A Discussion on the Paper "Modeling Agriculture in the Community Land Model"

B. Drewniak et al.,2013,
Geoscientific Model Development

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2016/11/4

Outline

- Introduction
- Methods
- Results
- Case Studies
- Discussion

0 1 INTRODUCTION

- Climate change can have a significant impact on crop yields. Agriculture can also have a influence on climate change .

- Most Earth system models either ignore agriculture or represent cultivation in a simplistic way without management or harvest activities.

- The influence of crops on carbon cycling varies with management practices such as crop rotation, tillage, fertilizer inputs, and residue harvesting (West and Post, 2002; Hooker et al., 2005; Dou and Hons, 2006; Huggins et al., 2007; Khan et al., 2007; Kim et al., 2009).

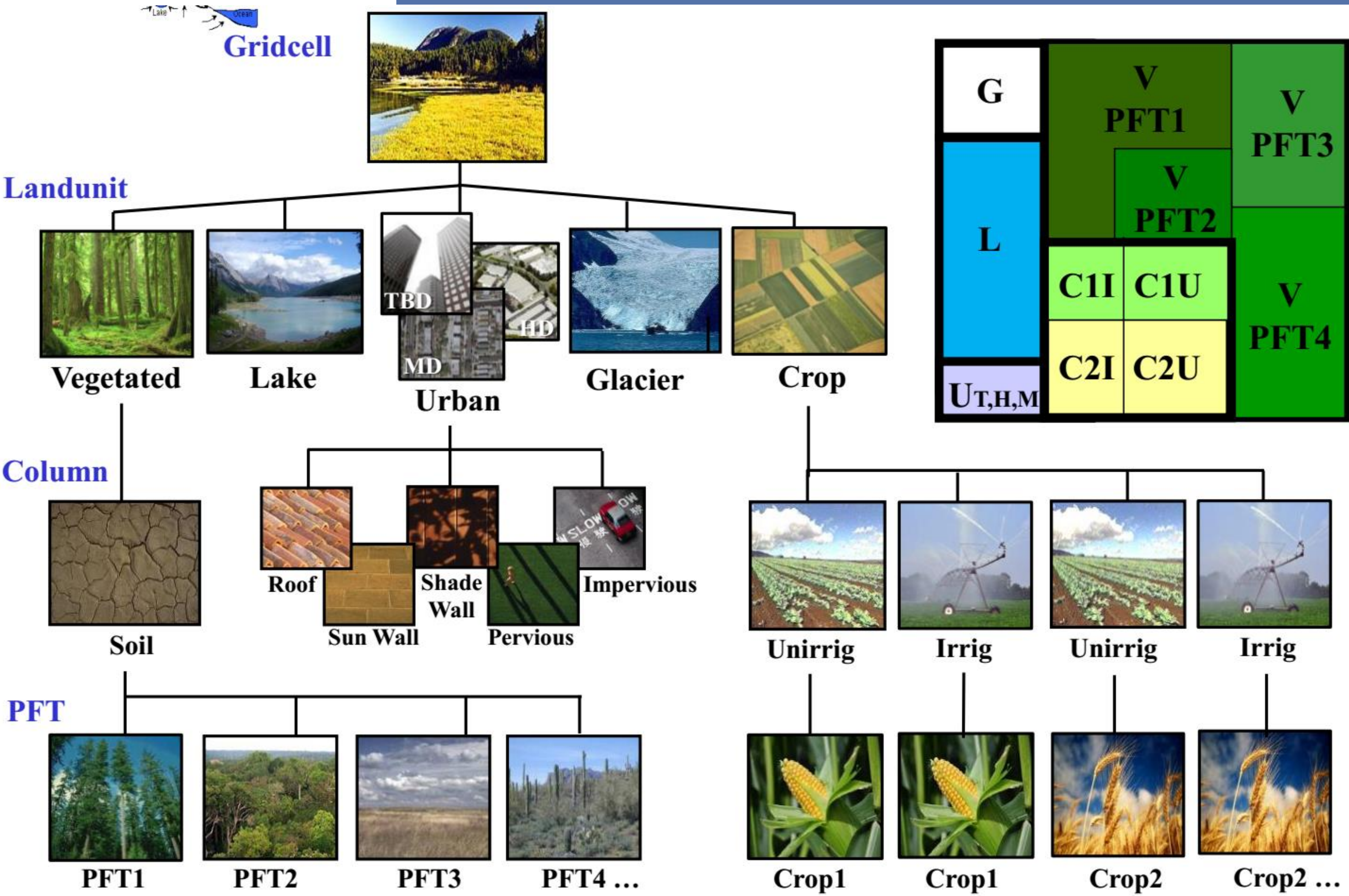
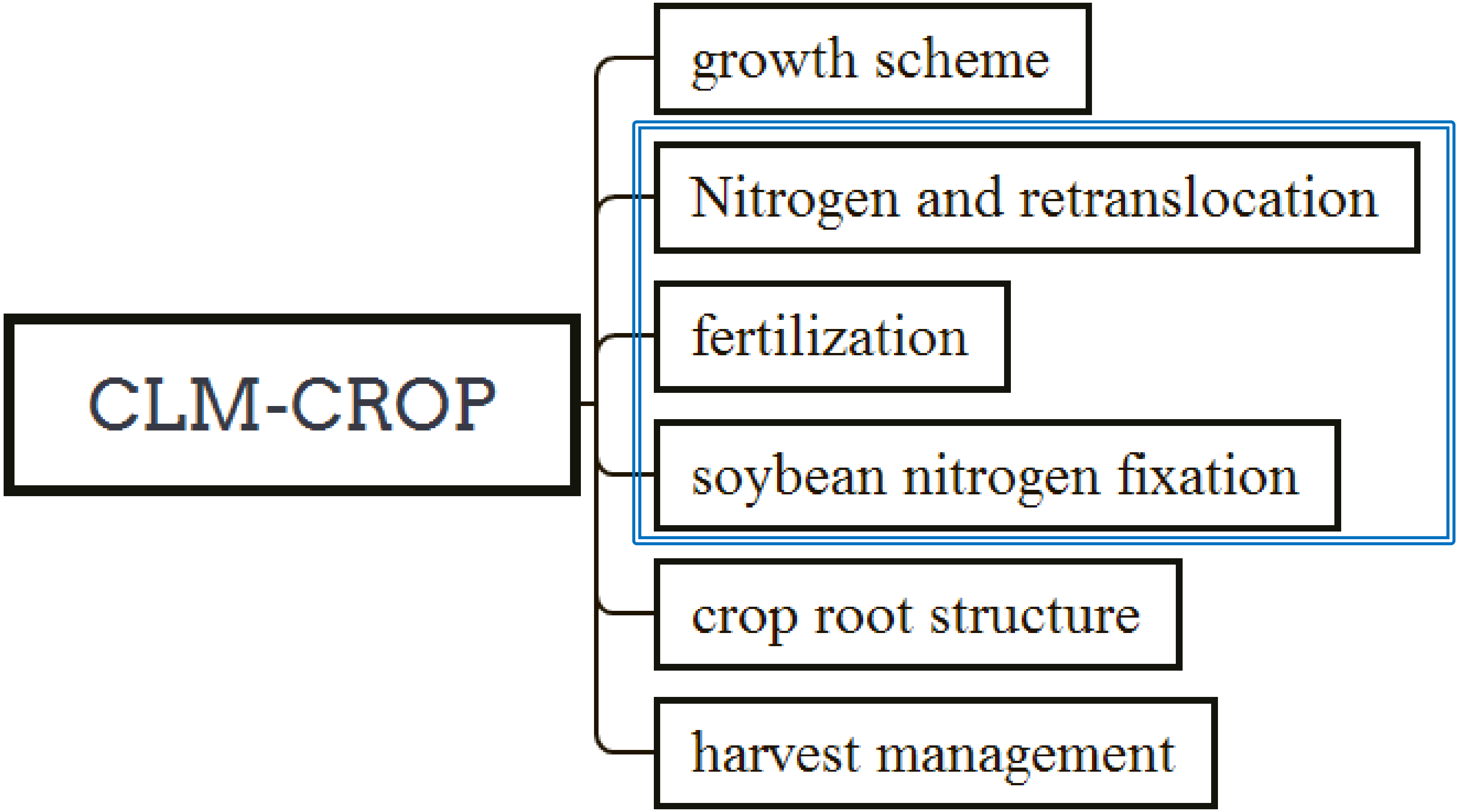


