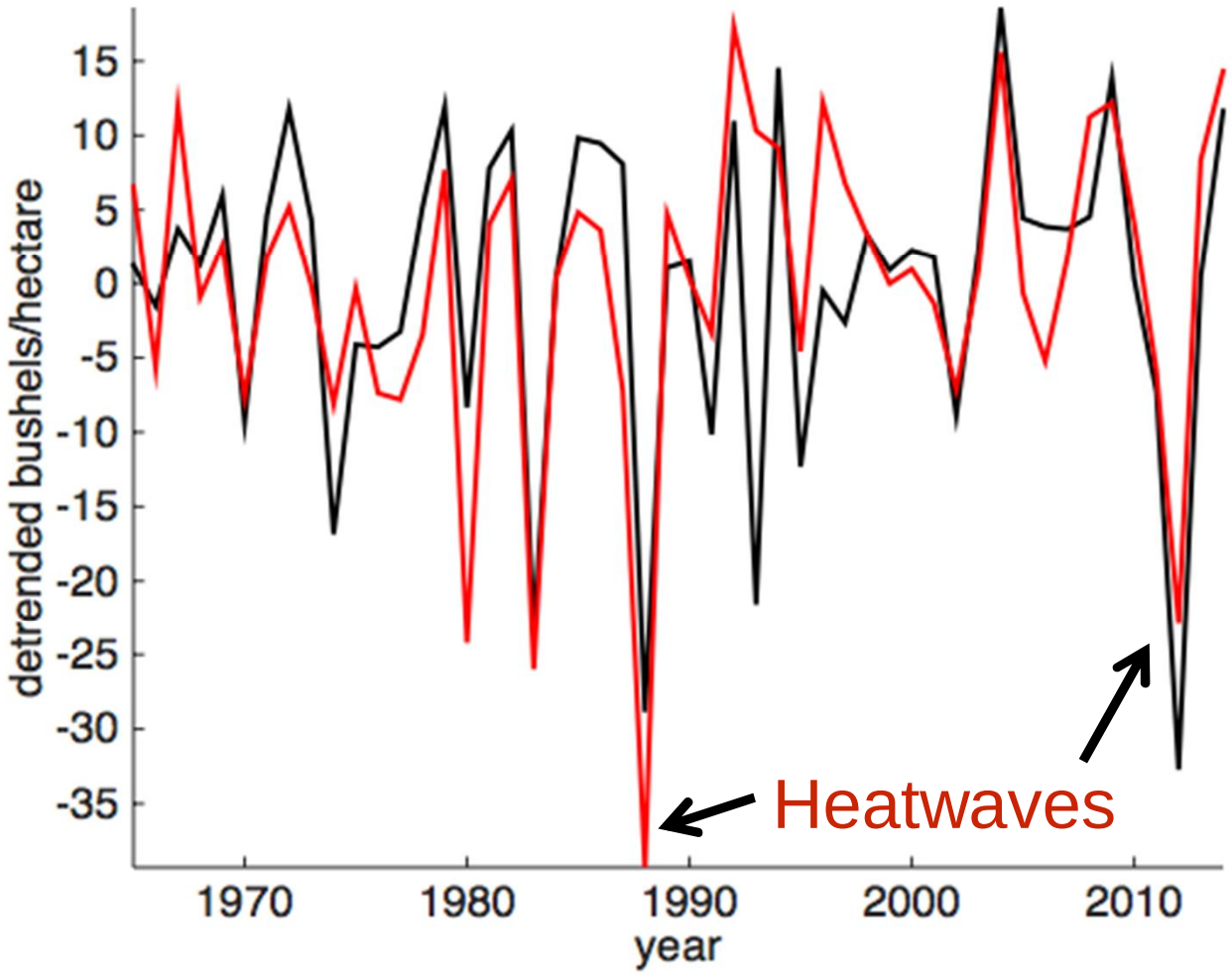
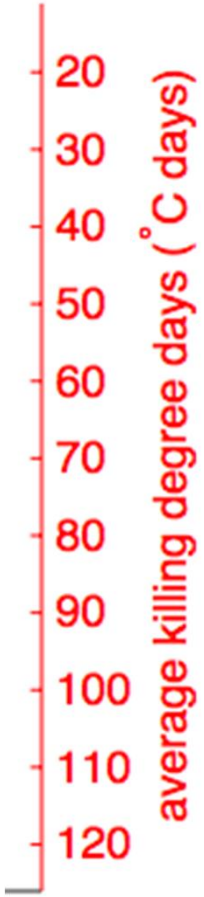
yield doubled from 1965-2014



