Supplemental: Peculiarly pleasant weather for U.S. maize

Ethan E. Butler, Nathaniel D. Mueller, and Peter Huybers

July 18, 2018

S1 Tables

Table S1: Sensitivity of yield in each growth phase to Growing Degree Days (GDD) and Killing Degree Days (KDD), including best estimate and bootstrap estimated 95% confidence interval (CI).

Phase	GDD (95% CI) [kg/ha]	KDD (95% CI) [kg/ha]
Vegetative	0.1 (-0.8 to 0.9)	-5.0 (-6.6 to -3.4)
Early Grain Filling	4.9 (3.8 to 6.0)	-27.2 (-30.3 to -23.9)
Late Grain Filling	8.8 (7.5 to 10.0)	-8.4 (-10.8 to -6.4)

Table S2: Sensitivity of yield difference trend comparing early development to recent development using different averaging periods. The reported P-values are from a single sided bootstrap test against a trend of 0.

Averaging Period	Trend [kg ha^{-1} yr^{-1} (95% CI)	P-value (one-sided)
1981-1985 and 2013-2017	11 (0.5 to 21)	$P \leq 0.05$
1981-1995 and 2003-2017	7.8 (-0.8 to 18)	$P \leq 0.05$

www.pnas.org/cgi/doi/10.1073/pnas.1808035115

Table S3: Sensitivity of yield difference comparing early development to recent development using different spatial averages. The reported P-values are from a single sided bootstrap test against a trend of 0 using 1000 draws, except for the regional trend where 10000 were used to achieve a more stable result with so few degrees of freedom.

Unit of Replication	Degrees of Freedom	Trend [kg ha^{-1} yr^{-1} (95% CI)	P-value (one-sided)
County-year	27806	16 (13–20)	$P \leq 0.001$
Cluster-year	3990	13 (4–21)	$P \leq 0.01$
Region-year	37	17 (-3–32)	$P \leq 0.05$

Table S4: Trend Components with and without precipitation.

Component	Trend [tonne ha^{-1} $decade^{-1}$] no Precipitation	Trend [tonne ha^{-1} $decade^{-1}$] Precipitation
Technology	0.92	0.93
Climate GDD	0.07	0.07
Climate KDD	0.13	0.12
Climate Precip	XX	0.01
Timing GDD	0.2	0.18
Timing KDD	-0.03	-0.03
Timing Precip	XX	0.01
Total Climate	0.19	0.20
Total Timing	0.17	0.16