Fig. 1. Configuration of the CLM sub-grid hierarchy.


CLM-CROP
growth scheme
Nitrogen and retranslocation
fertilization
soybean nitrogen fixation
crop root structure
harvest management

2.1.1 Growth Scheme

1.Algorithms are from the Agro-IBIS model (Kucharik and Brye, 2003).

2. The growth and development processes of crops: seeding, emergence, organ development, and harvest.

3.The growth stage is determined by the fraction of phenological heat units (FPHUs) accumulated.

$$FPHU = \frac{\sum_{i=planting}^{current\ day} HU_i}{PHU}$$

$$HU(heat\ units) = T_{ave} - T_{base}$$

- T_{ave}: the average 2m air temperature.
- T_{base}: the minimum temperature required for growth.
- PHU: the total number of phenological heat units necessary to reach maturity.

Table 1. Crop parameters.

Parameter	Maize	Wheat	Soybean
FPHUs for growth stages			
Seeding	0	0	0
Emergence	0.03	0.08	0.03
Grain fill	0.53	0.59	0.70
Harvest	1	1	1
Pre-grain-fill-stage CN ratio			
Leaf	10	15	25
Stem	50	50	50
Root	42	30	42
Organ	50	40	60
Post-grain-fill-stage CN ratio			
Leaf	65	65	65
Stem	120	100	130
Root	42	40	42
Organ	50	40	60

2.1.2 Nitrogen and Retranslocation

1. Nitrogen allocation for crops is based on carbon : nitrogen (CN) ratios for leaves, stems, roots, organs, and litter.

2. Prior to organ development, CN ratios are optimized to allow maximum nitrogen accumulation for later use during organ development.

3. When grain fill begins, nitrogen from the leaves, stems, and roots (for wheat) is transferred to a retranslocation pool. The organ nitrogen demand is first supplied from the retranslocated nitrogen pool, and any remaining demand is drawn from the soil nitrogen pools.

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2.1.3 Fertilization

They adopted a fertilizer scheme delivering nitrogen directly to the soil mineral nitrogen pool over a 20 day period, beginning at emergence.

2.1.4 Soybean Nitrogen Fixation

Nitrogen fixation is similar to that in the SWAT model (Neitsch et al., 2005).

$$N_{fix} = N_{\mathrm{plant}\_ndemand} \times \min(1, fxw, fxn) \times fxg$$

- N_{fix}: *added directly to the soil mineral nitrogen pool for use*
- $N_{plant\_ndemand}$: *the balance of nitrogen needed to reach potential growth that cannot be supplied from the soil mineral nitrogen pool*
- *fxw:* *the soil water factor*
- *fxn:* *the soil nitrogen factor*
- *fxg:* *the growth stage factor*

$$fxw = \frac{wf}{0.85}$$

- *wf : the soil water content as a fraction of the water holding capacity for the top 0.05 m*

$$f_{xn} = \begin{cases} 1 & for\ smin \le 10 \\ 1.5 - 0.005 \times (sminn \times 10) & for\ 10 < smin \le 30 \\ 0 & for\ smin > 30 \end{cases}$$

- *sminn: the total nitrogen in the soil pool (g* m^{-2}*)*

$$fxg = \begin{cases} 0 & for\ FPHU \le 0.15 \\ 6.67 \times FPHU - 1 & for\ 0.15 < FPHU \le 0.30 \\ 1 & for\ 0.30 < FPHU \le 0.55 \\ 3.75 - 5 \times FPHU & for\ 0.55 < FPHU \le 0.75 \\ 0 & for\ FPHU > 0.75 \end{cases}$$

2.1.5 Crop Root Structure

- Vegetation has a constant root depth and density profile; root density decreased linearly with depth.

- Crops have a dynamic rooting depth that depends on growth stage.

2.1.6 Harvest Management

- CLM-CROP
  - Atmosphere pools
    - the carbon and nitrogen in the grain
    - a percentage of C and N in the leaves and stems
  - Litter pools
    - the remaining above-ground
    - all of the below-ground

2.2 Input Data

- **Climate Data**

Three-hourly data for temperature, wind speed, humidity, precipitation, solar radiation, and surface pressure from NCEP reanalysis data for the period 1948–2004 (Kalnay et al.,1996).

- **Surface Data**

Land use: natural vegetation (Bonan et al.,2002) and crop coverage maps (Leff et al.,2004).

Planting date: Crop Calendar Dataset (Sacks et al., 2010).

PHUs: Crop Calendar Dataset (Sacks et al., 2010).