1 plains the majority eld variability





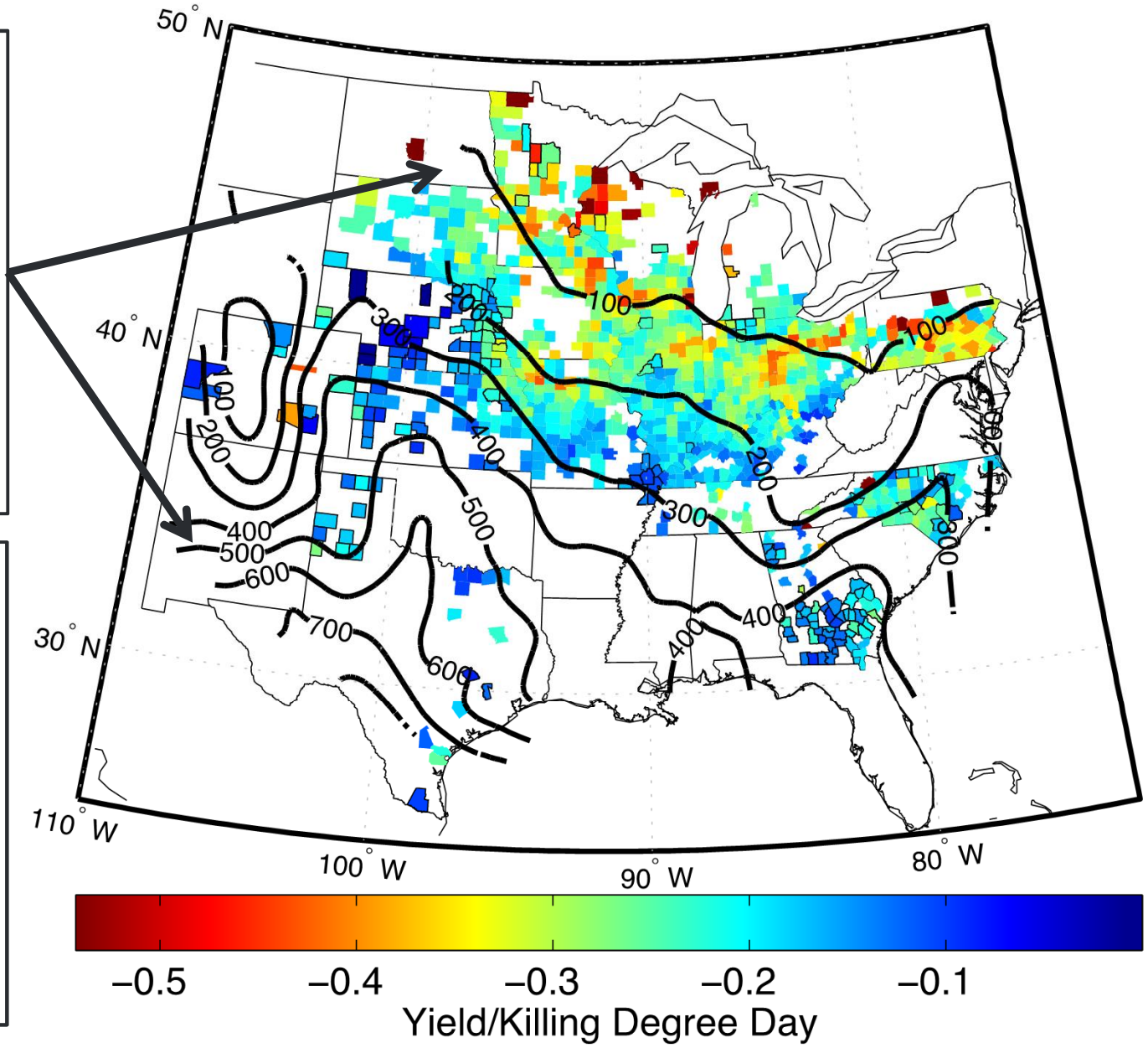
Killing degree days are defined as the sum of temperatures exceeding an optimum of 30°C,

