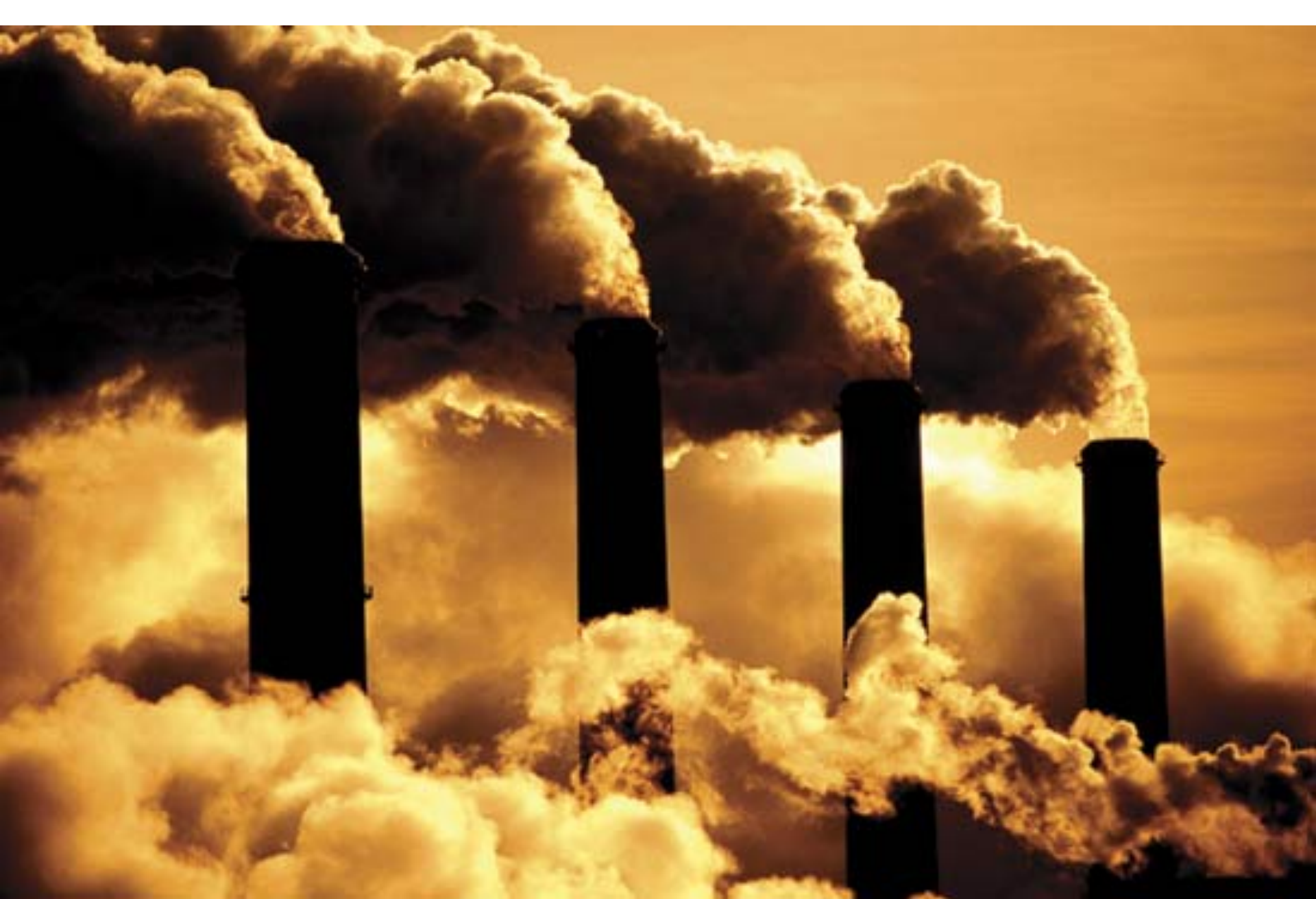


Natural Resource Availability under Future Environmental Change

Danica Lombardozzi
(dll@ucar.edu)

Sam Levis, & Gordon Bonan

National Center for Atmospheric Research*





How will resource productivity change under future change scenarios?



How will resource productivity change under future change scenarios?



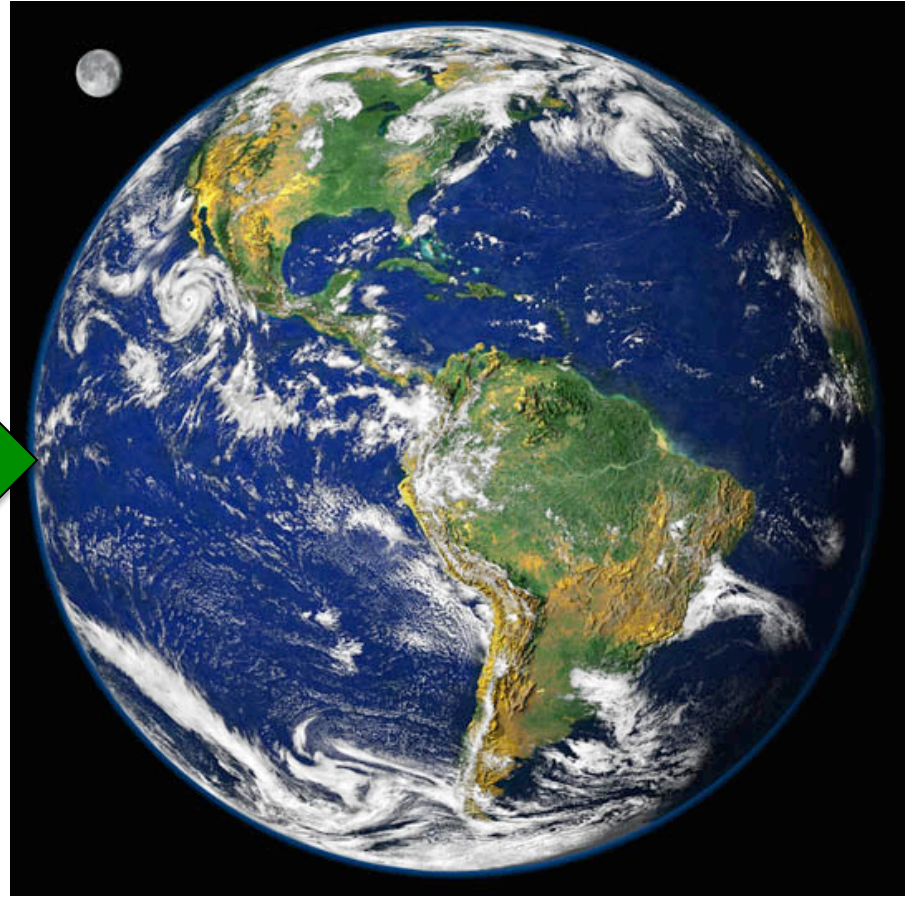
Timber & Grain
Responses to:
Climate, CO₂, O₃



CLM 4.5 with interactive crop management

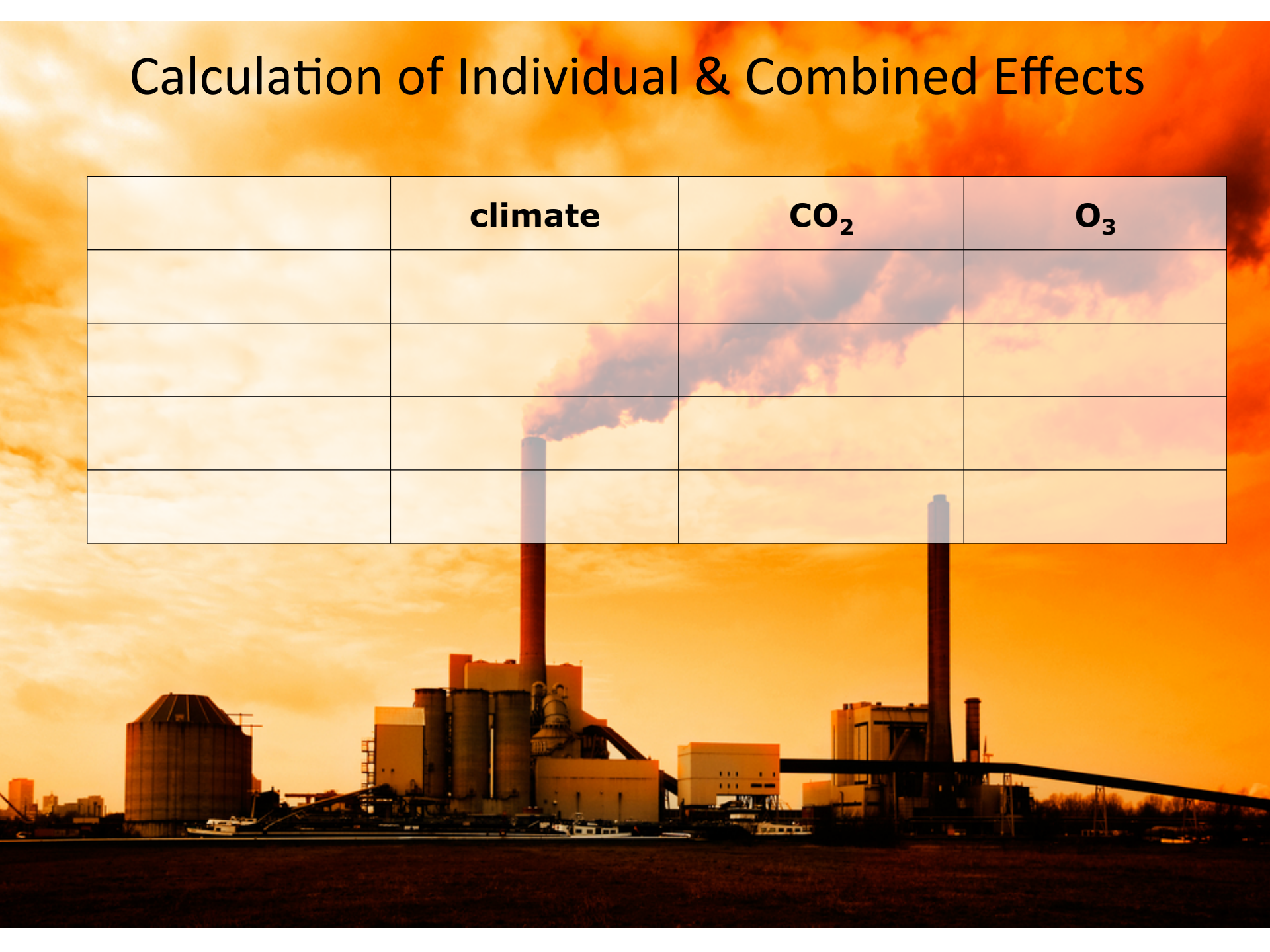
Developed by Sam Levis

- 32 new crop functional types
- Crop-specific phenology
 - leaf emergence, grain fill, maturity
- Management
 - planting, harvest, fertilizer, irrigating



Calculation of Individual & Combined Effects

	climate	CO₂	O₃



Calculation of Individual & Combined Effects

	climate	CO₂	O₃
Constant Control	2005	2005	None
Constant CO₂	transient RCP8.5	2005	None
Transient Control	transient RCP8.5	transient RCP8.5	None
O₃	transient RCP8.5	transient RCP8.5	2100 RCP8.5





Timber Focal Regions:

Northwestern US

Southeastern US

Eastern Europe



Crop Focal Regions:

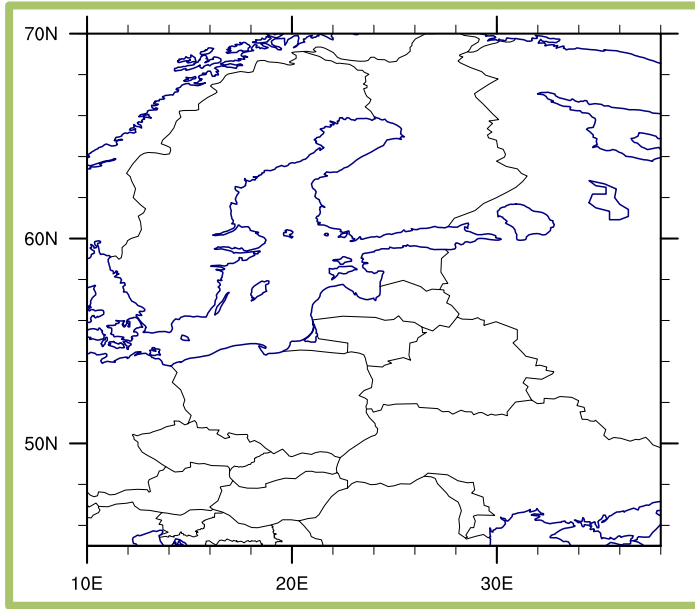
Central US

Europe

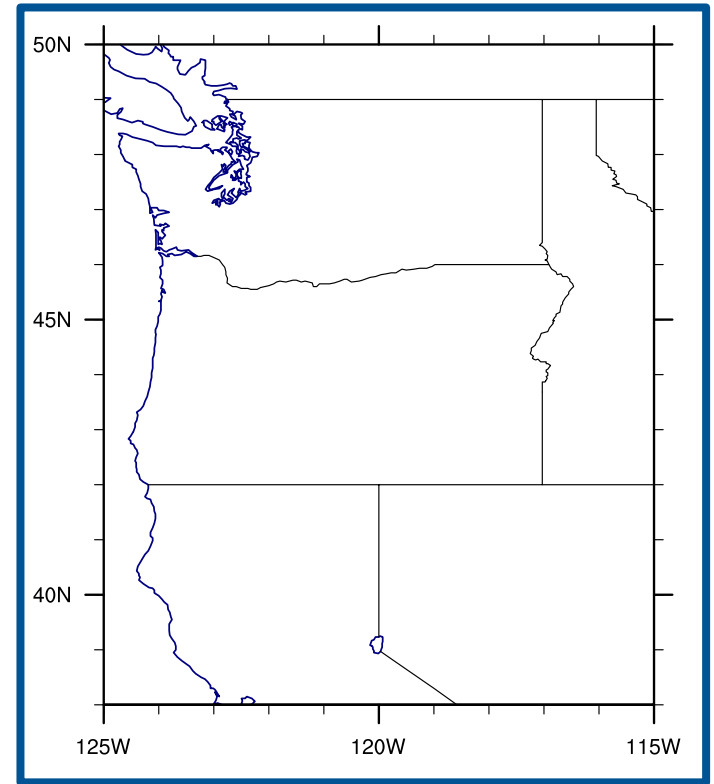
Eastern China

Timber Focal Regions

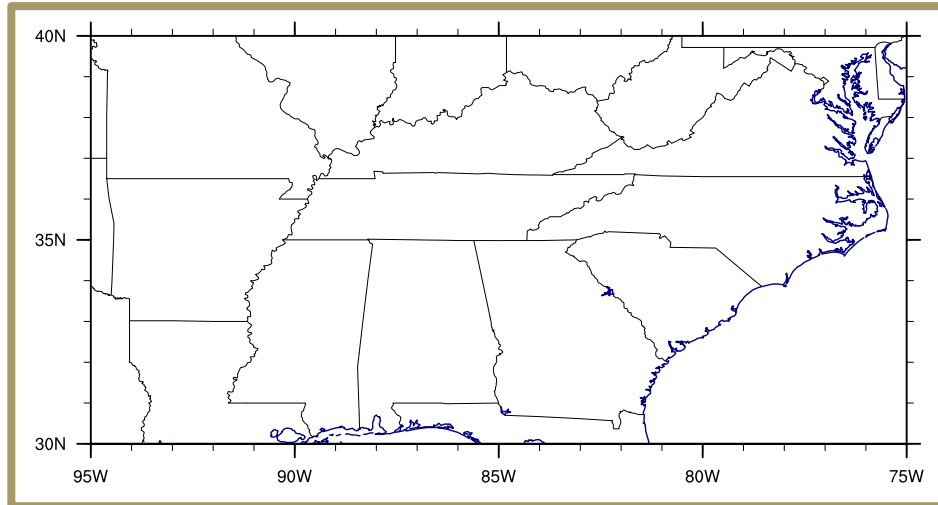
Eastern Europe



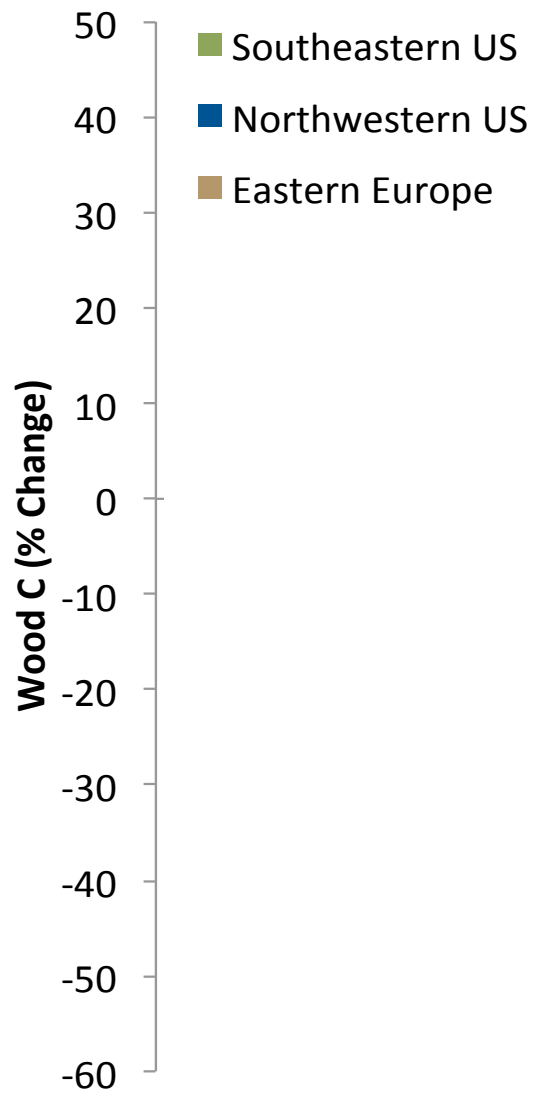
Northwestern US



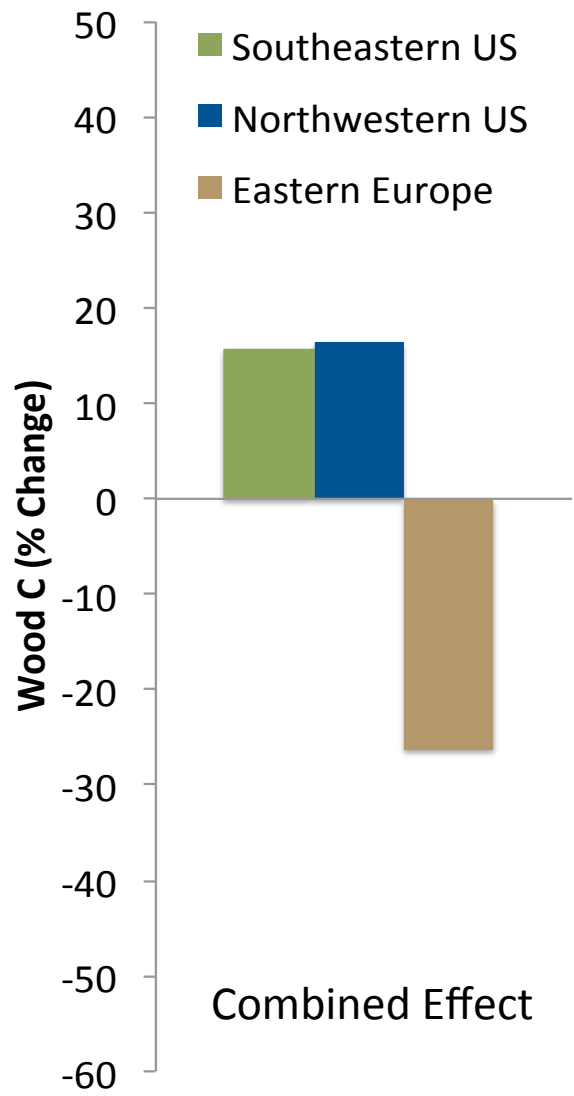
Southeastern US



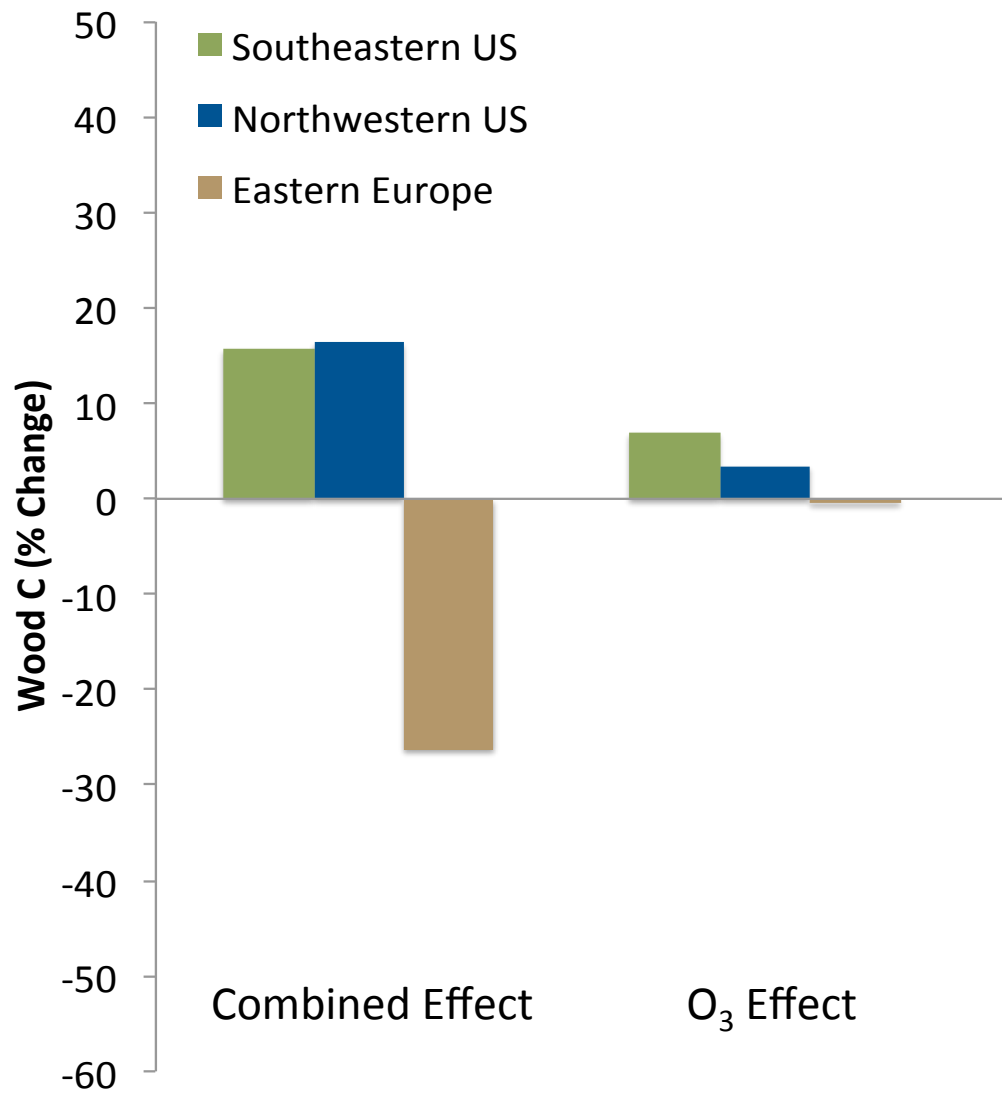
20-year (2080-2100) Averages