S2 Figures

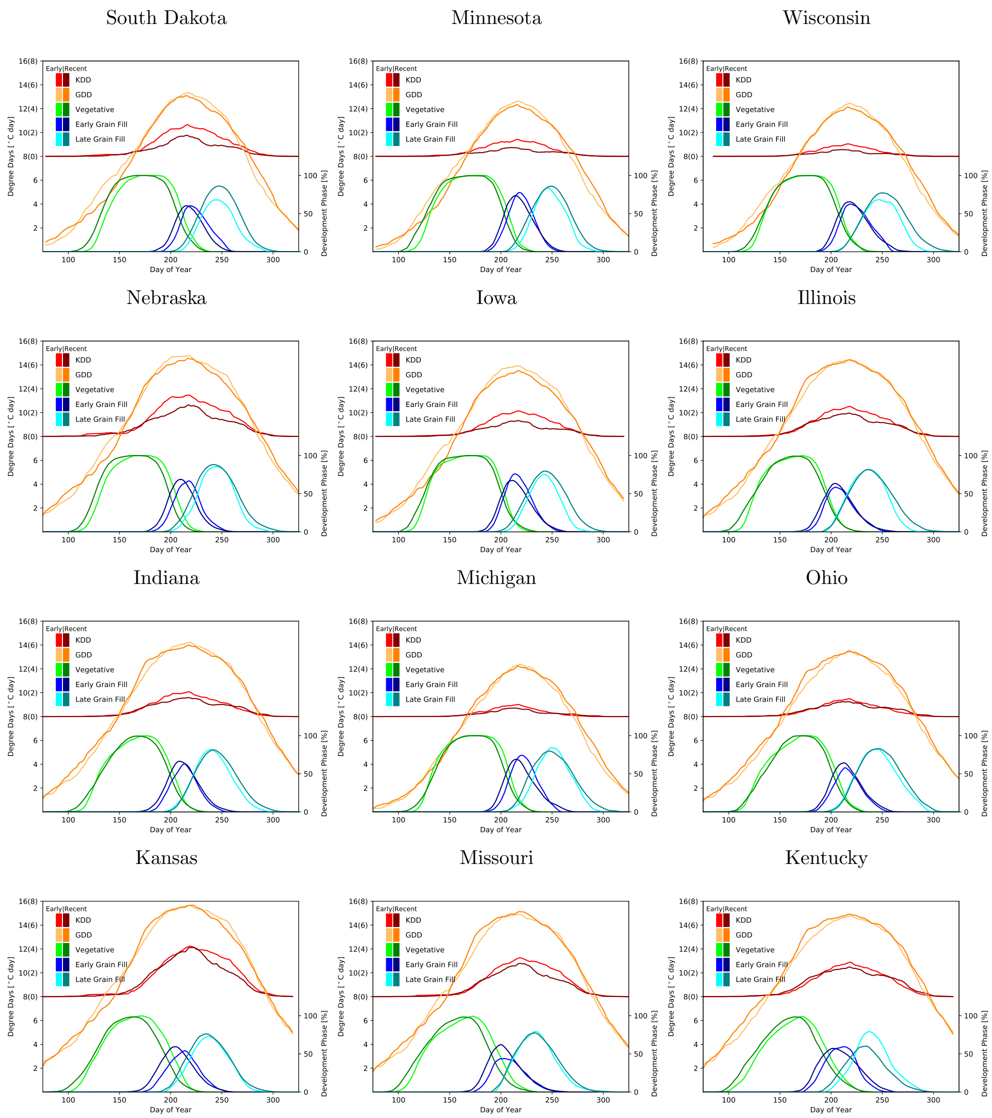

Figure S1: All of the states exhibit similar patterns as the regional average (Fig. 1), though the cooling in KDDs varies.