$$\sum_{day}(T_{\max} - 30) > 0$$

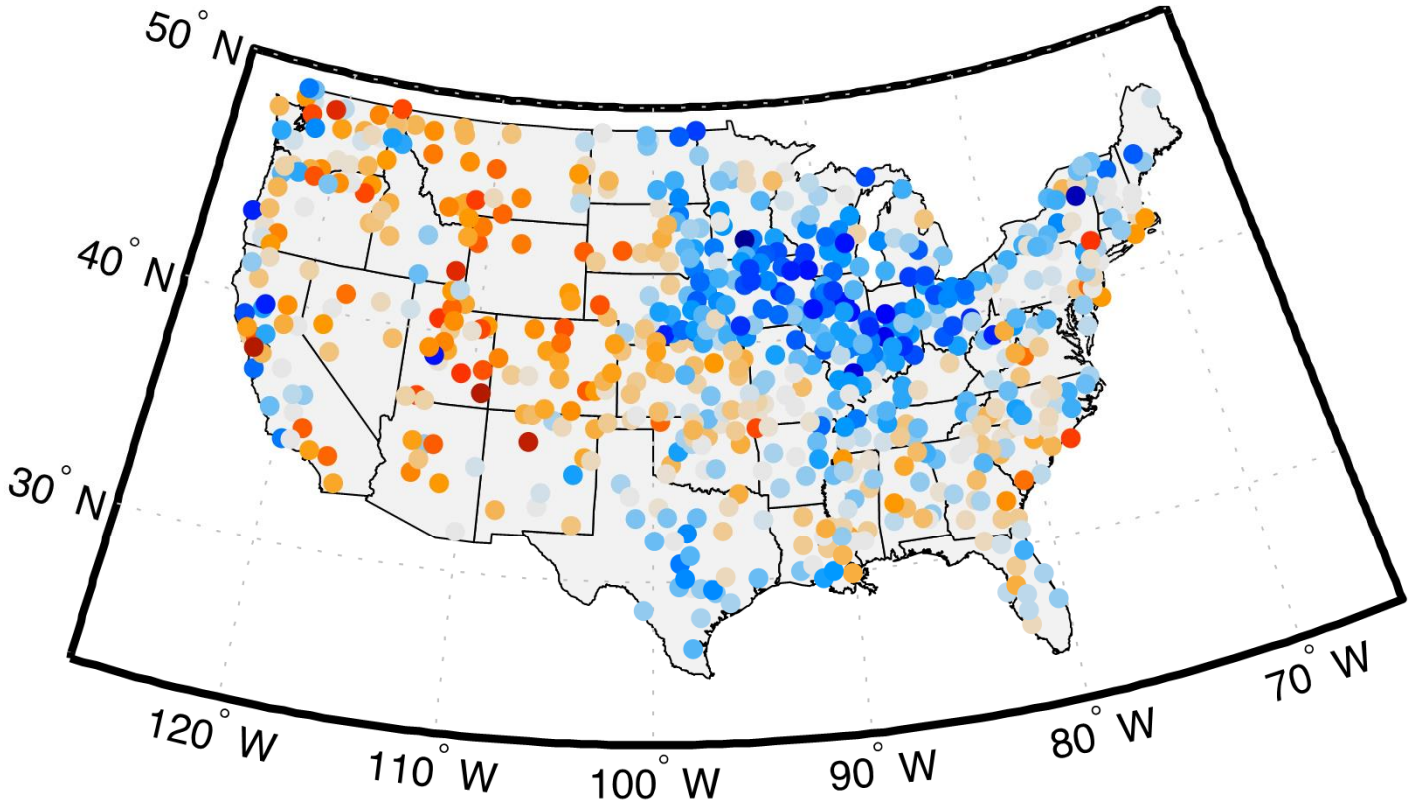
d analysis shows that sensitivity of mperatures is lower in hotter regions.

Killing Degree Day climatology increases from 100 (°C days) in the North to 500 (°C days) in the Southwest. Corn is less sensitive to Killing Degree Days in hotter regions.

Using this spatial adaptation as a proxy for temporal adaptation implies that yields losses from a 2°C warming can be **mitigated from 14% to only a 4%** decline.