2.3 Model Simulation

- Model Output versus Observations

  Bondville, IL (40.01°N, 88.29°W)

  Mead, NE (41.18°N, 96.43°W)

- Two scenario

  Agriculture scenario(hereafter CROP)

  Grassland scenario (hereafter GRASS)

- Four case studies

  Residue management

  Planting date

3.1 Model Performance Compared with Observations

- CO_2 fluxes: GPP, NEE
- Leaf area index
- Yields

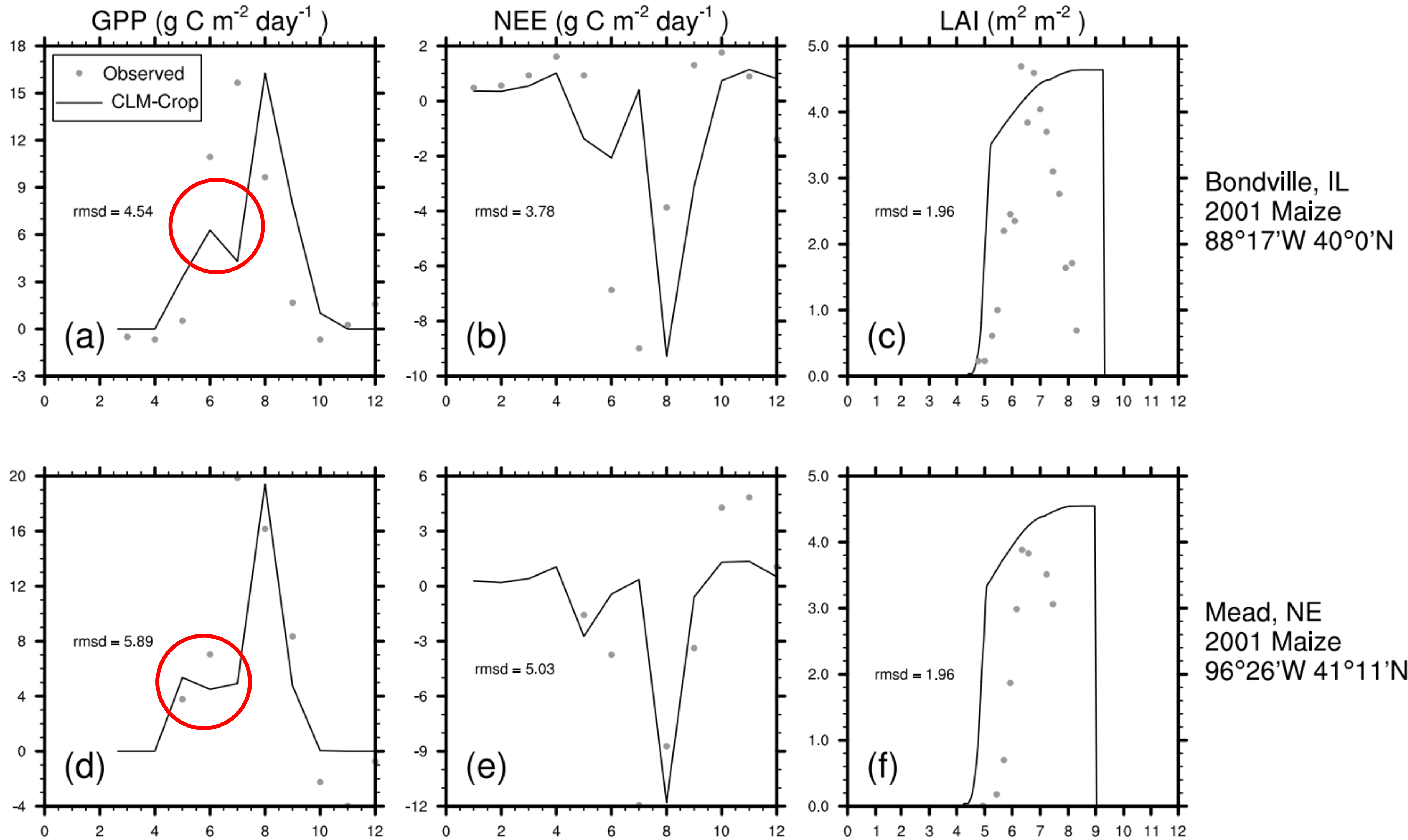


Fig. 2(a). Simulated (lines) and observed (circles) monthly averaged gross primary productivity (GPP; g C m^{-2} day^{-1}), net ecosystem exchange (NEE; g C m^{-2} day^{-1}), and LAI (m^2 m^{-2}) during 2001 for maize at two sites: Bondville, IL and Mead, NE.

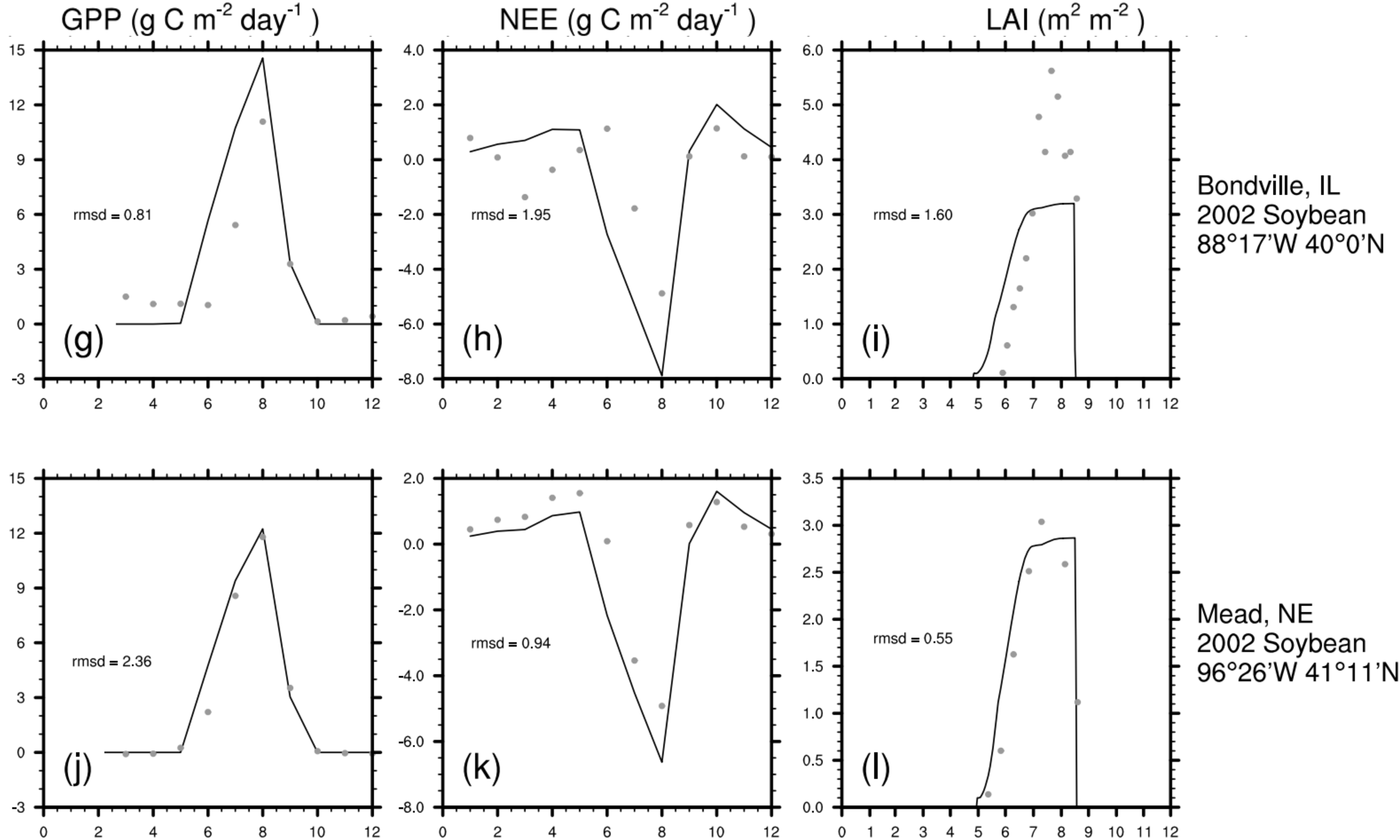


Fig. 2(b). Simulated (lines) and observed (circles) monthly averaged gross primary productivity (GPP; g C m^{-2} day^{-1}), net ecosystem exchange (NEE; g C m^{-2} day^{-1}), and LAI (m^2 m^{-2}) during 2002 for soybean at two sites: Bondville, IL and Mead, NE.