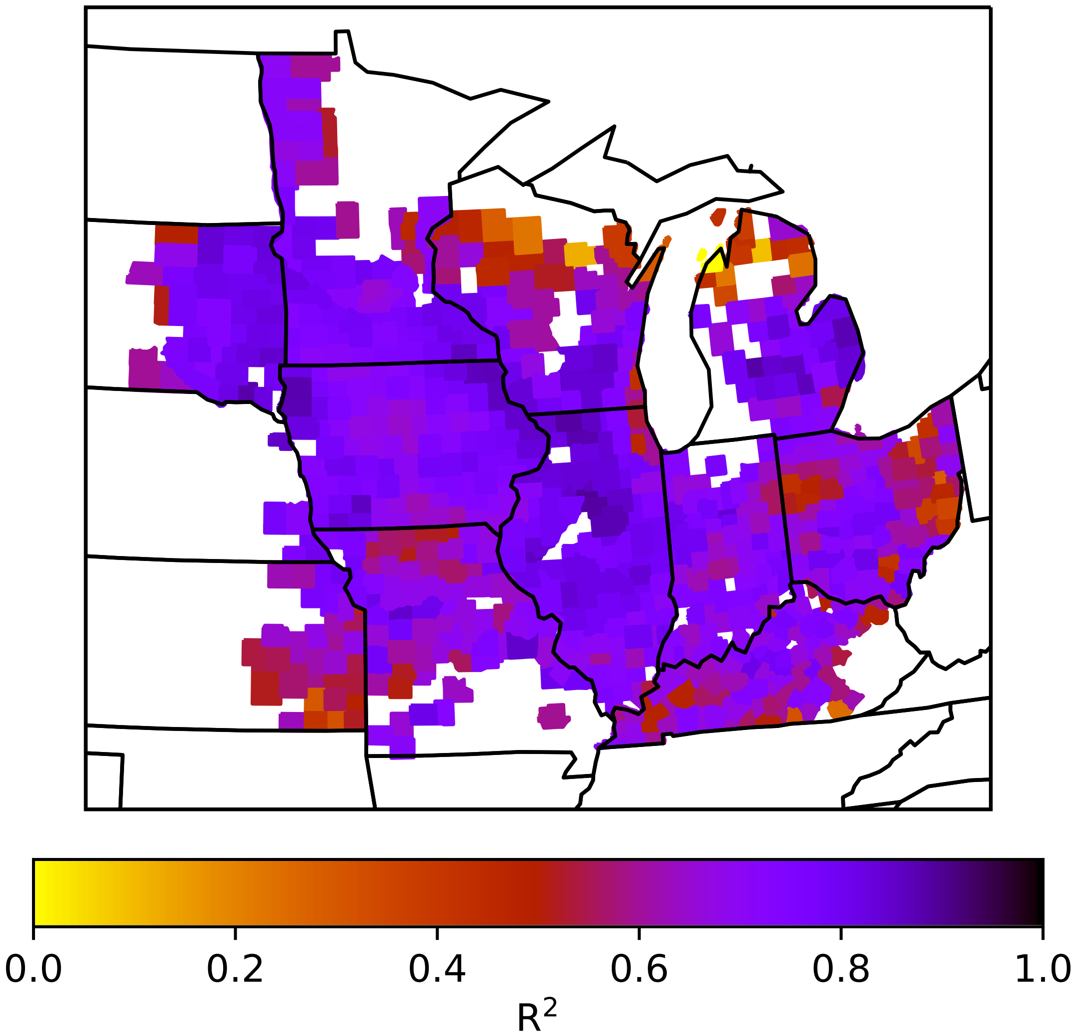

Figure S2: The squared correlation of modeled yield (Eqn. 4) and yield data. The model is constructed for the entire region, but captures the variation of individual counties well. We also evaluated the skill of the model at predicting yields through a cross-validation procedure in which 20% of the county years were omitted from the training dataset, the total model R^2 was 0.78 for the predictive set, comparable to that for the training set, 0.79.

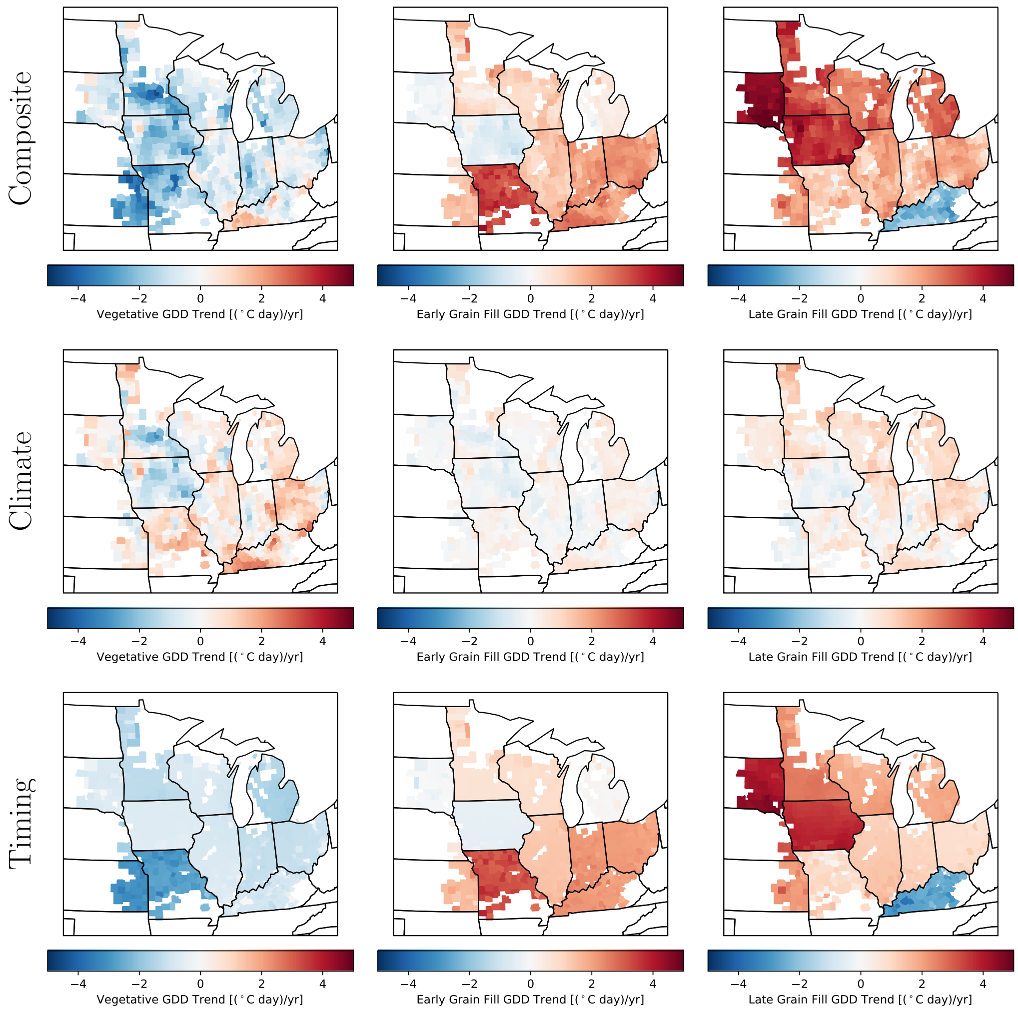

Figure S3: Trends in GDD for each county during each phase, according to the full record and the breakdown by climate and timing.