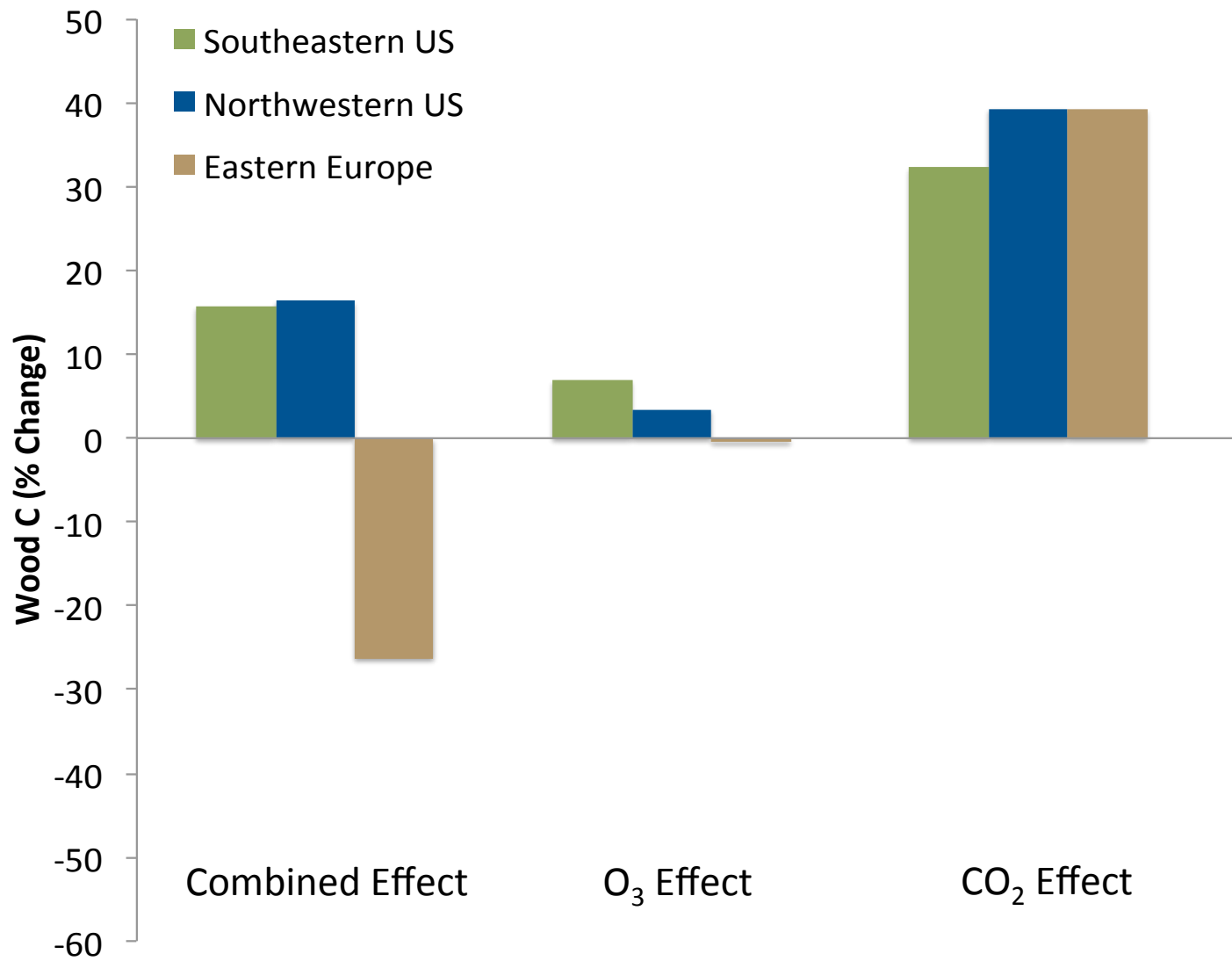
20-year (2080-2100) Averages



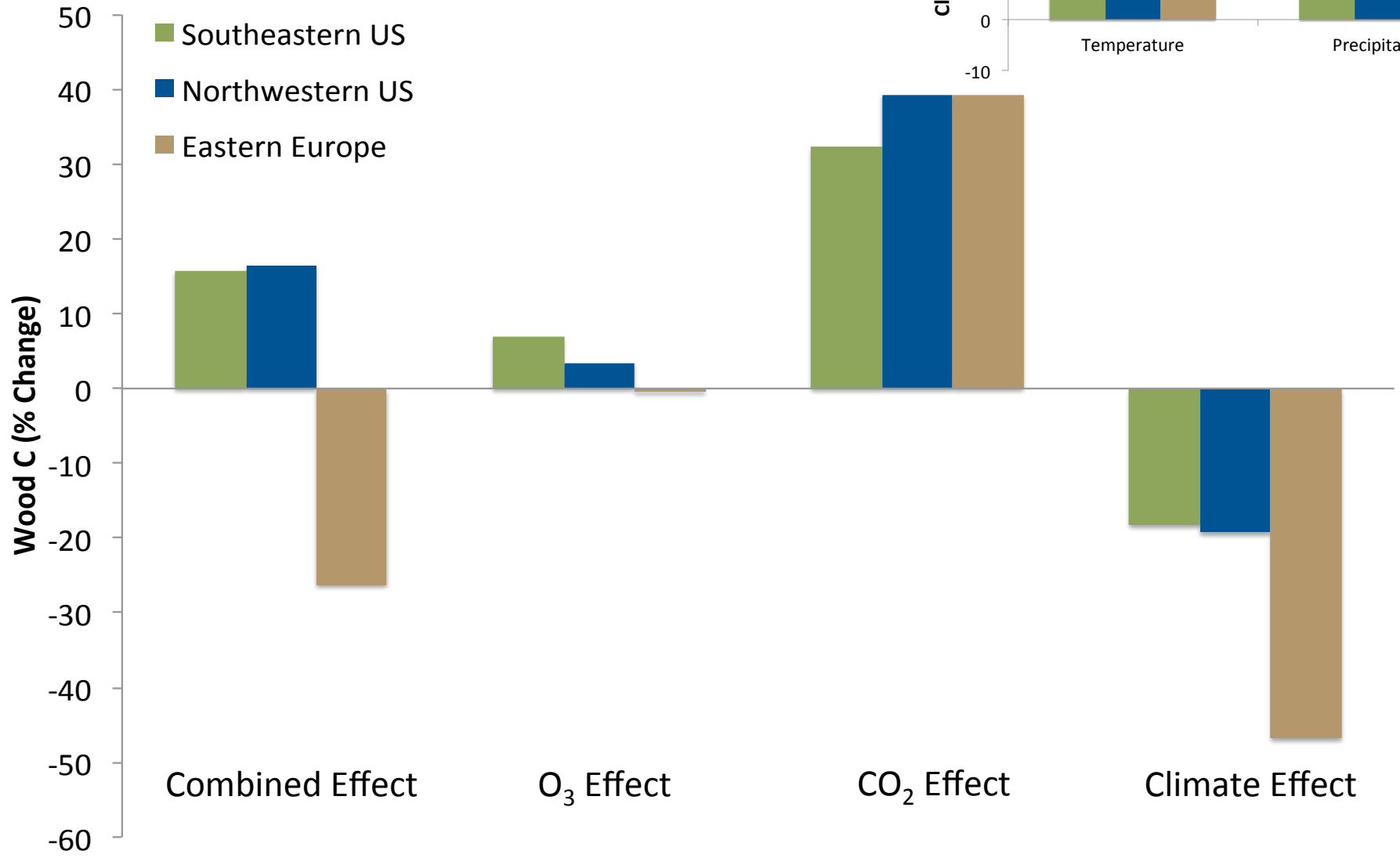
20-year (2080-2100) Averages



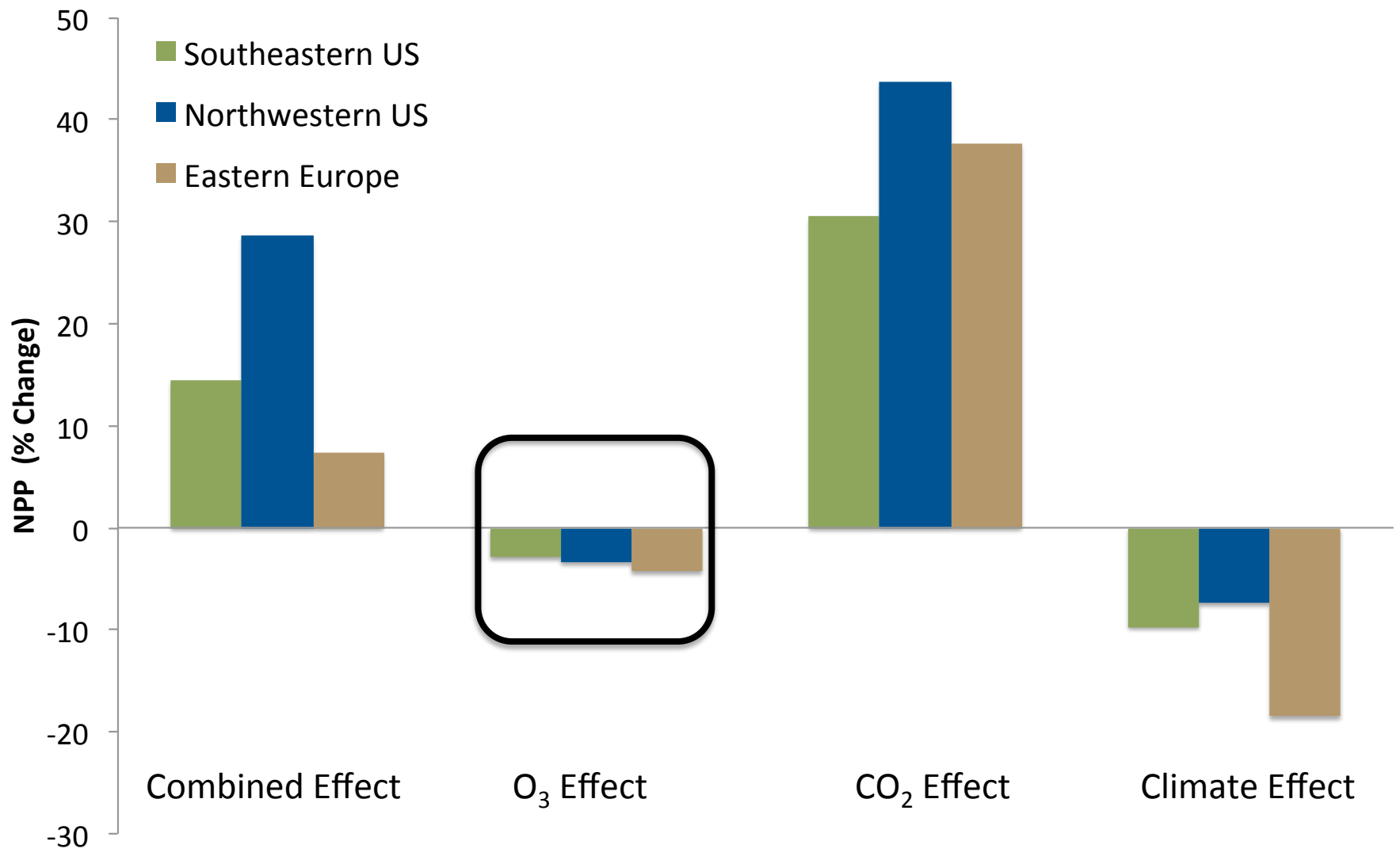
20-year (2080-2100) Averages



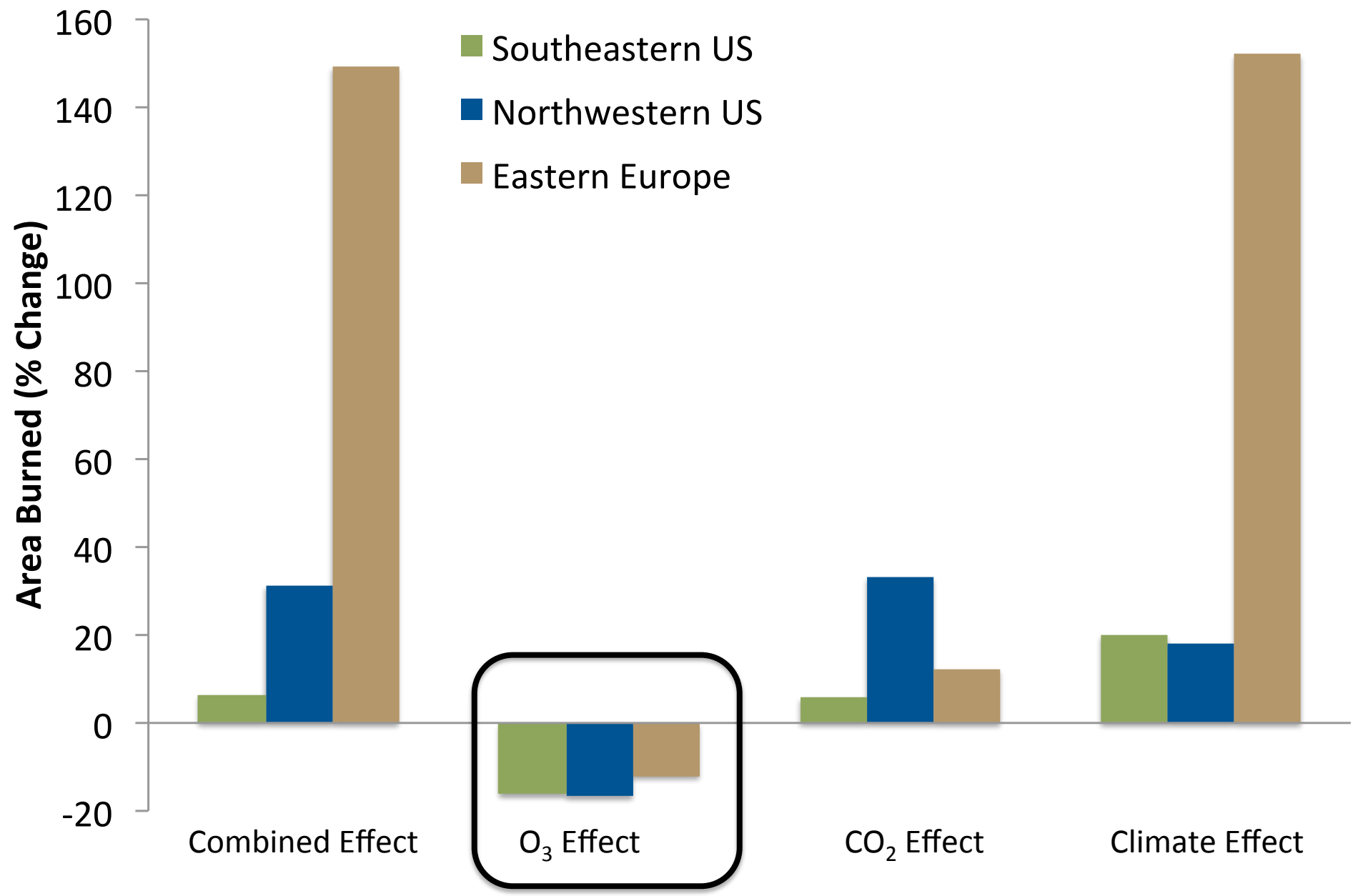
20-year (2080-2100) Averages



20-year (2080-2100) Averages



20-year (2080-2100) Averages



Wood C Summary

Future Climate, CO₂, and O₃ Effects:

- Combined: wood C increases in US regions, but decreases in Eastern Europe
- O₃: increases wood C due to reduction in fire
- CO₂: largest effect, increasing wood C
- Climate: decreases wood C in all regions, largest in Eastern Europe





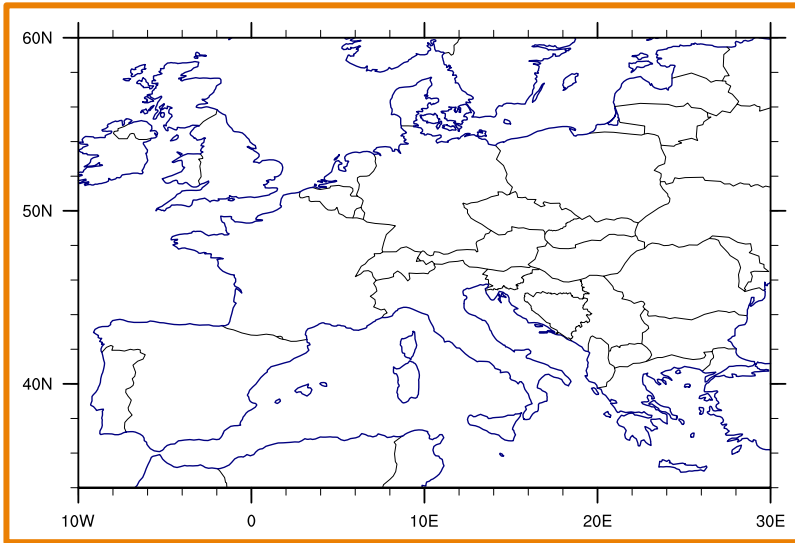
Timber Focal Regions:
Northwestern US
Southeastern US
Eastern Europe



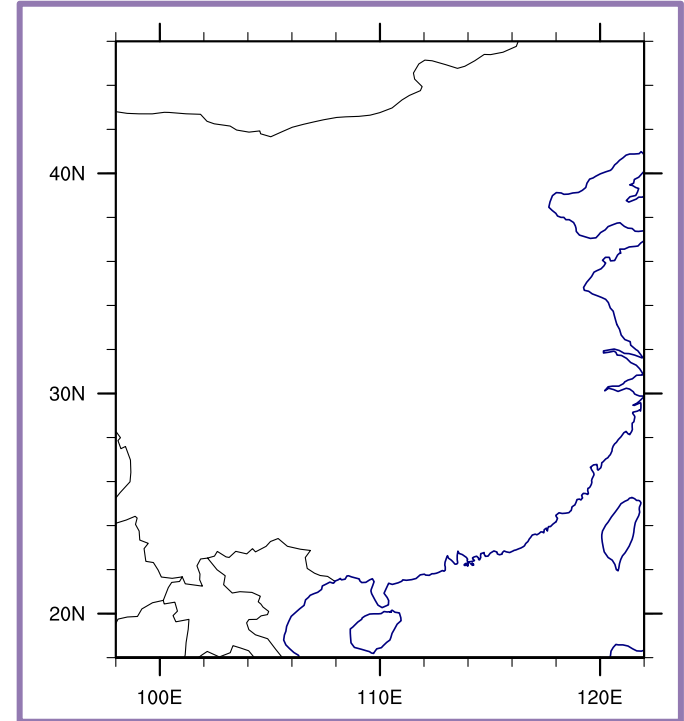
Crop Focal Regions:
Central US
Europe
Eastern China

Crop Focal Regions

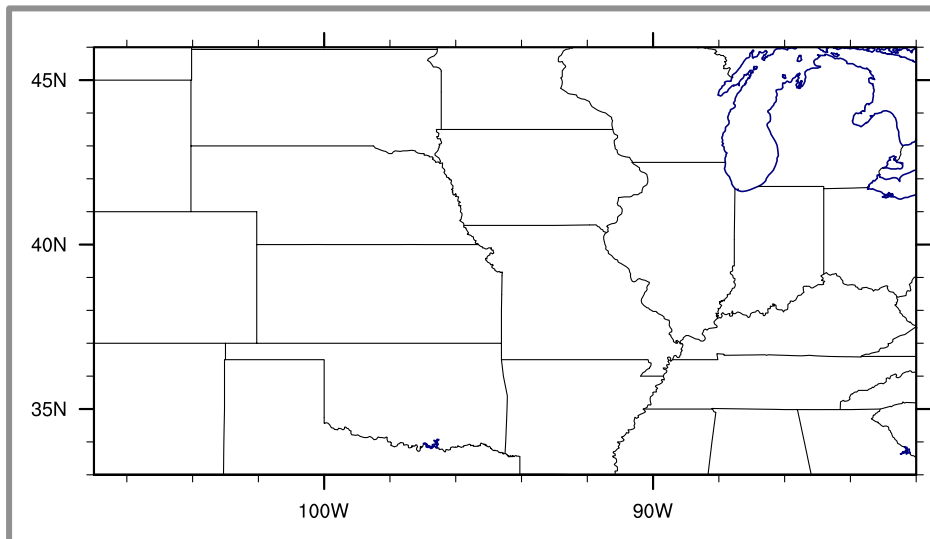
Europe



Eastern China

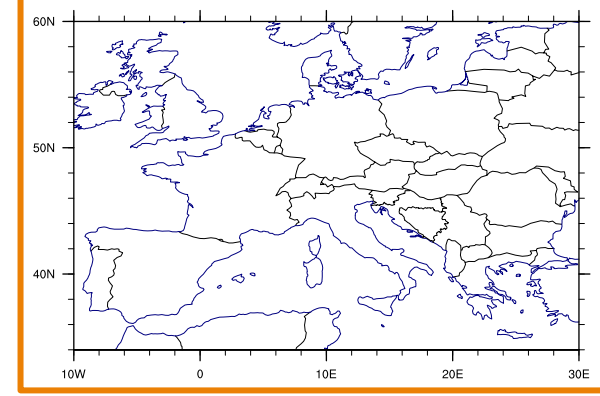
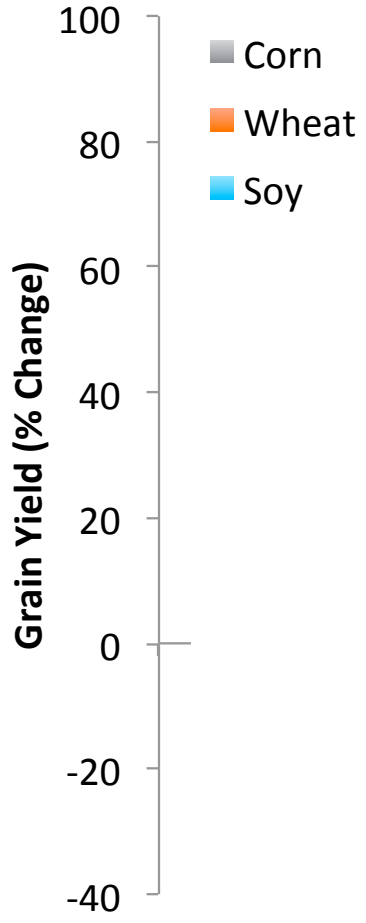


Central US



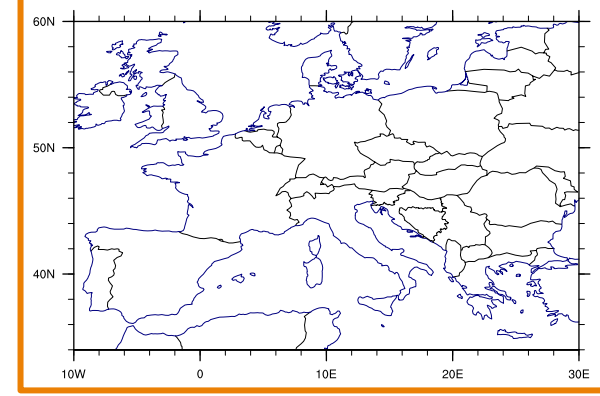
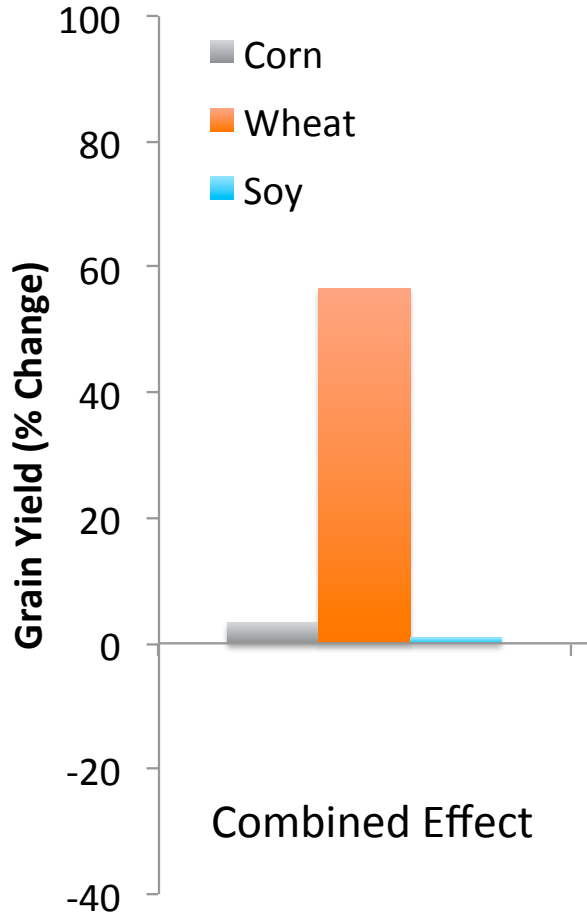
20-year (2080-2100) Averages