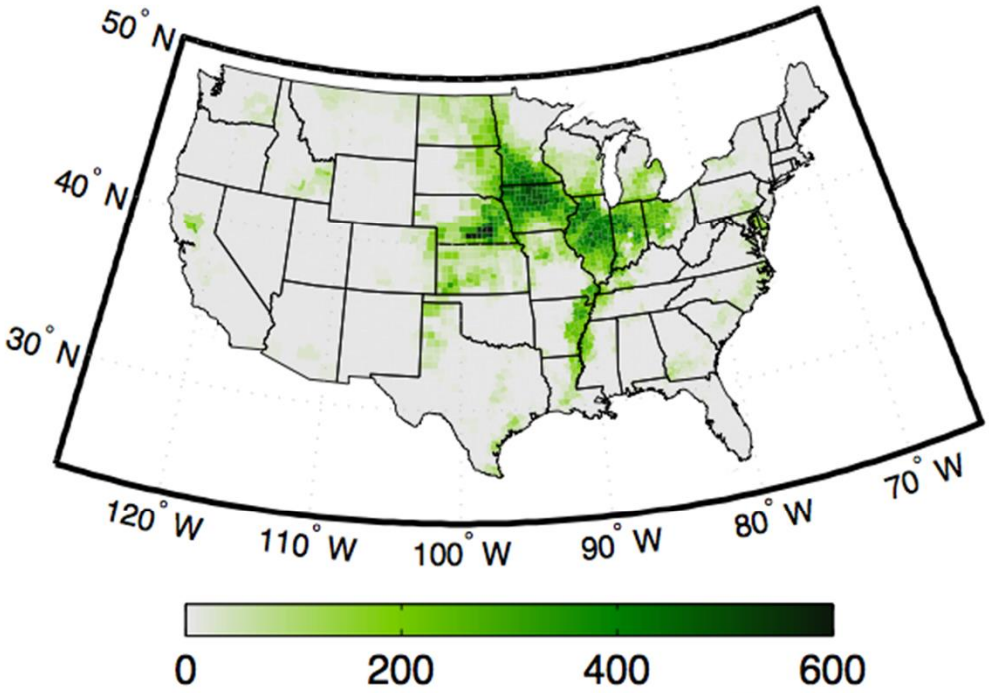


tures reached during the growing season ooled in the Midwest over the last century