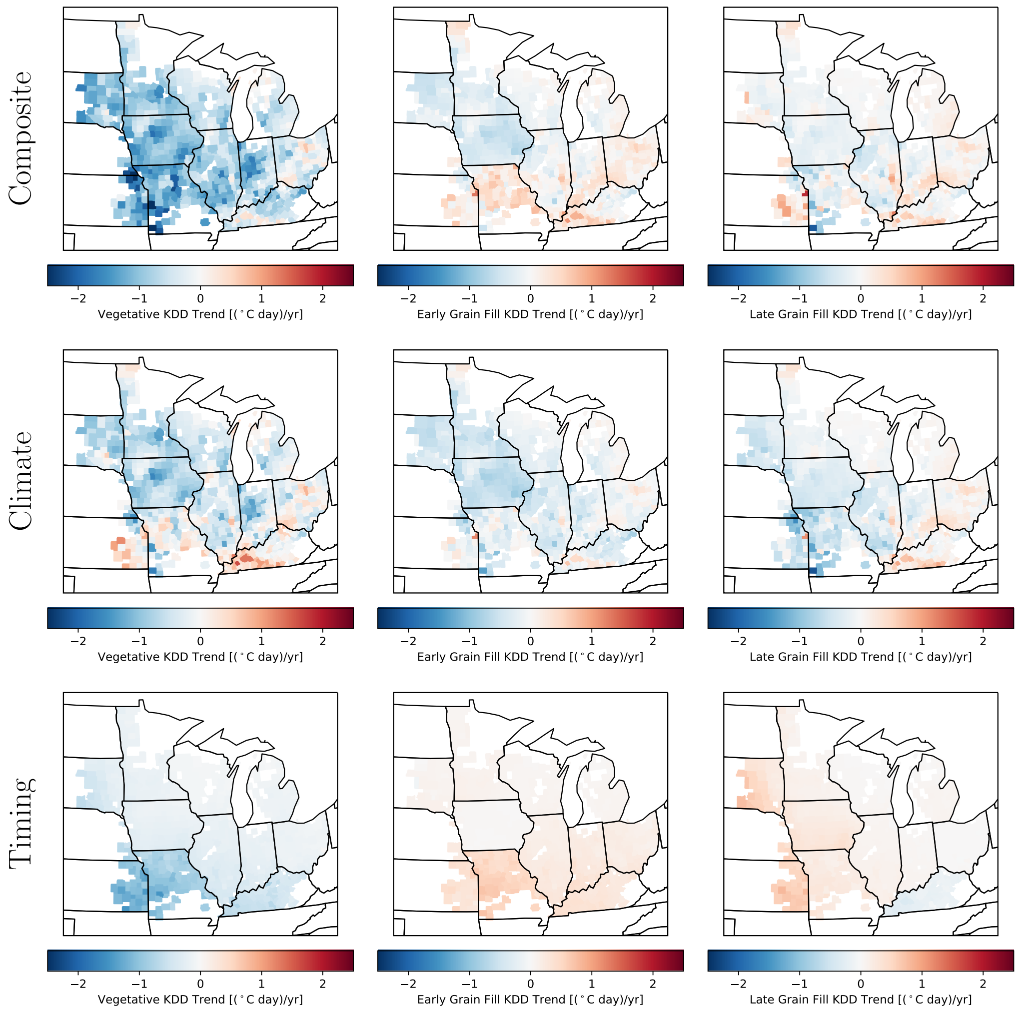

Figure S4: Trends in KDD for each county during each phase, according to the full record and the breakdown by climate and timing.