Europe



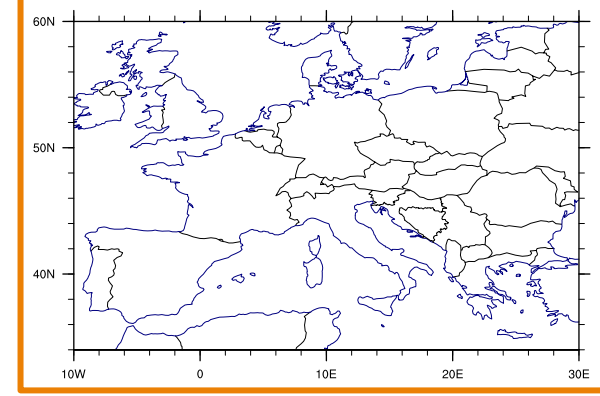
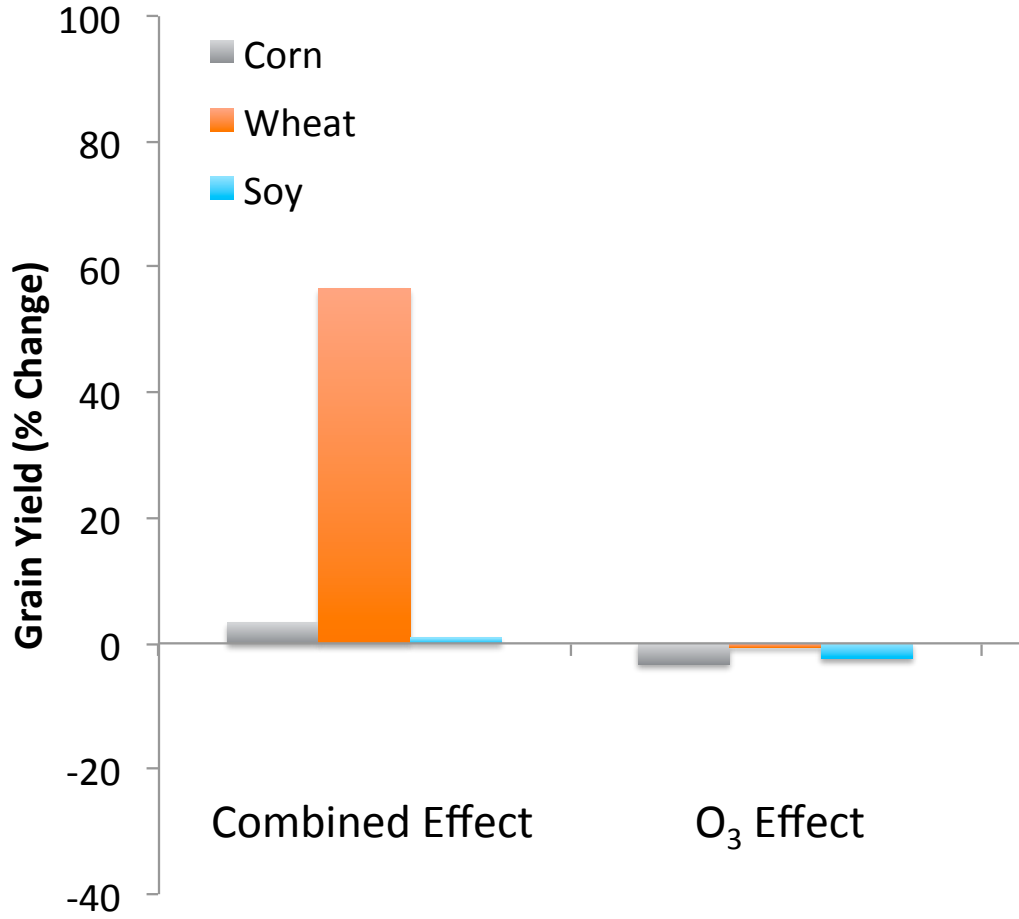
20-year (2080-2100) Averages

Europe



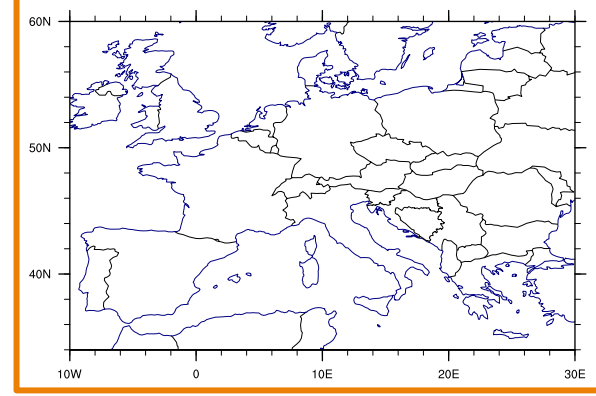
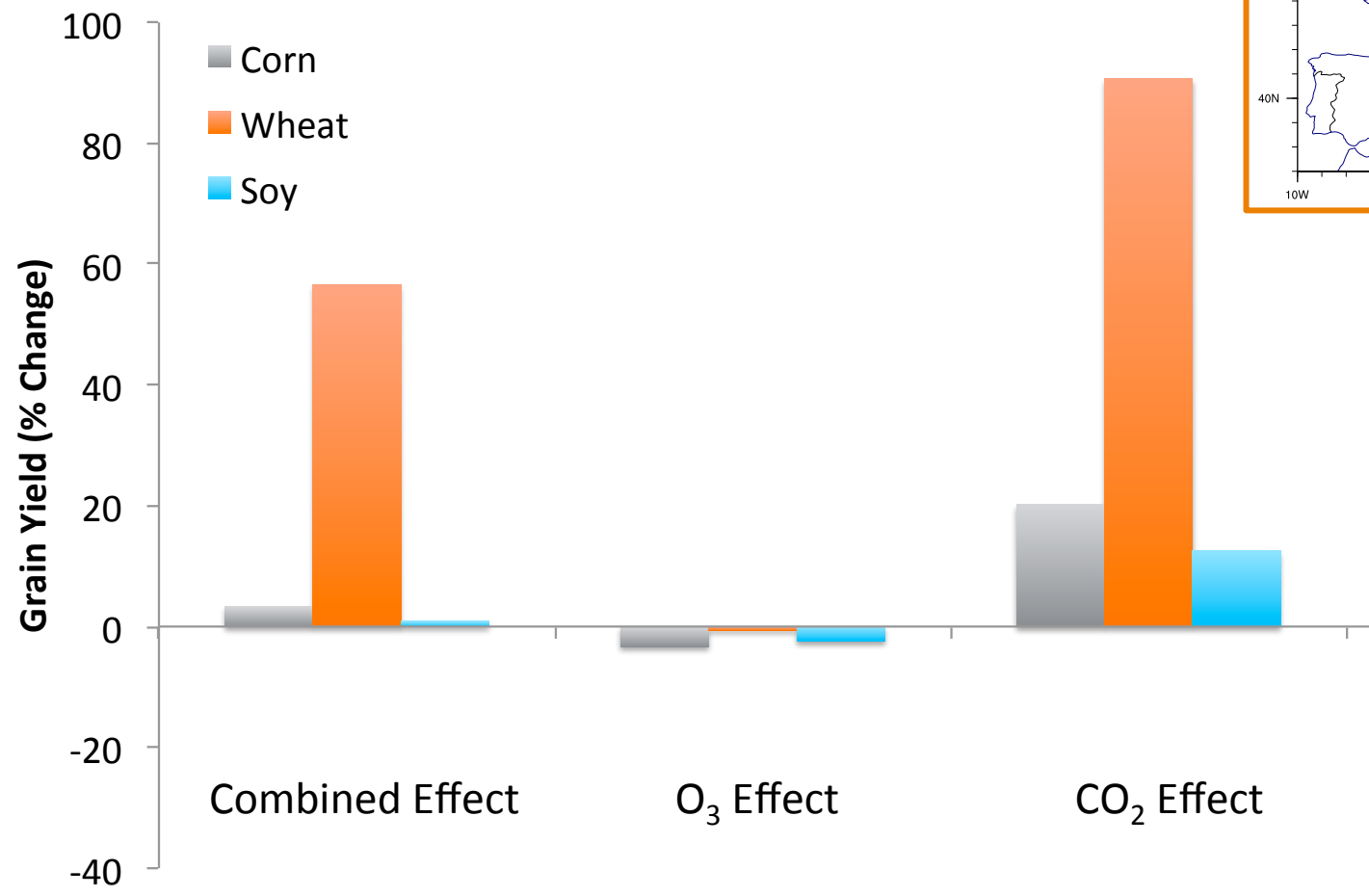
20-year (2080-2100) Averages

Europe



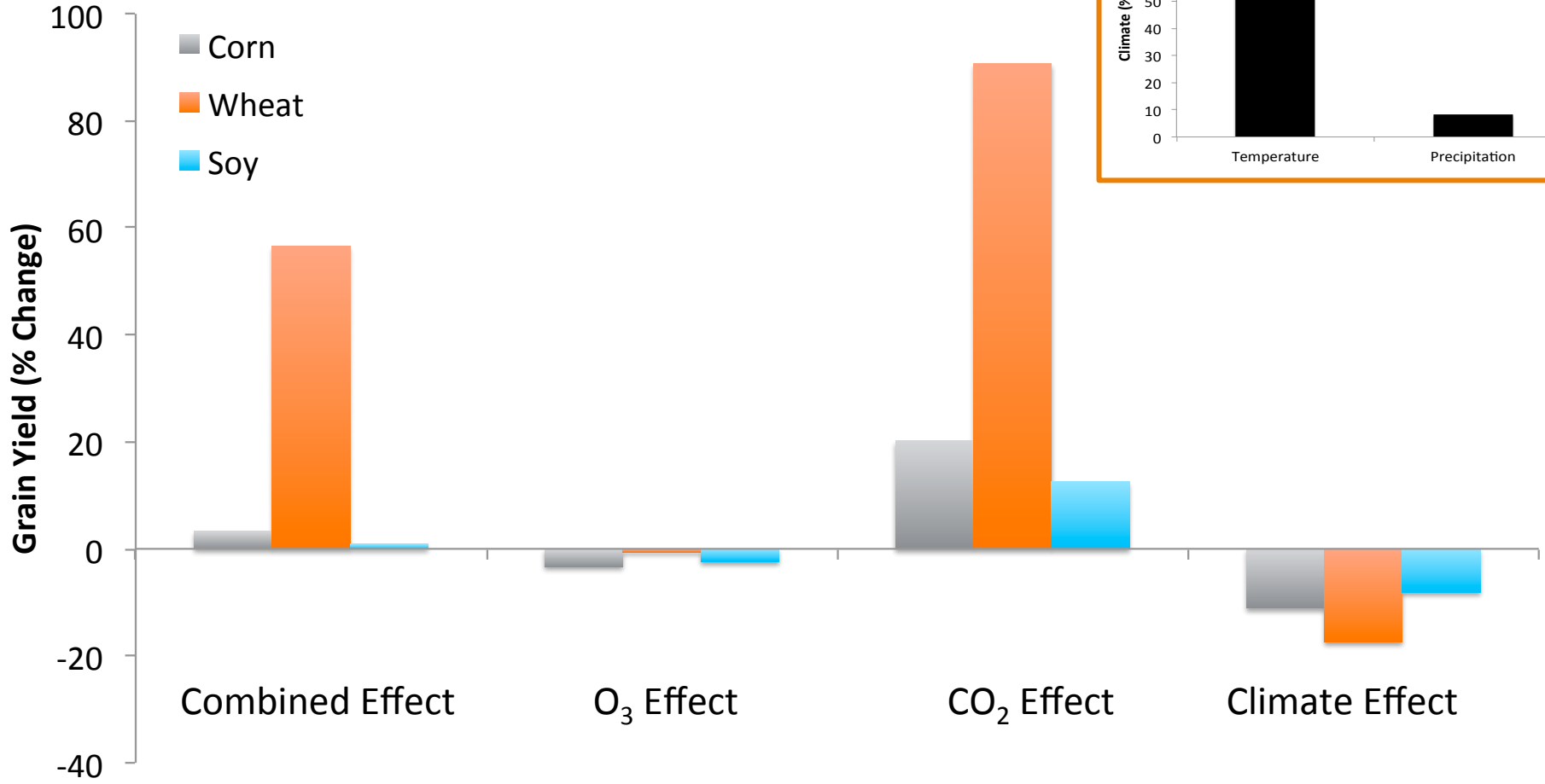
20-year (2080-2100) Averages

Europe



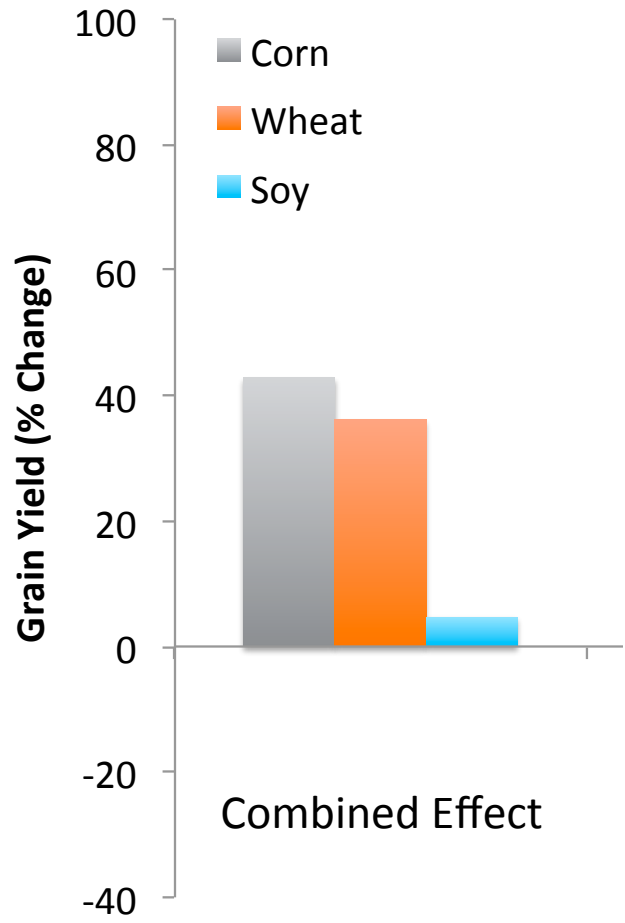
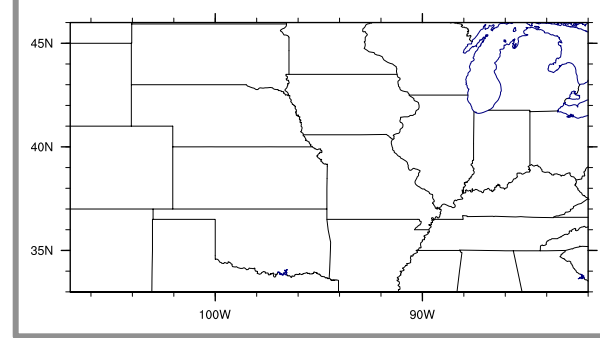
20-year (2080-2100) Averages