Table 2. Root-mean-squared error of GPP for selected regions from CROP and GRASS simulations, as compared with MODIS satellite data of Zhao et al. (2005).

Country	CROP	GRASS	Percent Change
United States	510.86	581.77	−12.19
France	625.62	751.16	−16.71
Mexico	712.22	855.15	−16.71
Spain	475.86	505.03	−5.78
Italy	809.42	861.61	−6.05
Germany	359.30	381.11	−5.72
South Africa	240.14	266.87	−10.01
Greece	727.64	806.89	−9.82
Netherlands	422.54	478.28	−11.65
Portugal	801.06	845.56	−5.20
Turkey	618.34	684.91	−9.71
United Kingdom	431.07	468.62	−8.01

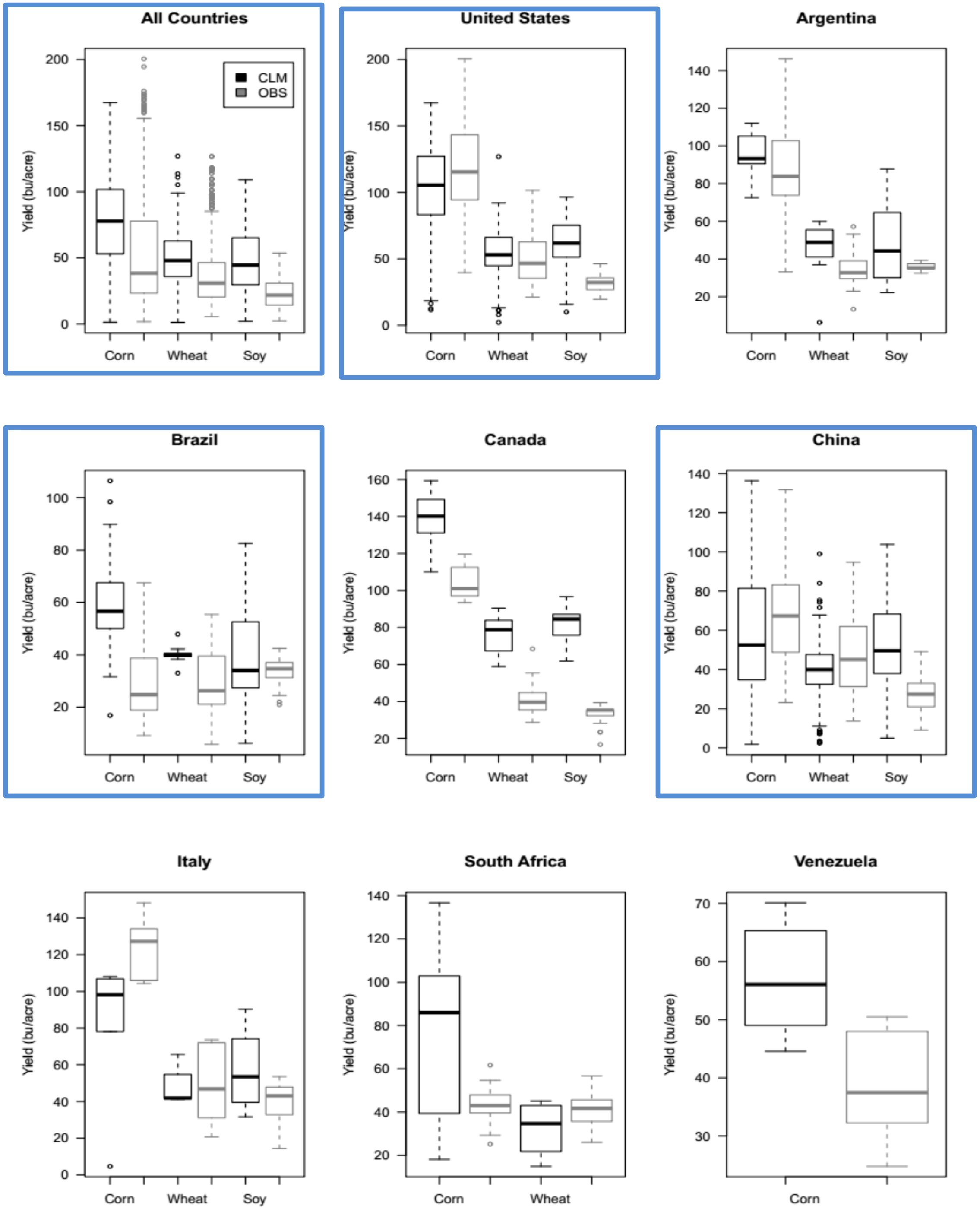
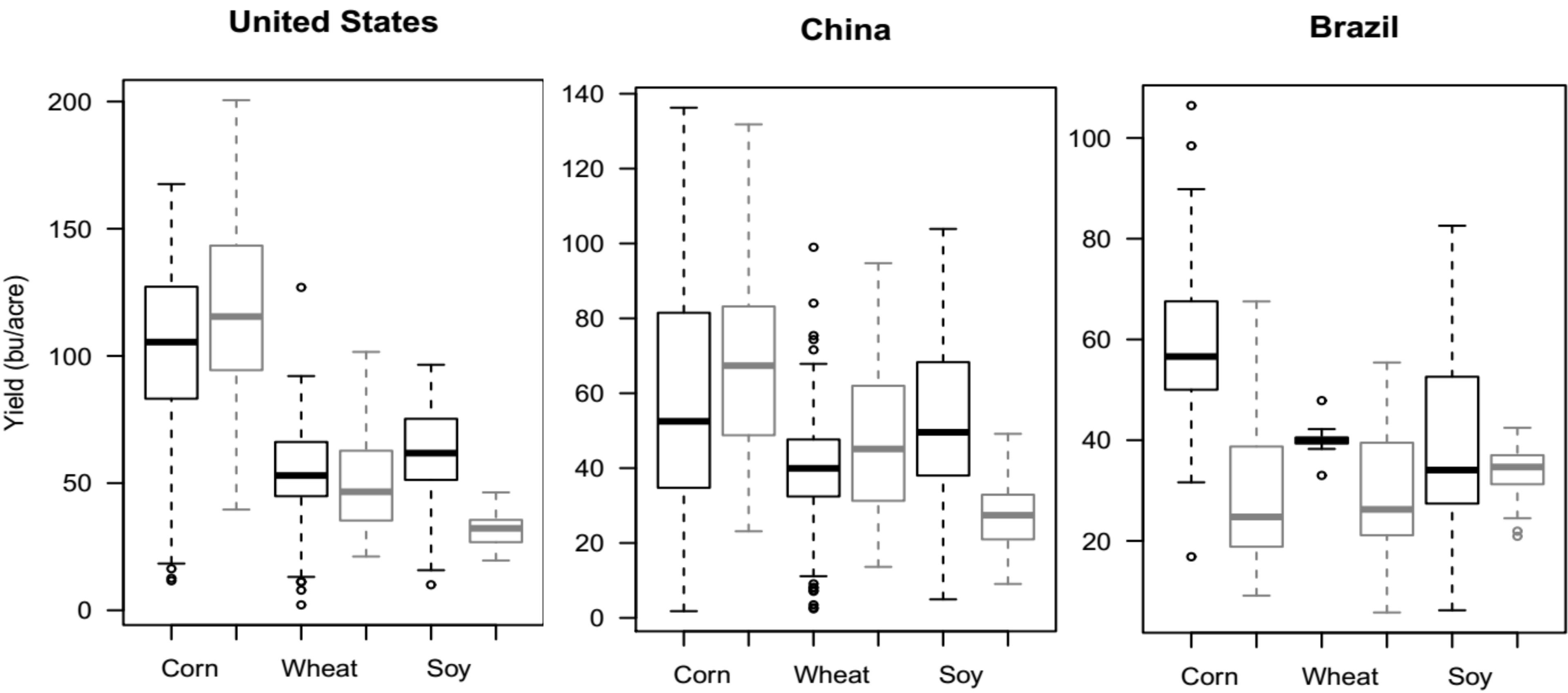