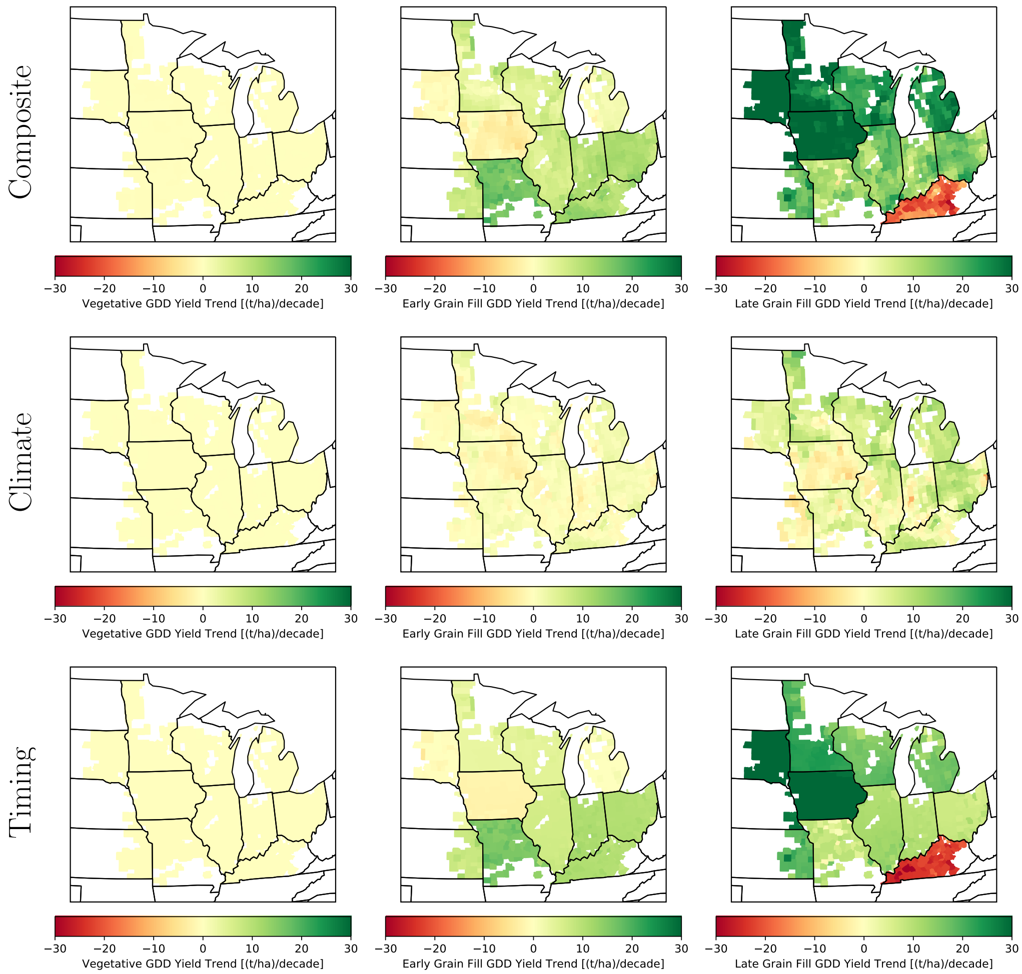

Figure S5: Yield Trends from GDD for each county during each phase, according to the full record and the breakdown by climate and timing.