Europe



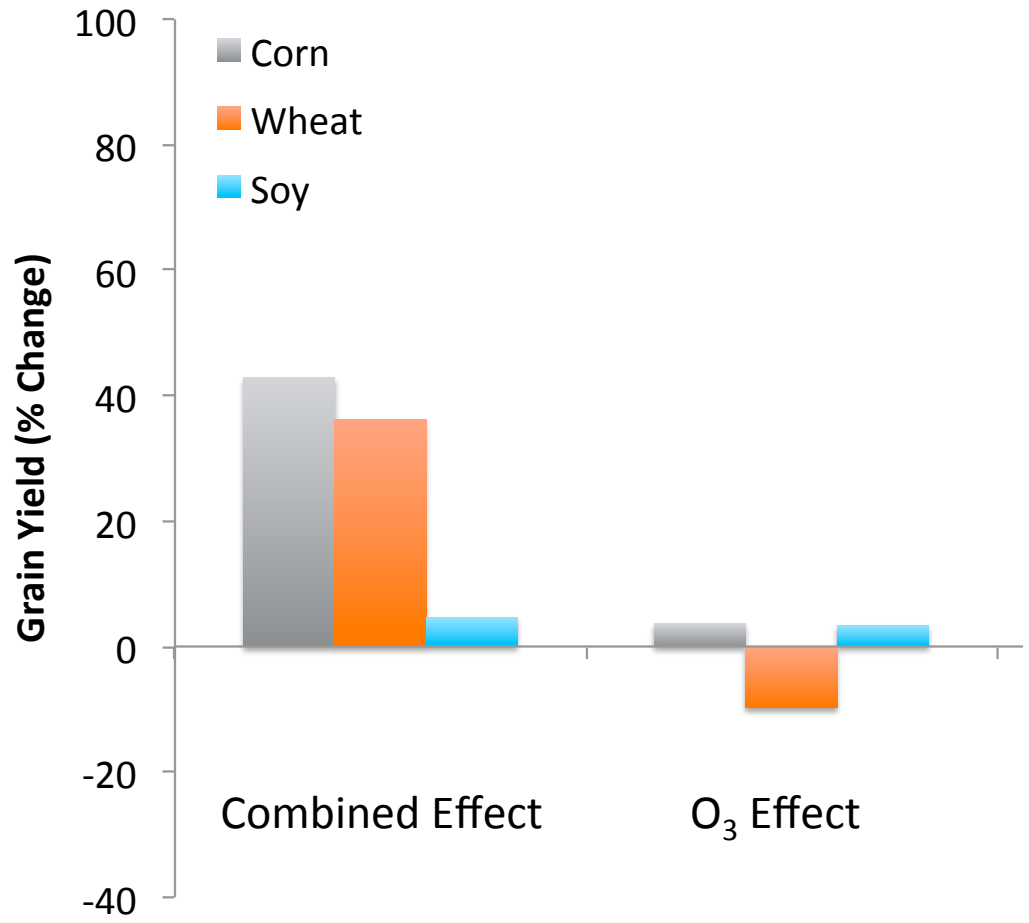
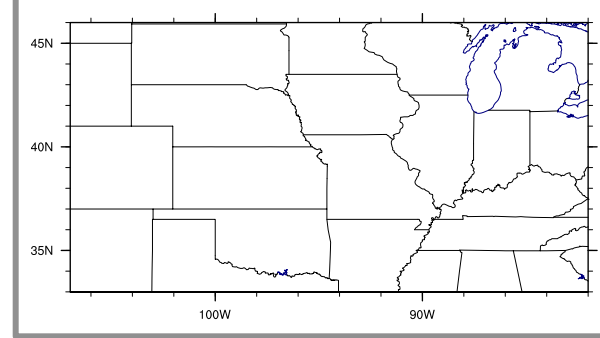
20-year (2080-2100) Averages

Central US



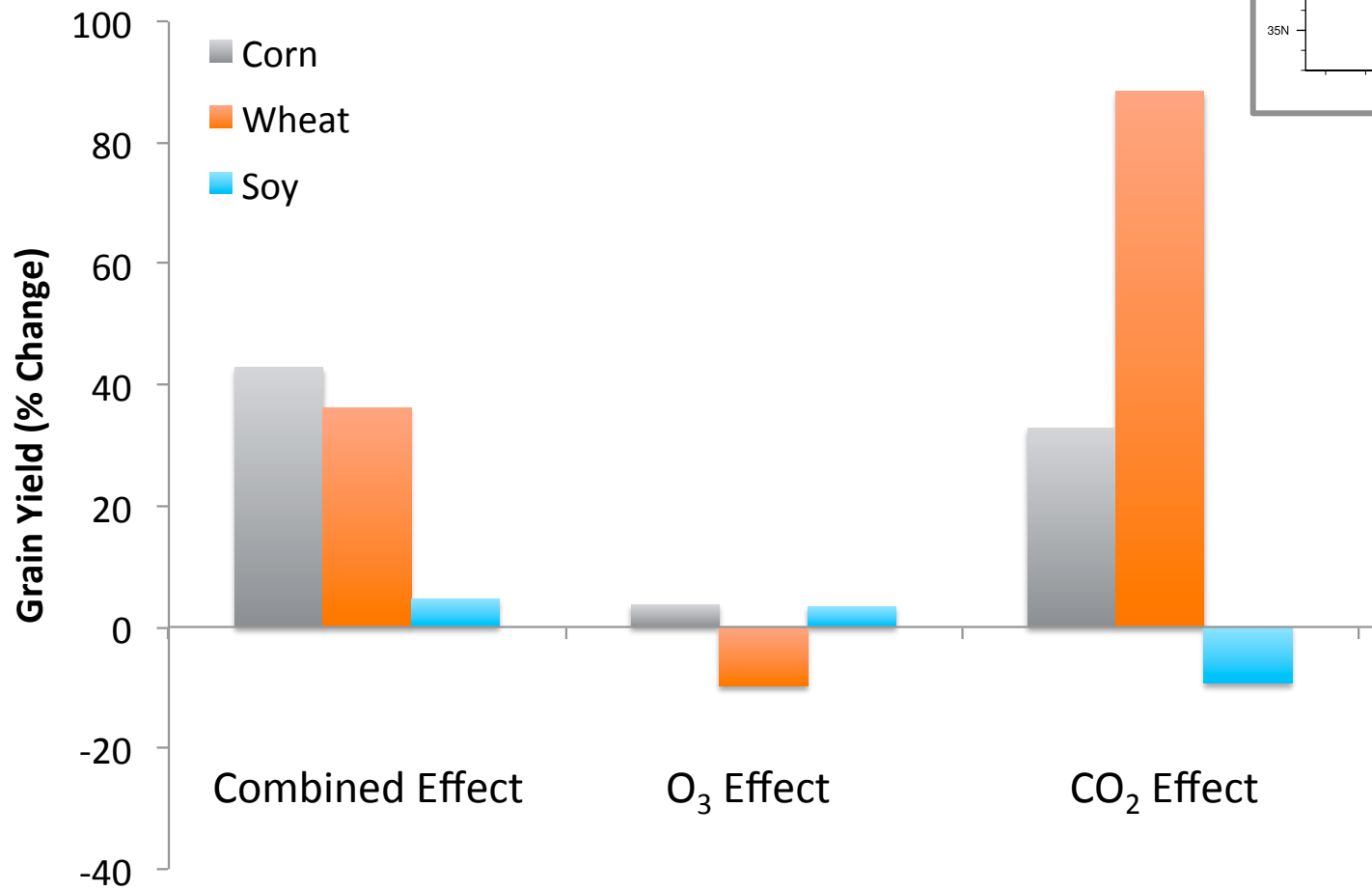
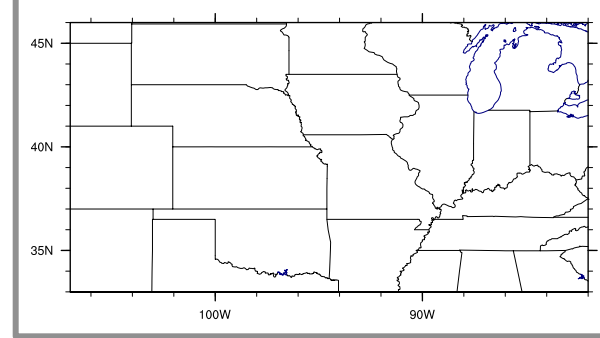
20-year (2080-2100) Averages

Central US



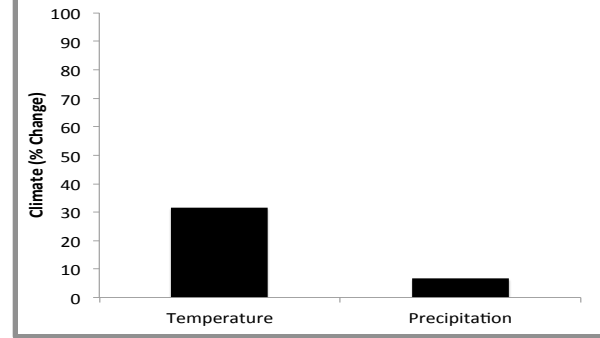
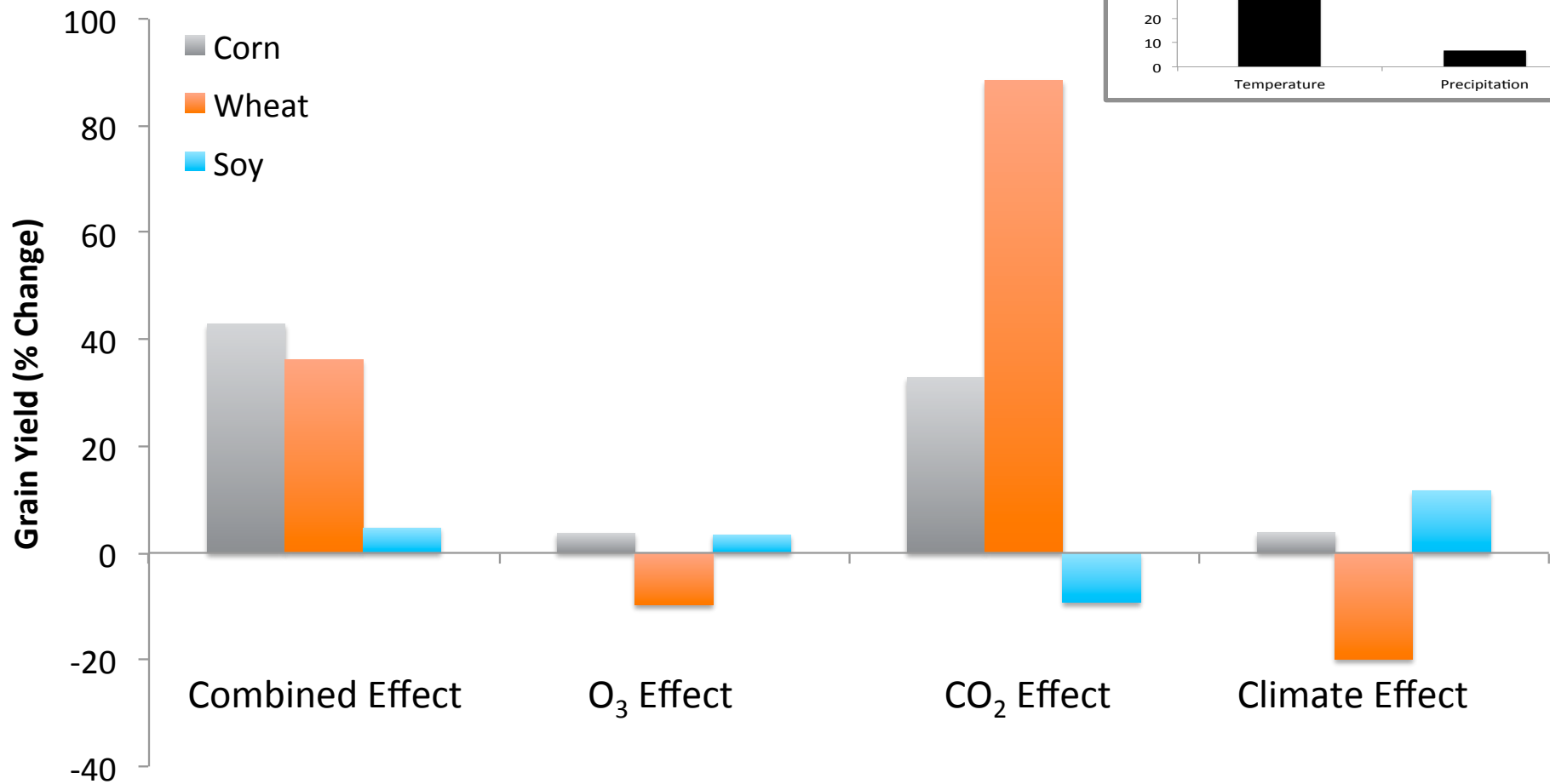
20-year (2080-2100) Averages