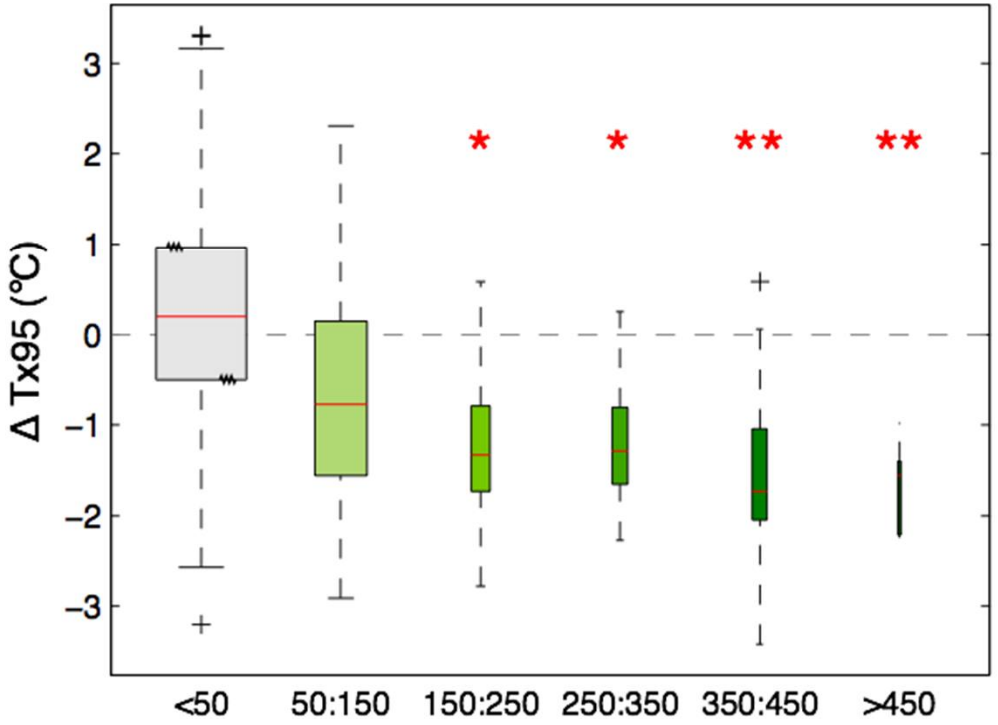


Change in 95th percentile temperature in °C between 1911-1950 and 1988-2012

oling pattern maps onto increases in sity and capacity for evapotranspiration



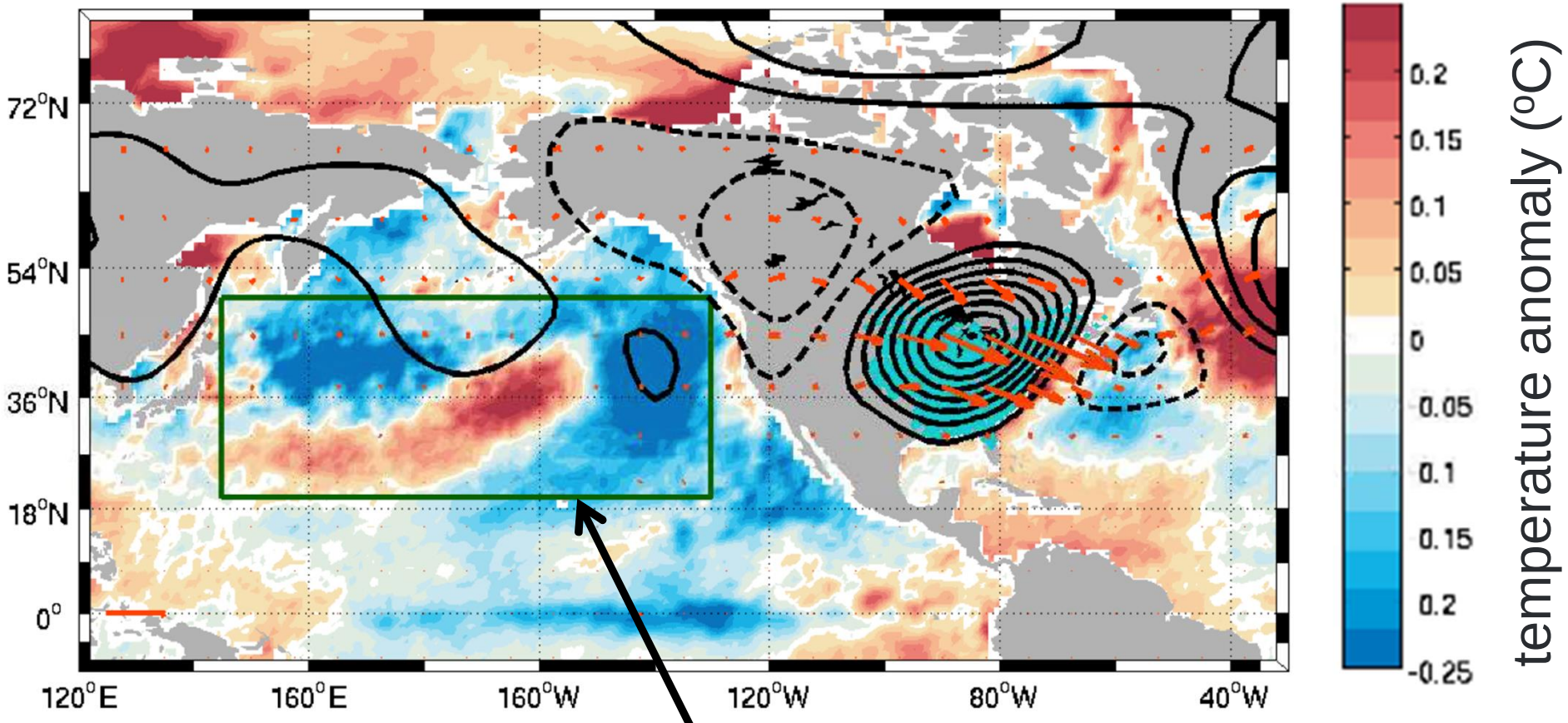
Change in Net Primary Production gC/(m^{2}yr)