Fig. 3. CLM-Crop-simulated (black) and observed (gray; data from Monfreda et al., 2008) yields (bu acre^{-1}) for maize, wheat, and soybean of selected regions.



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3.2 Climate Influence on Crop Yields

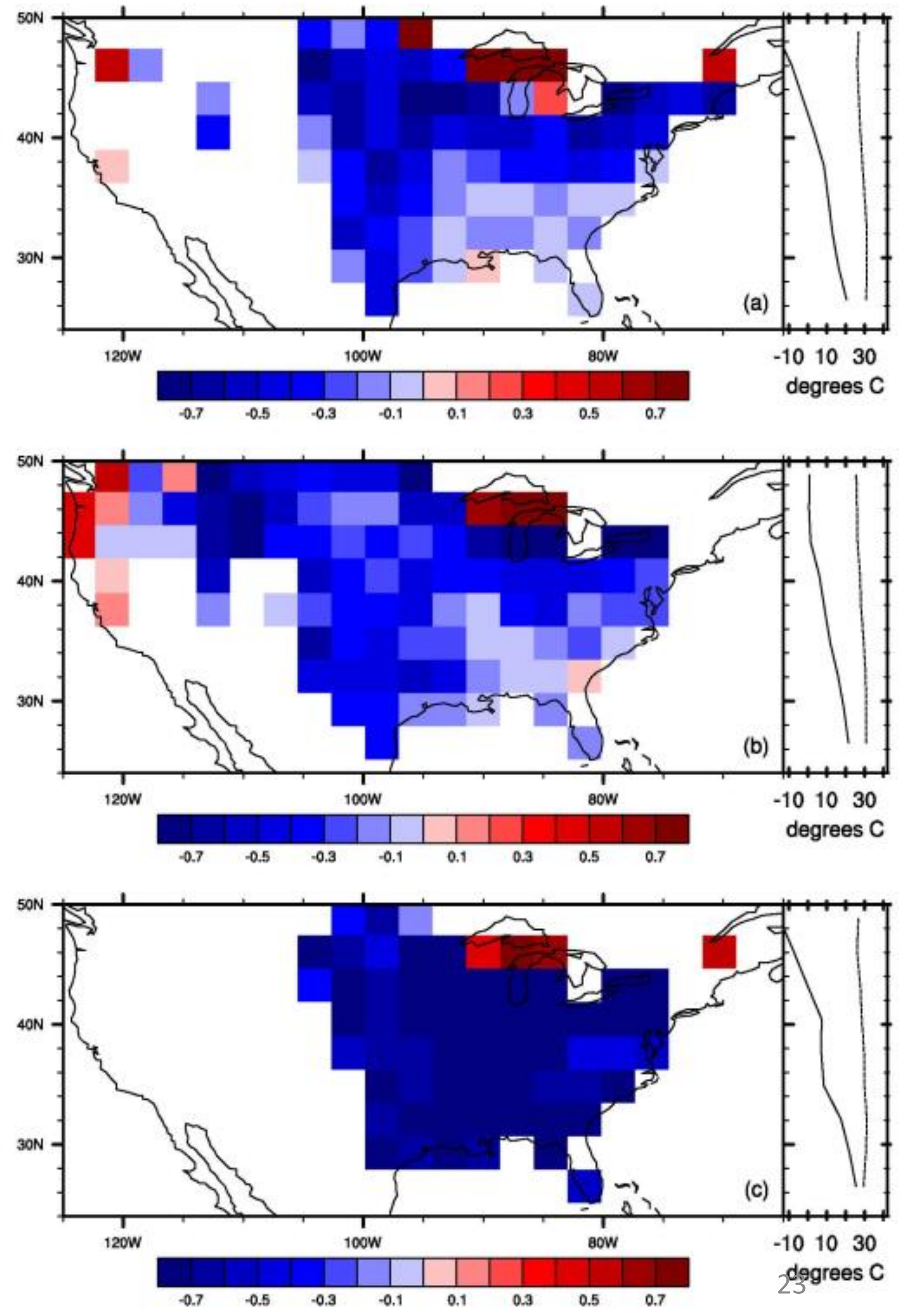

Fig. 4. Correlation coefficient between temperature and yield for **(a)** maize, **(b)** spring wheat, and **(c)** soybean. The right half of each panel shows the latitudinal maximum and minimum temperatures (°C) during the growth period for each crop.