Central US



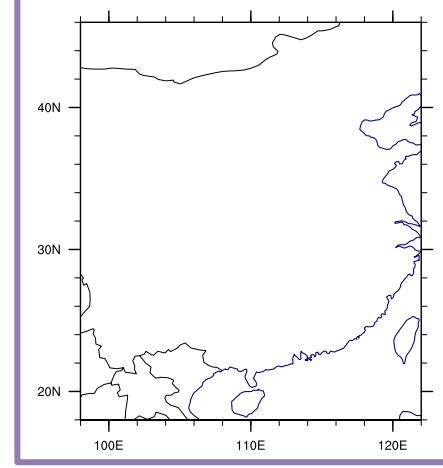
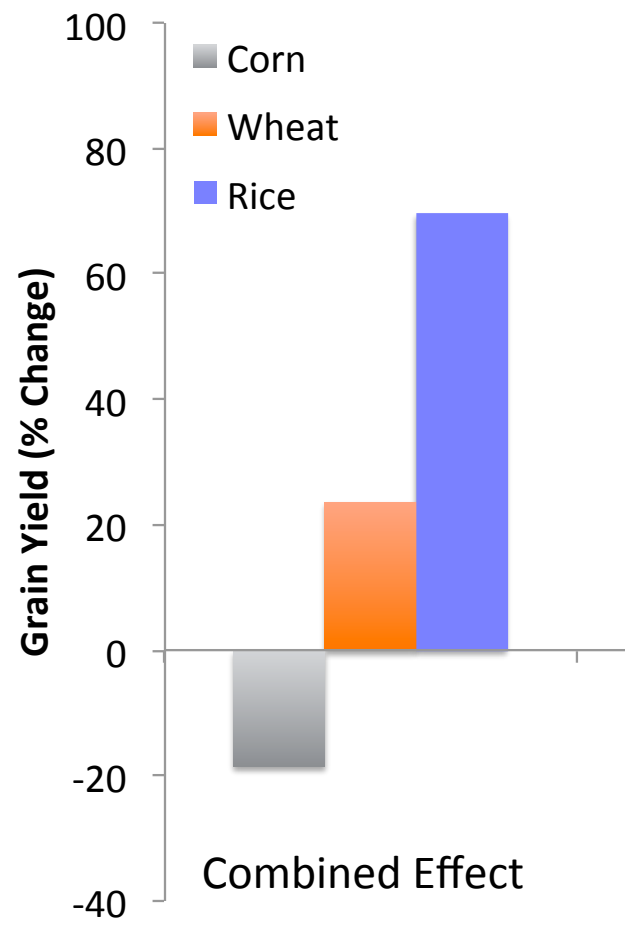
20-year (2080-2100) Averages

Central US



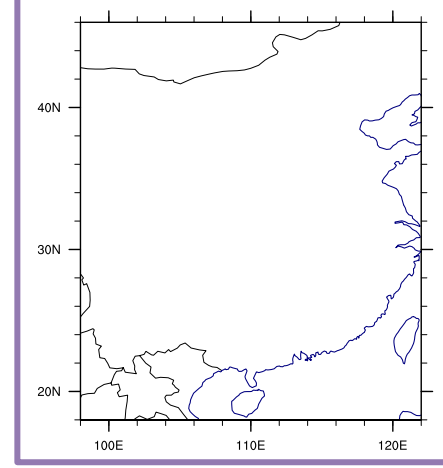
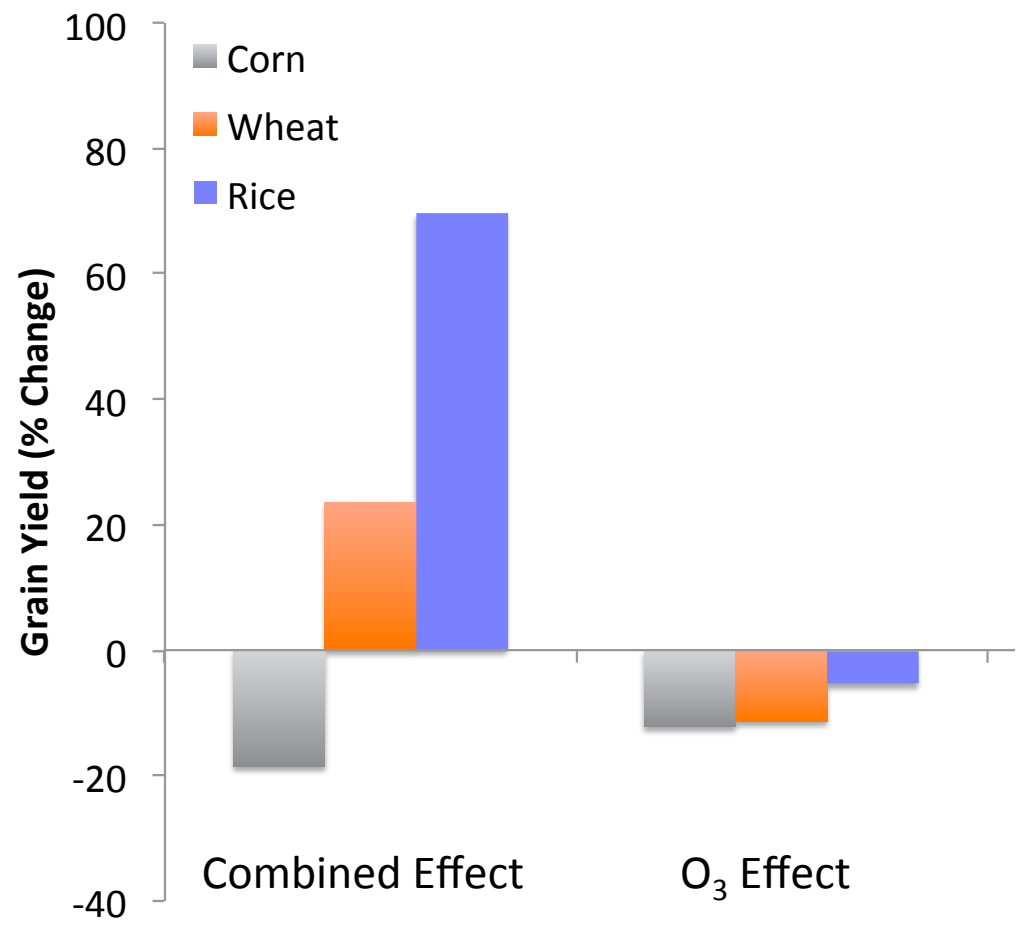
20-year (2080-2100) Averages

Eastern China



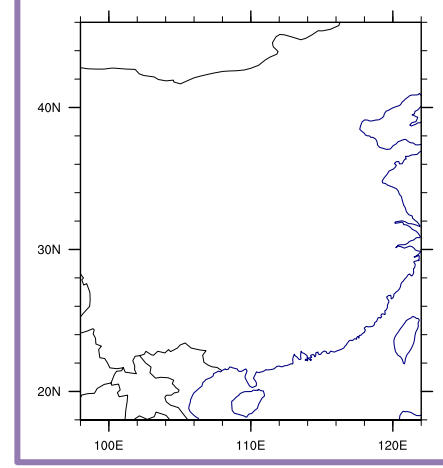
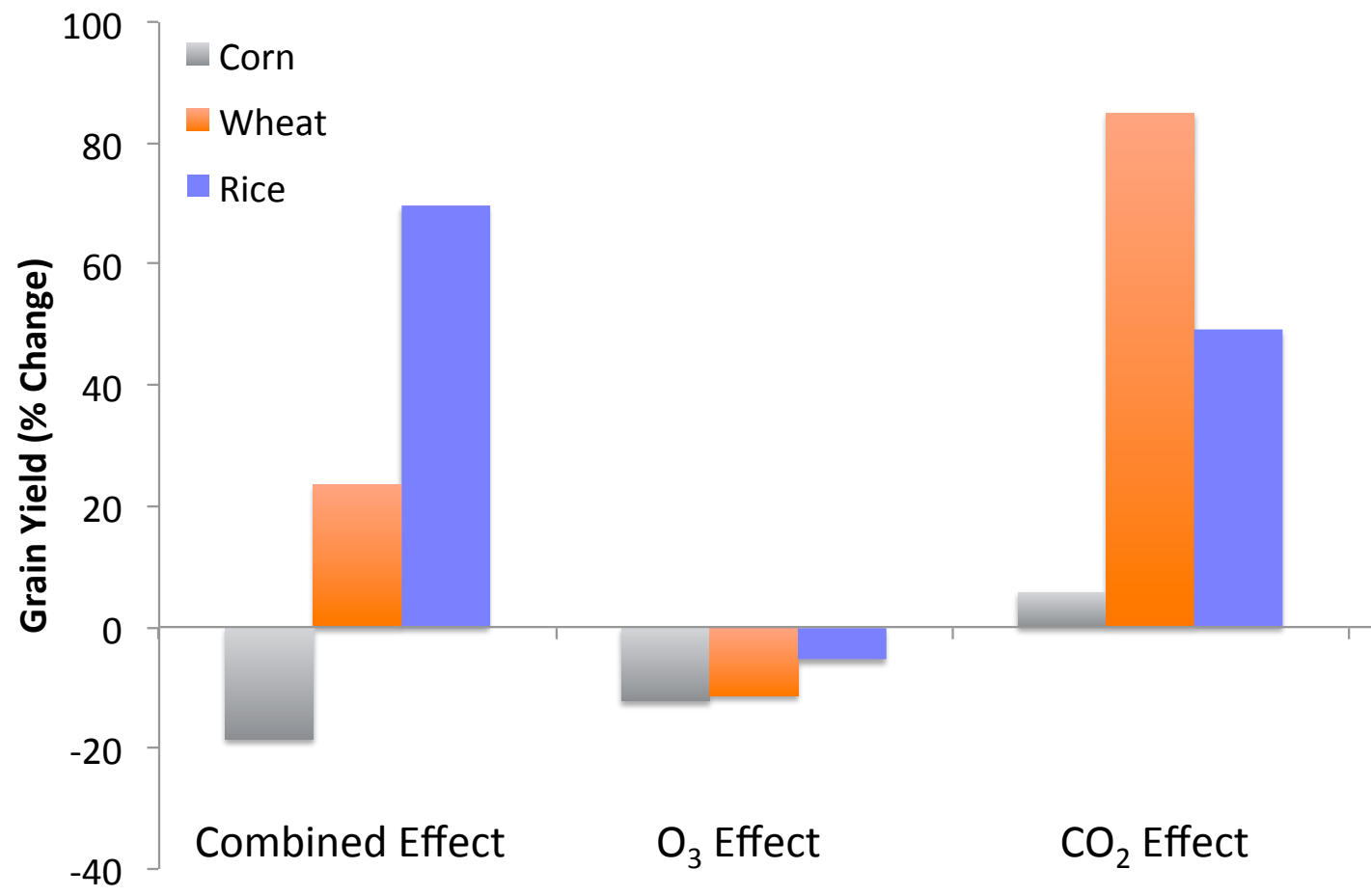
20-year (2080-2100) Averages