Change in Net Primary Production gC/(m^{2}yr)

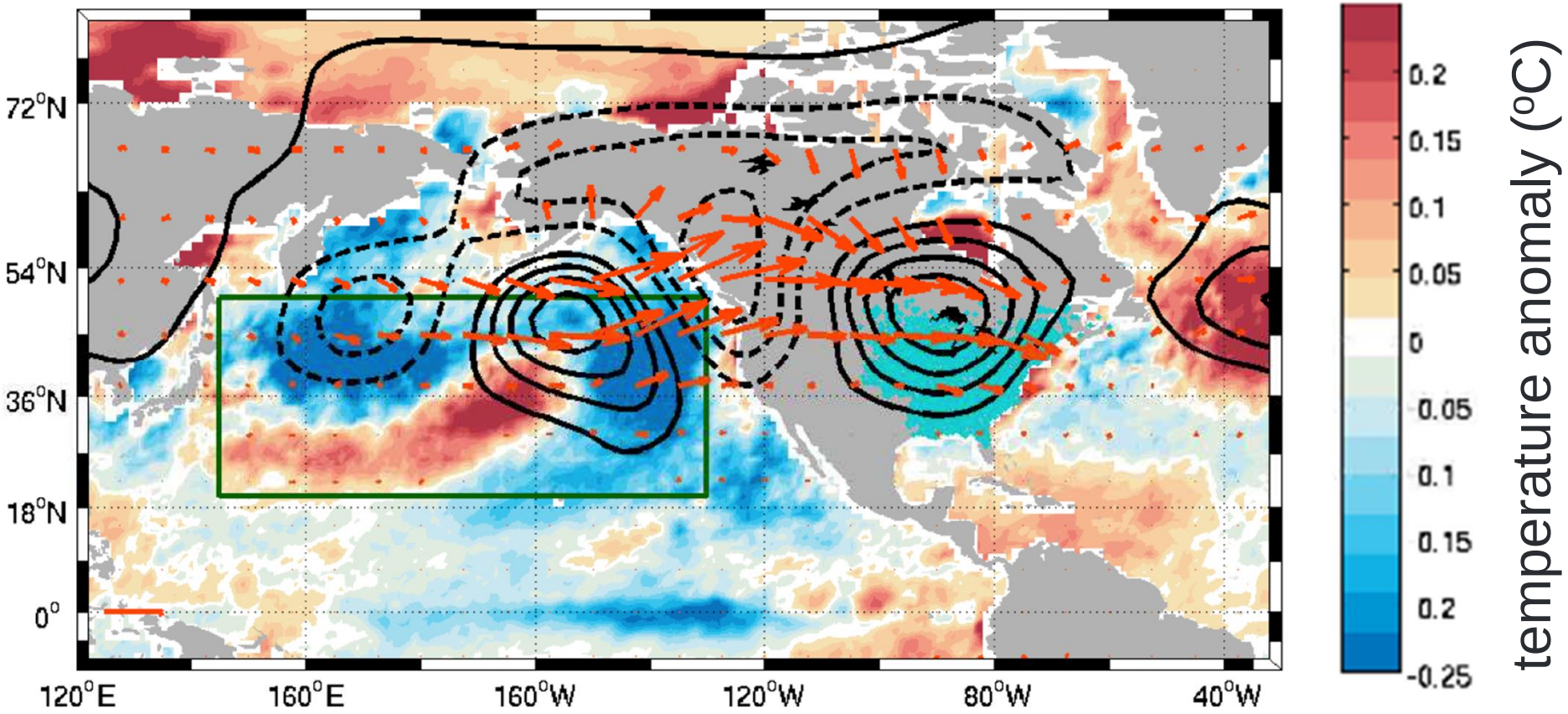
Field studies demonstrate that more recent cultivars of wheat, soy, and maize each show lower canopy temperatures. Wheat and soy cooling is associated with greater stomatal conductance. Maize cooling may be associated with delayed leaf senescence and a rooting that gives greater access to water.