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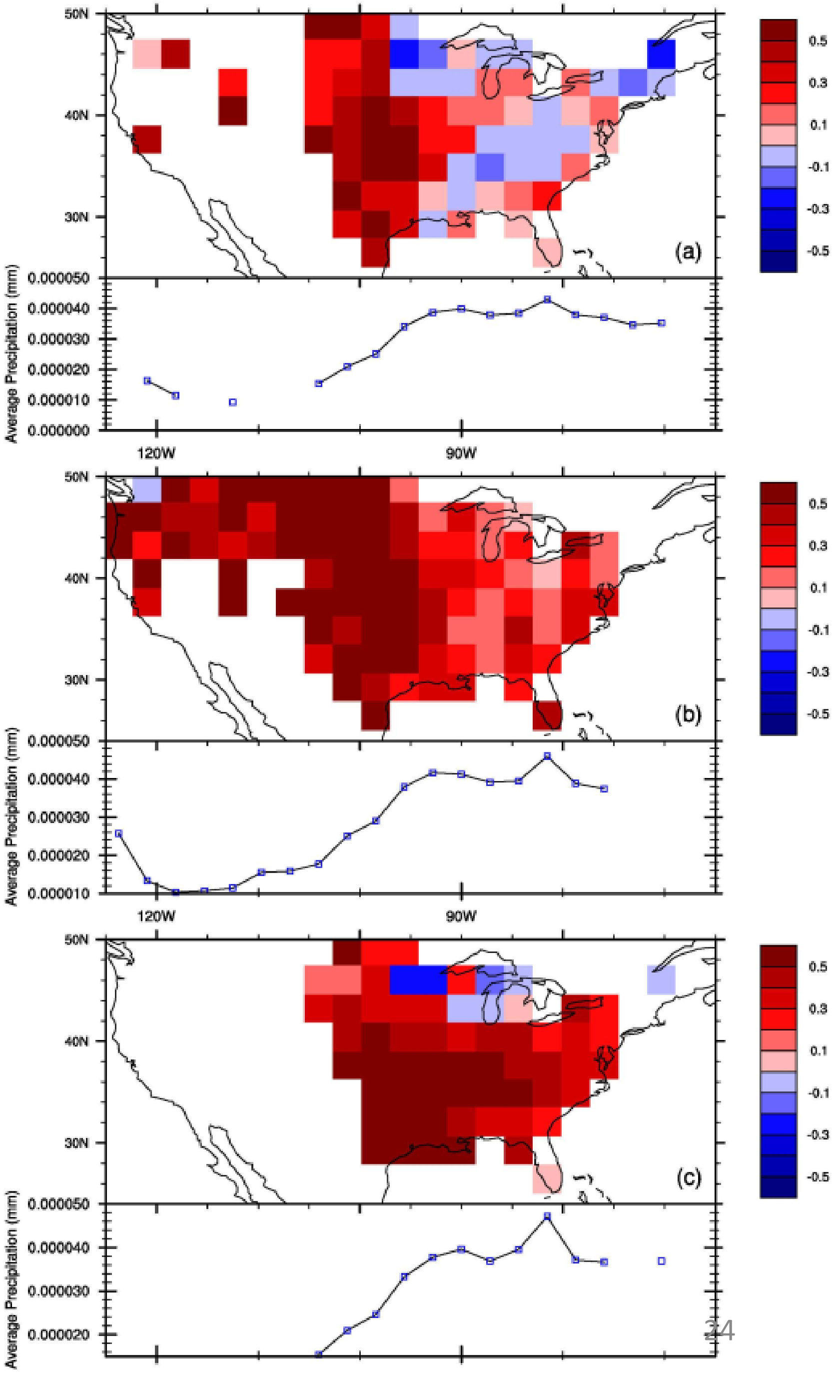

Fig. 5. Correlation coefficient between precipitation and yield for **(a)** maize, **(b)** spring wheat, and **(c)** soybean. The bottom half of each panel shows the longitudinal average precipitation (mm) during the growth period for each crop.

Table 3. Parameter values for the baseline CLM-Crop simulation and the case studies.

Type of Change	Scenario	Maize	Spring Wheat	Soybean
Residue Management (% non-grain residue returned to litter pool)	CROP	30 %	30 %	40 %
	HIGHRES	70 %	70 %	70 %
	LOWRES	10 %	10 %	10 %
Planting Date (10 day running average temperature threshold for planting)	CROP	NA – fixed	NA – fixed	NA – fixed
	HighPTEMP	22 °C	21 °C	17 °C
	LowPTEMP	12 °C	11 °C	7 °C

4.1 Sensitivity of Yield and GPP to Residue Management

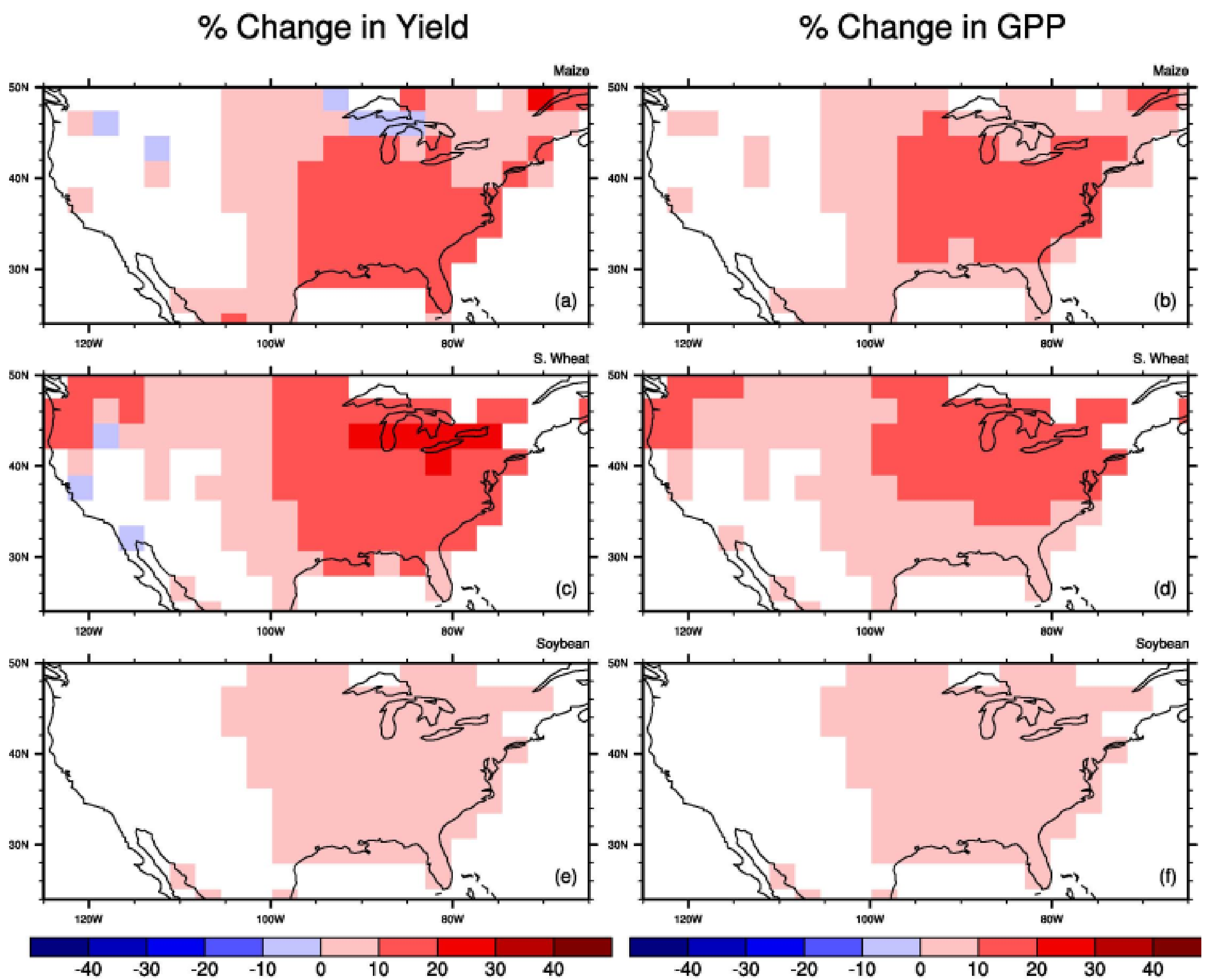

Fig. 6. The percent change in yield (left column) and GPP (right column) for **(a, b)** maize, **(c, d)** spring wheat, and **(e, f)** soybean from a 70% residue return management practice (HIGHRES).