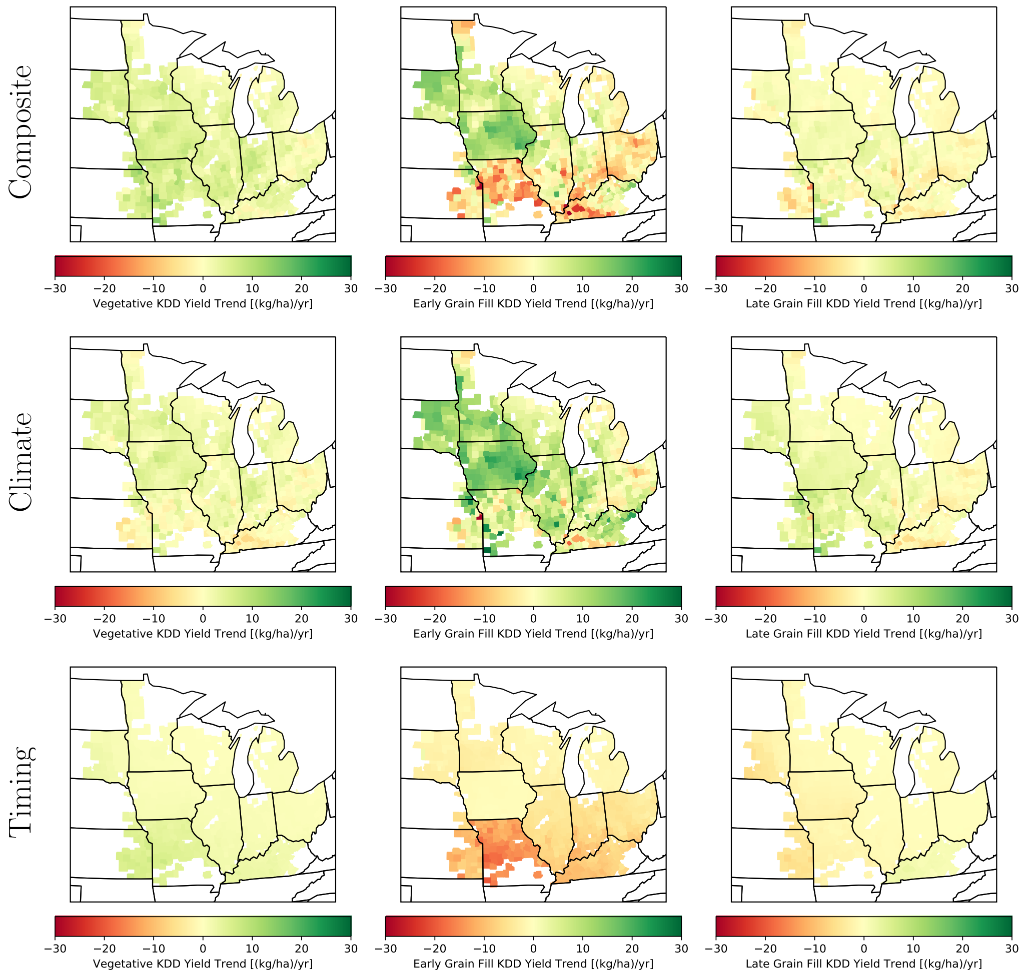

Figure S6: Yield trends from KDD for each county during each phase, according to the full record and the breakdown by climate and timing.