surface temperature associated with waves in the Eastern US



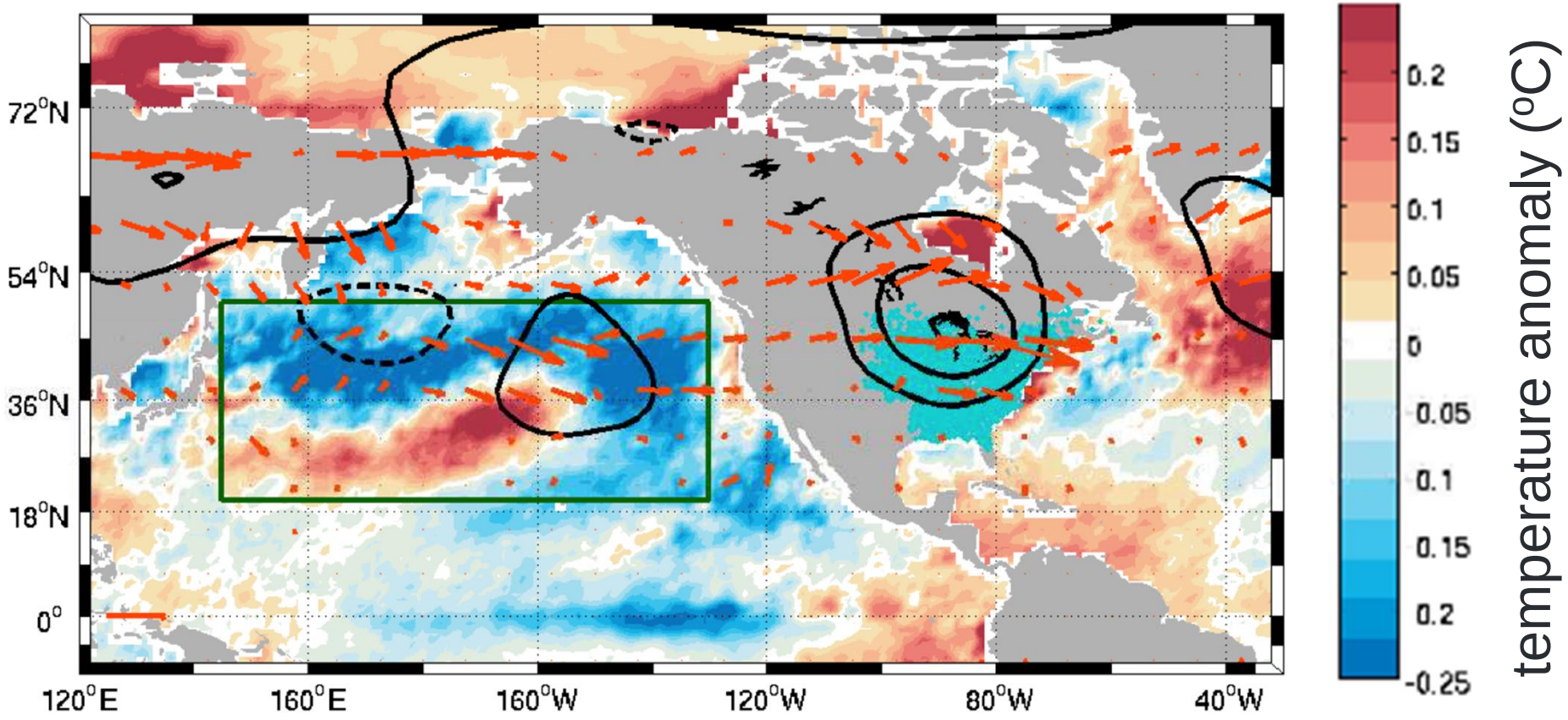
A tri-pole in Pacific mid-latitude sea surface temperature is characteristic during Eastern US heat waves.