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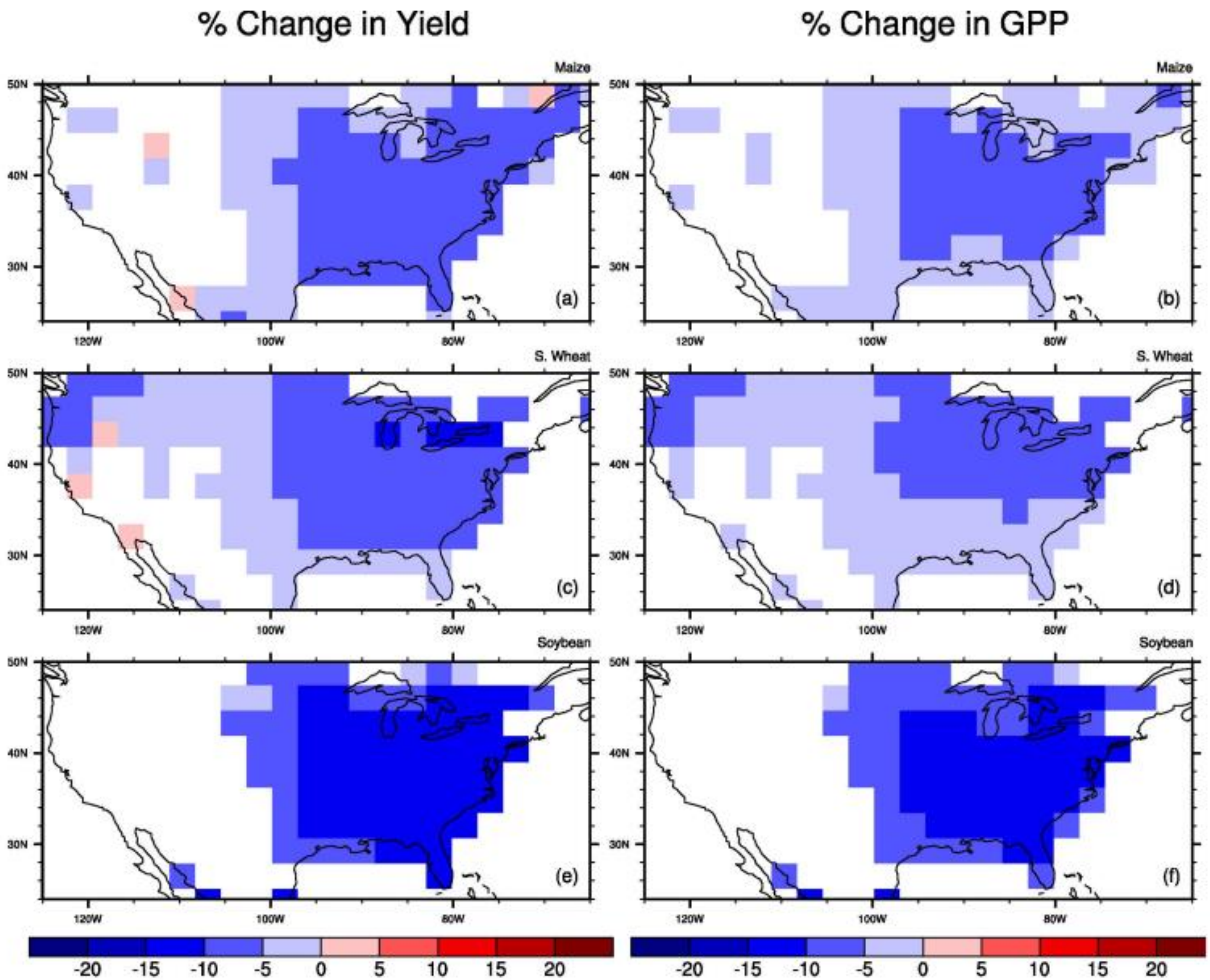

Fig. 7. The percent change in yield (left column) and GPP (right column) for (a, b) maize, (c, d) spring wheat, and (e, f) soybean from a 10 % residue return management practice (LOWRES).