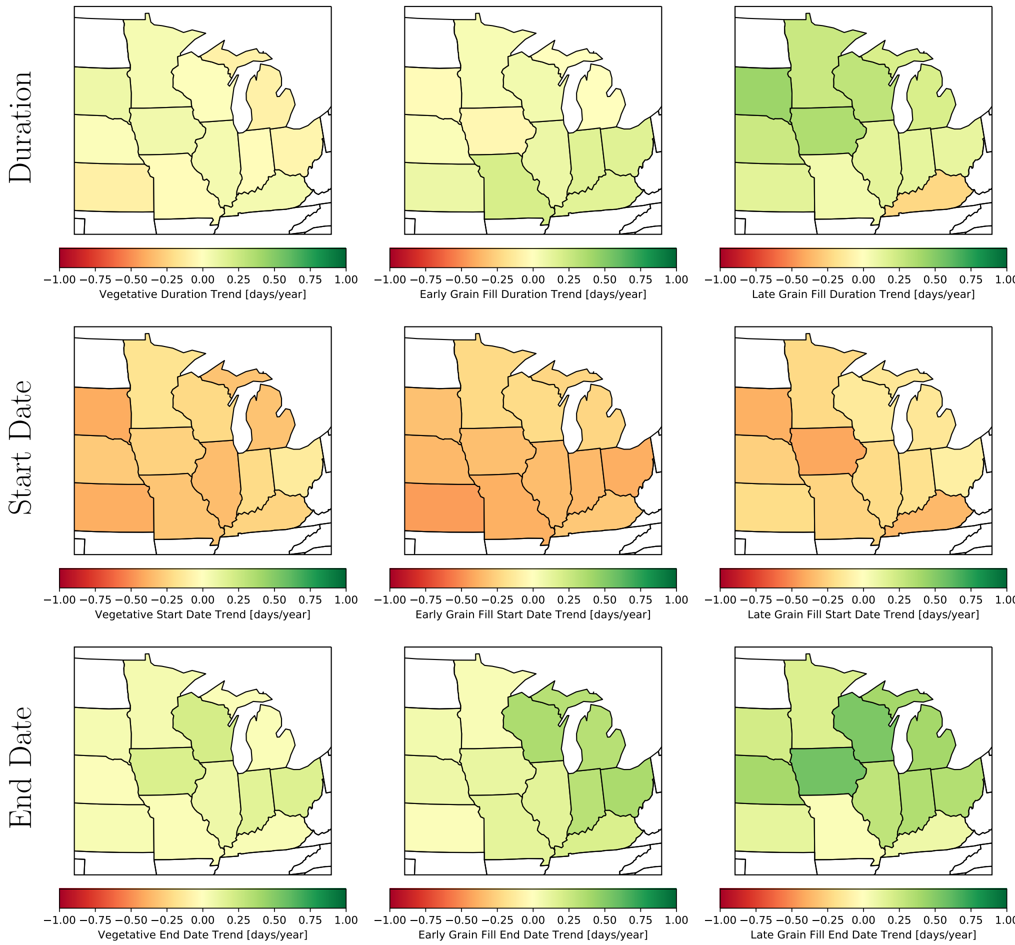

Figure S7: **Trends in timing** The timing trend in each state is presented in each row, with each column representing one of the three phases: vegetative, early grain fill, and late grain fill. top) All states have increased the duration of one of the grain filling phases while many have decreased the vegetative phase. Increasing duration of grain filling is associated with longer maturing cultivars and more GDDs in this period. middle) In every state start dates for each phase have moved earlier, consistent with earlier planting shifting the dates of subsequent development phases. bottom) End date trends are weaker but generally reflect a lengthening of the growing season.