ays prior to a heat wave



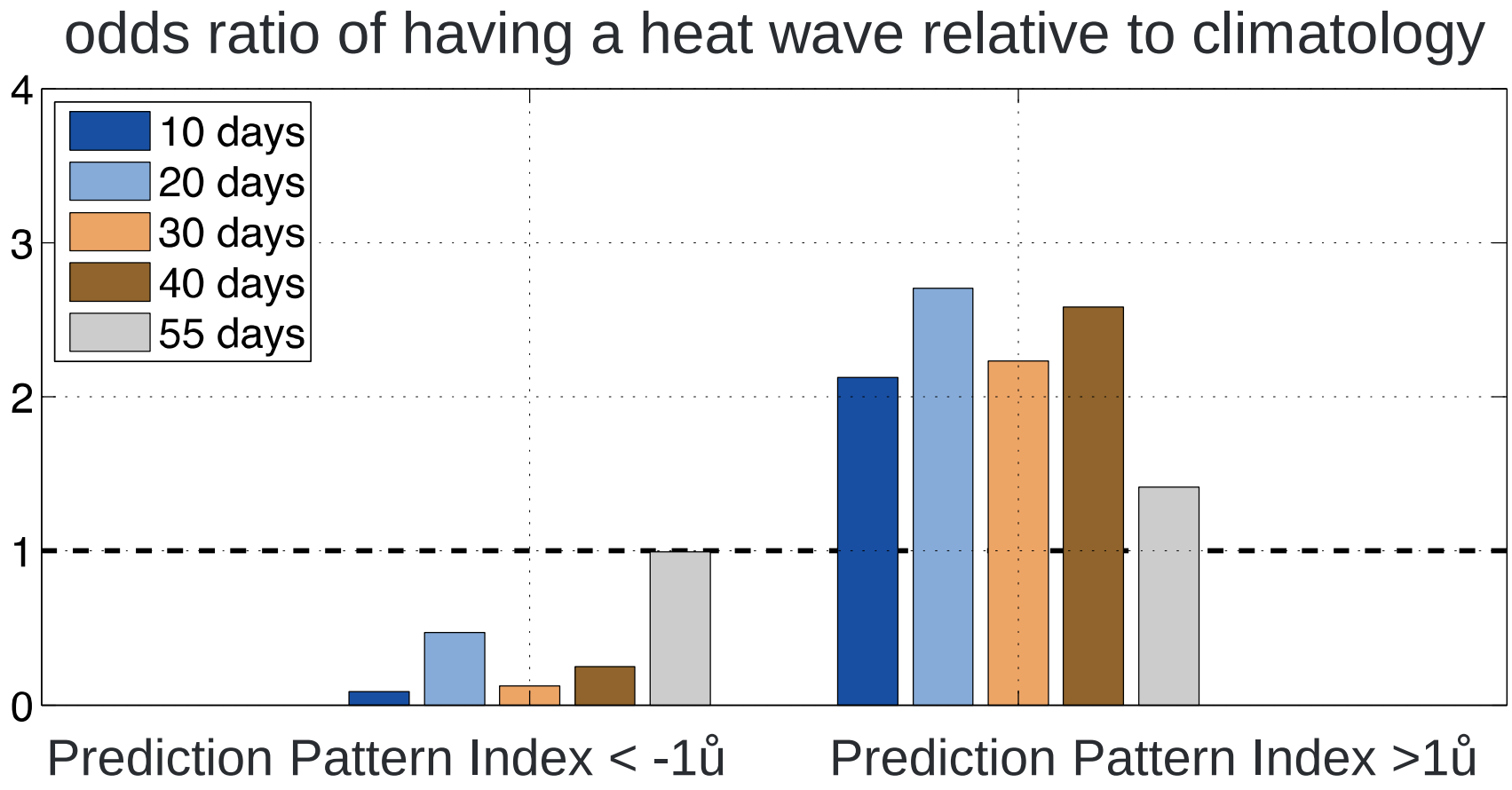
The sea surface temperature tri-pole causes anomalous atmospheric wave activity (red arrows) to converge on the Eastern US.

ys prior to a heat wave



Development of the sea surface temperature tri-pole follows a characteristic pattern that can be reliably tracked more than 40 days prior to a heat wave.

s up to 40 days out change by >2X for malies in the prediction pattern



(significance is confirmed through cross-validation on withheld data)

1. Based on the modern pattern of sensitivity, it is estimated that adaptation could counter the majority of corn yield damages associated with moderate warming in the Eastern US. Adaptation to changes in water availability, temperature variance, etc. requires further assessment.

1. The hottest Midwestern growing season temperatures have trended cooler over the last century. A relationship with overall increases in crop intensity and capacity for evapotranspiration suggests that these cooling effects will persist, so long as sufficient groundwater is available.

2. The odds of heat waves in the Eastern US can be skillfully predicted more than 40 days out based on sea surface temperature patterns in the mid-latitude Pacific. Improved ocean forecasting may permit for further extending this prediction horizon.