4.2 Impact of Variable Planting Date on Yield and GPP

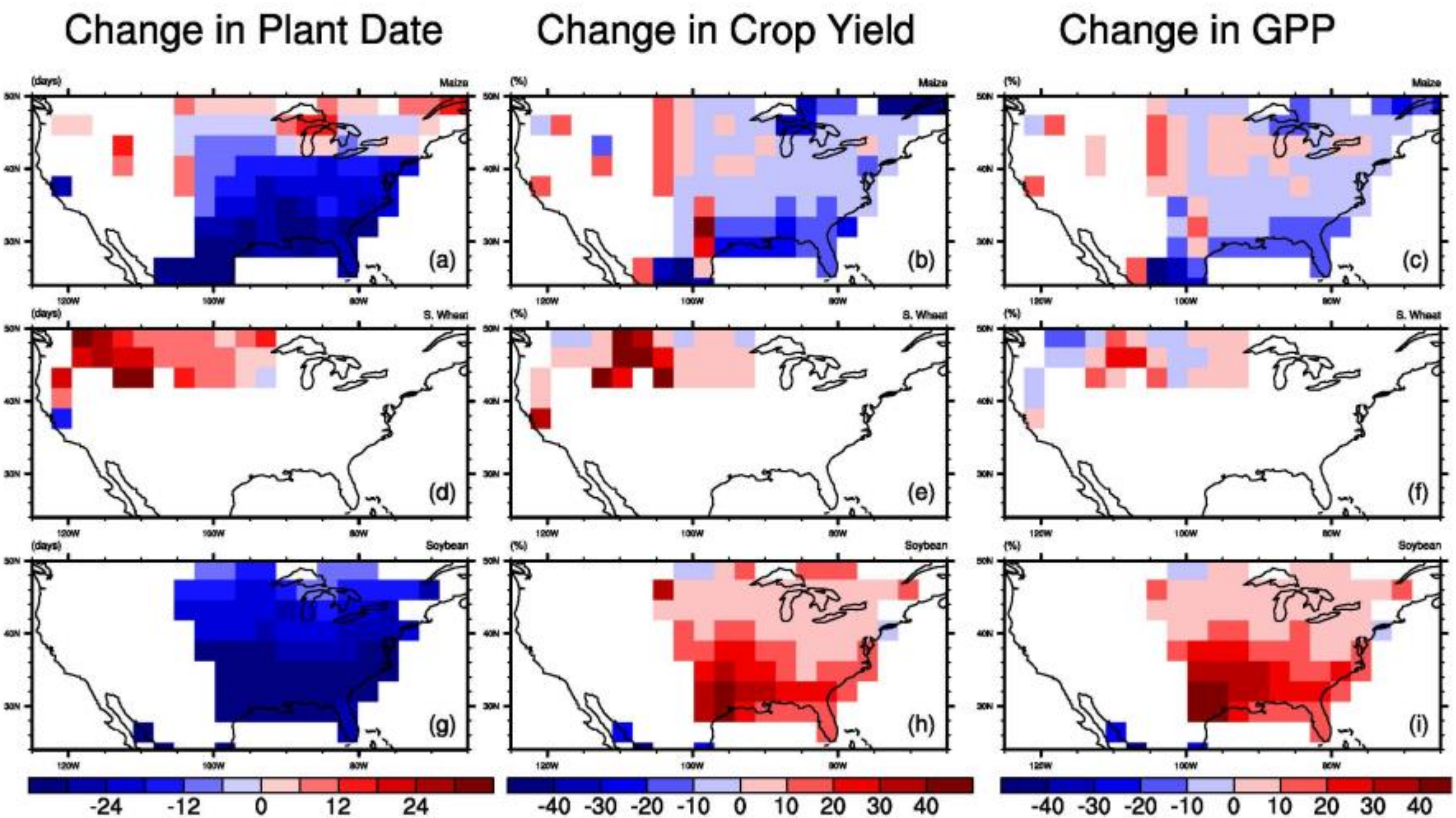

Fig. 8. The left column is the change in planting date (days), represented by the difference between LowPTEMP and CROP for (a) maize, (d) spring wheat, and (g) soybean. The center and right columns are the percent change in crop yield for (b) maize, (e) spring wheat, and (h)soybean and the GPP for (c) maize, (f) spring wheat, and (i) soybean resulting from new planting dates.

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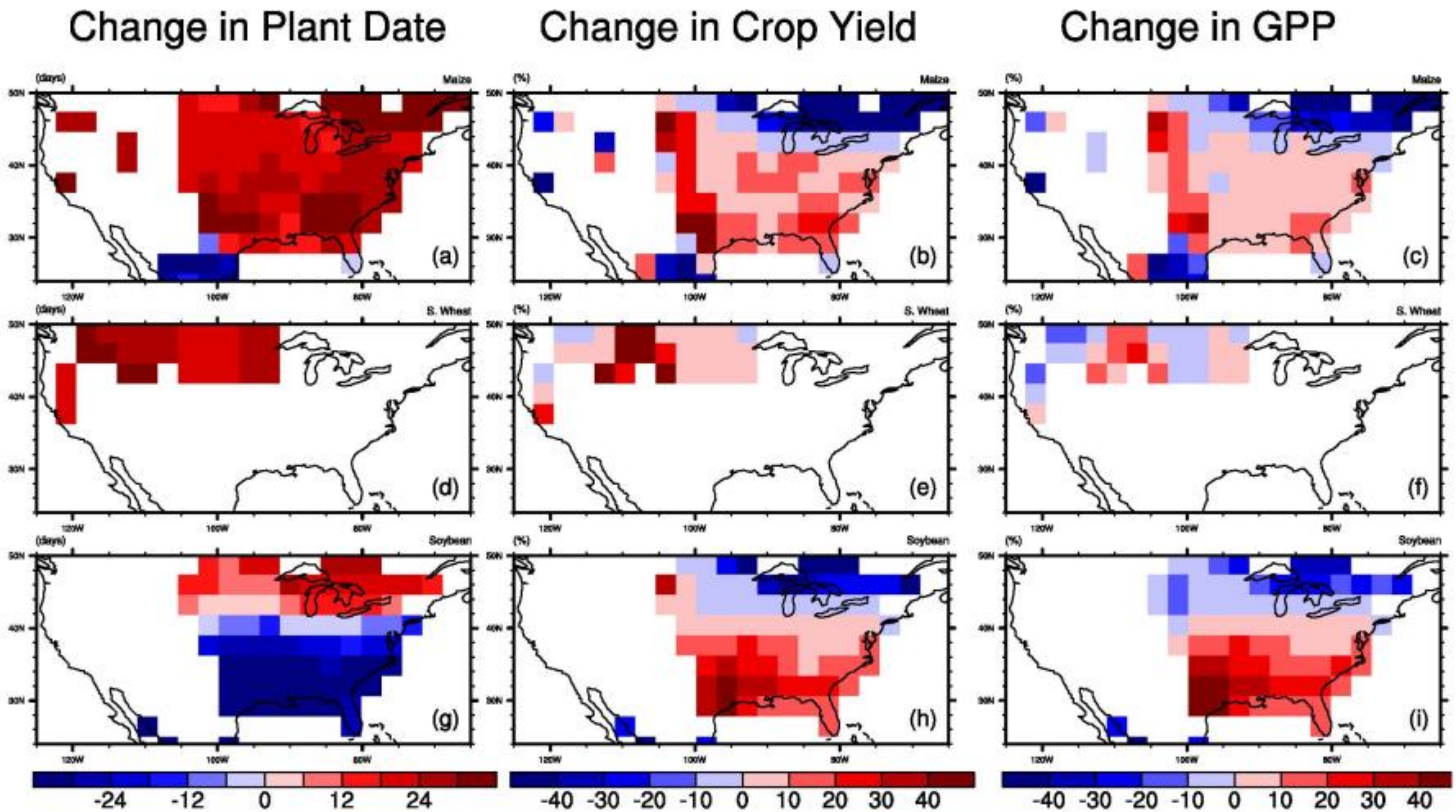

Fig. 9. The left column is the change in planting date (days), represented by the difference between HighPTEMP and CROP for (a) maize, (d) spring wheat, and (g) soybean. The center and right columns are the percent change in crop yield for (b) maize, (e) spring wheat, and (h)soybean and the GPP for (c) maize, (f) spring wheat, and (i) soybean resulting from new planting dates.

- Although the model does well in representing appropriate responses for agriculture systems, carbon fluxes compared well with field measurements for soybean, but not as well for maize.

- Crop yields and productivity were negatively correlated with temperature and positively correlated with precipitation.

- Increased residue returned to the litter pool increased crop yield, while reduced residue returns resulted in yield decreases.

- When low temperature threshold resulted in early planting, maize responded with a loss of yield, but soybean yields increased.

Next Work

- Improvements on the nitrogen scheme in the model, including a more complex fertilizer application and denitrification factor.
- Improvements on SLA.
- Expanding the model to incorporate other management practices (tillage, crop rotation, etc.) .
- Expanding parameters to capture other cultivars grown more broadly.

Thank you!