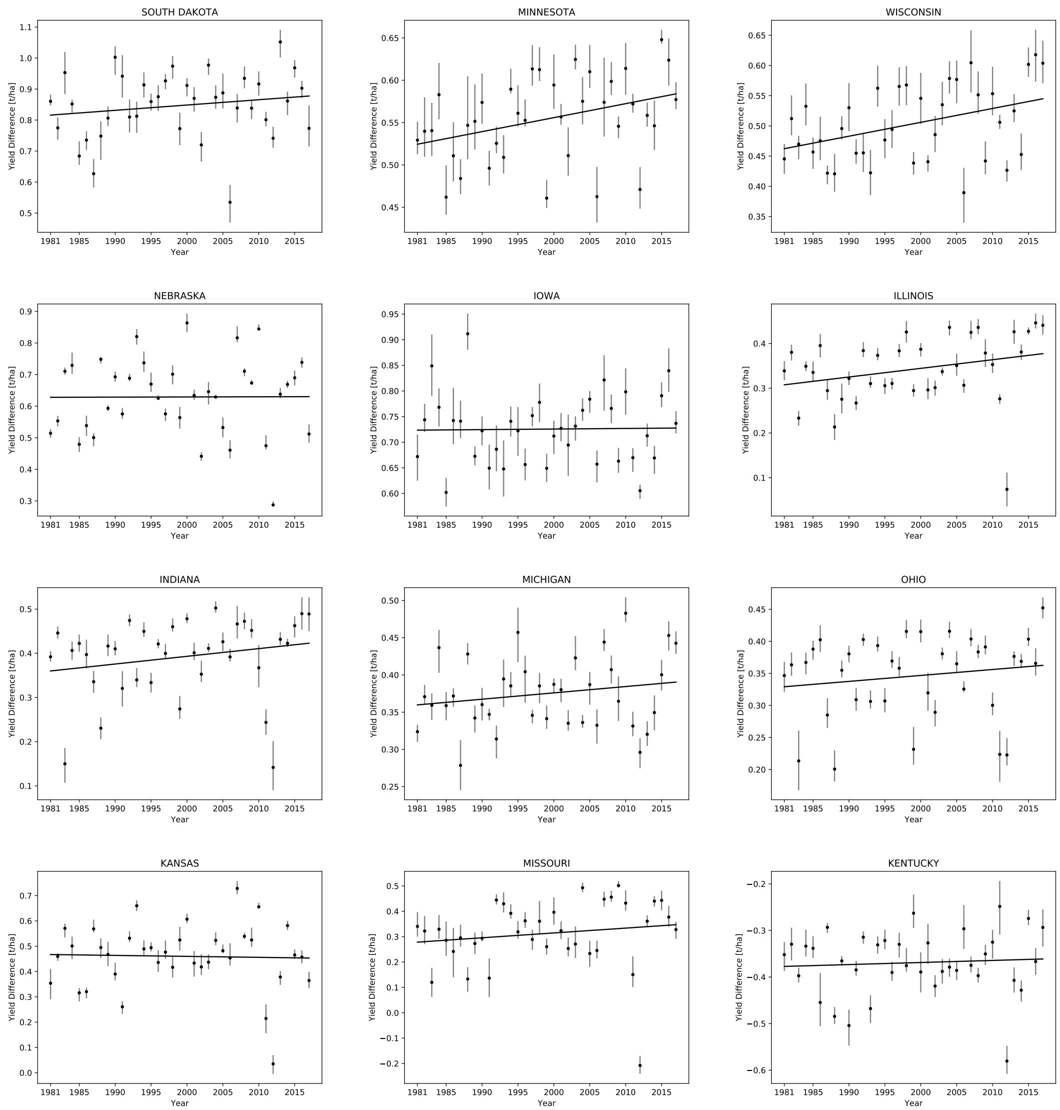

Figure S8: **State yield difference trends:** Each state's yield differences tend to cluster within a narrow band of improvement. Kentucky is the only state with consistently lower yield estimates. Note the different limits of the y-axes within each subplot to accomodate considerable inter-state variation in yield improvement.

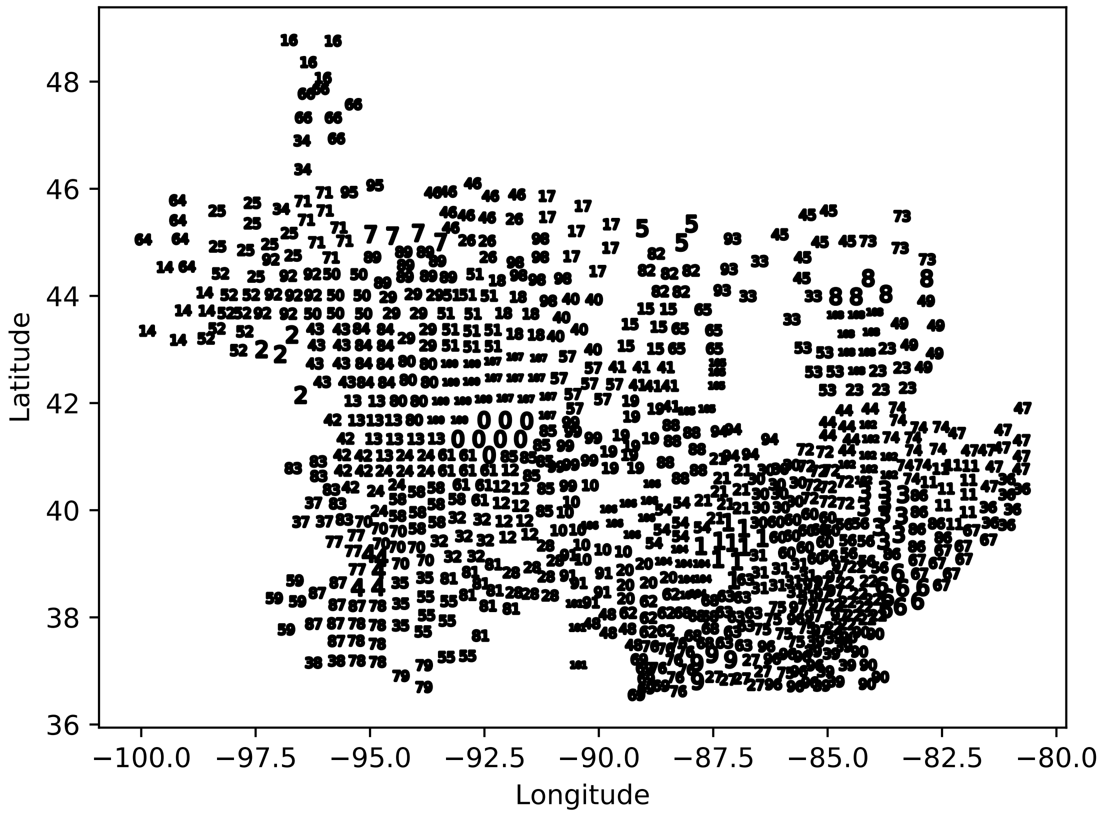

Figure S9: **County Clusters:** The numerical values indicate membership in a cluster, from 0 to 107 and the location is the interpolated latitude and longitude of each county. Note that clusters are geographically continuous.