Eastern China



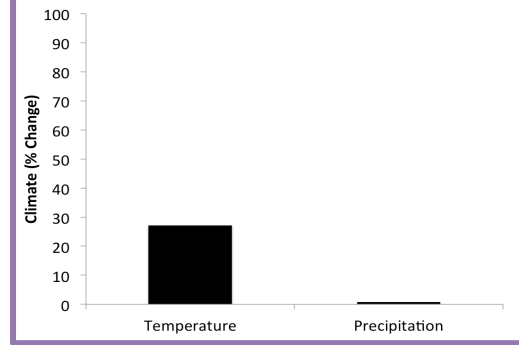
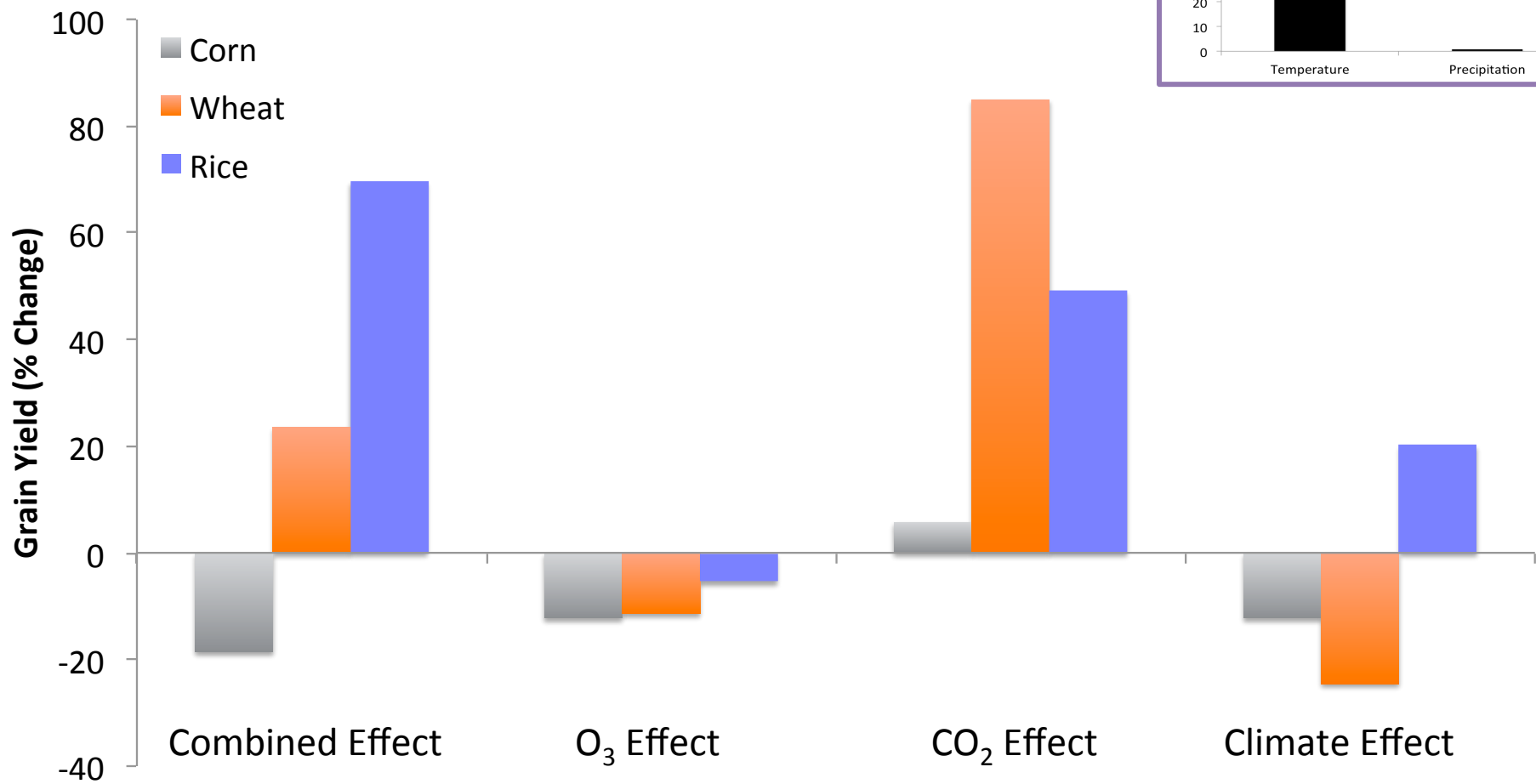
20-year (2080-2100) Averages

Eastern China



20-year (2080-2100) Averages

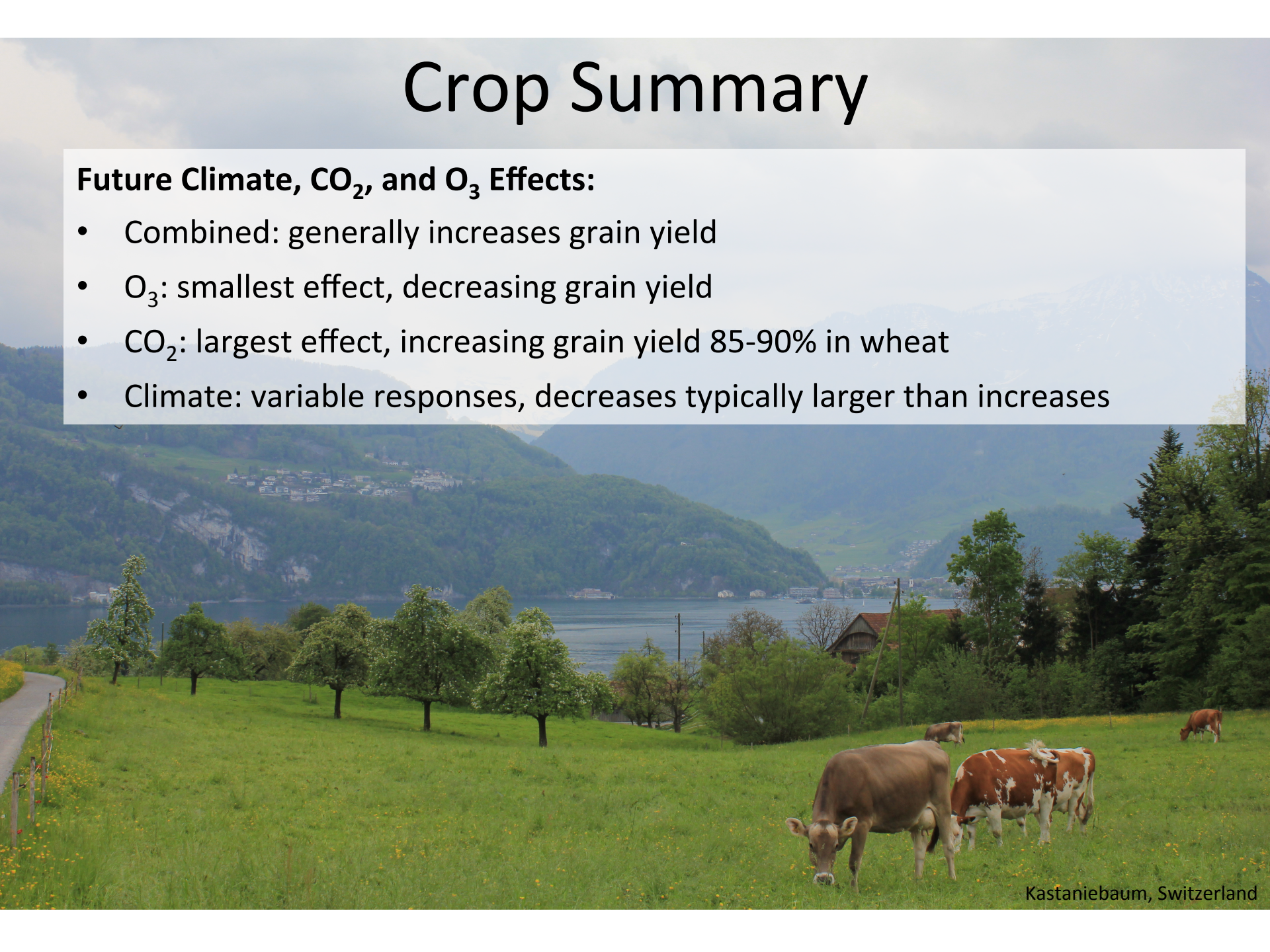
Eastern China



Crop Summary

Future Climate, CO₂, and O₃ Effects:

- Combined: generally increases grain yield
- O₃: smallest effect, decreasing grain yield
- CO₂: largest effect, increasing grain yield 85-90% in wheat
- Climate: variable responses, decreases typically larger than increases



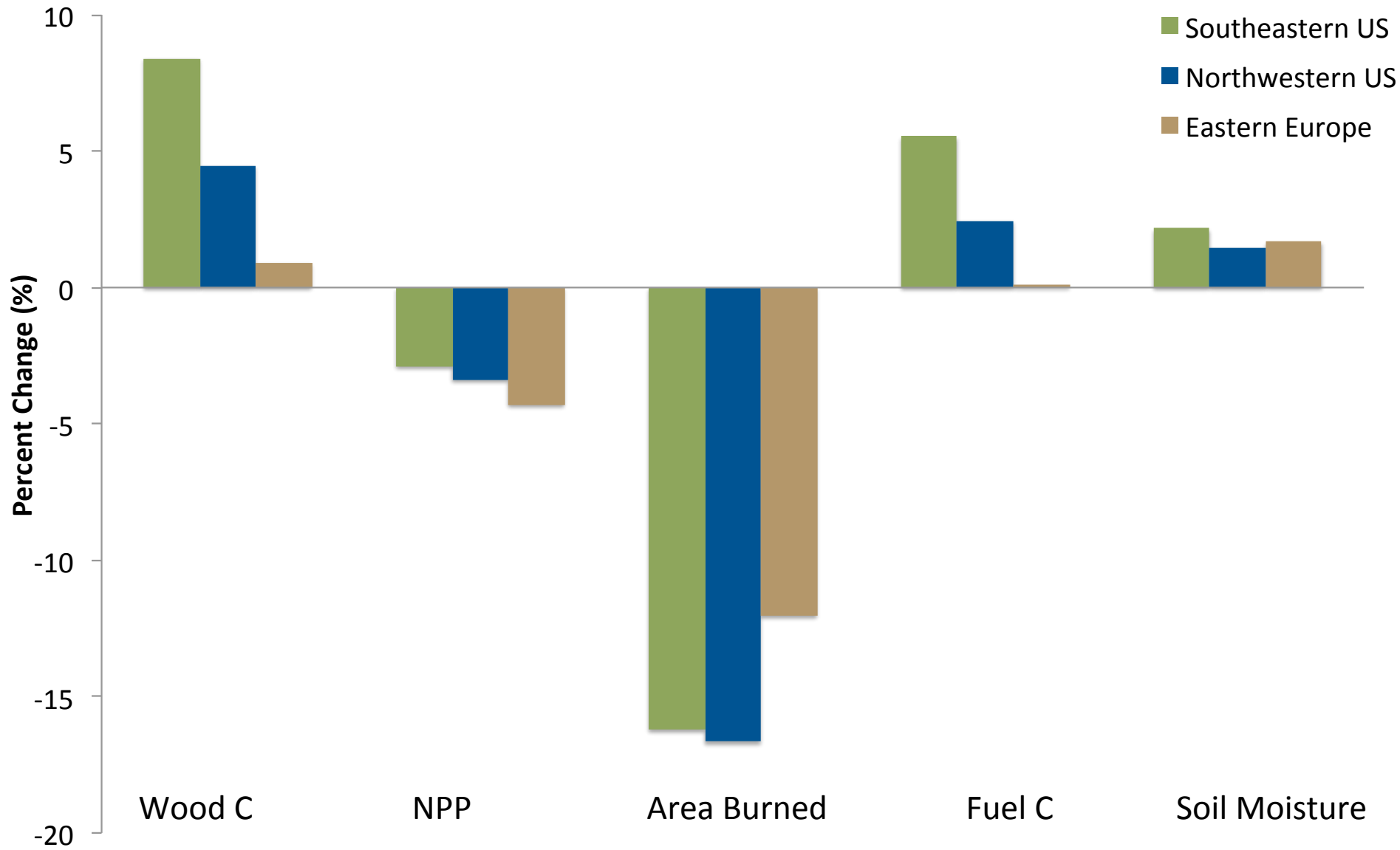
Conclusions

- **Grain yield increases (average: 24%)**
- **Wood C increases (average: 2%)**
- **CO₂ typically has the largest impact on both wood (37%) and grain (42%)**

Conclusions

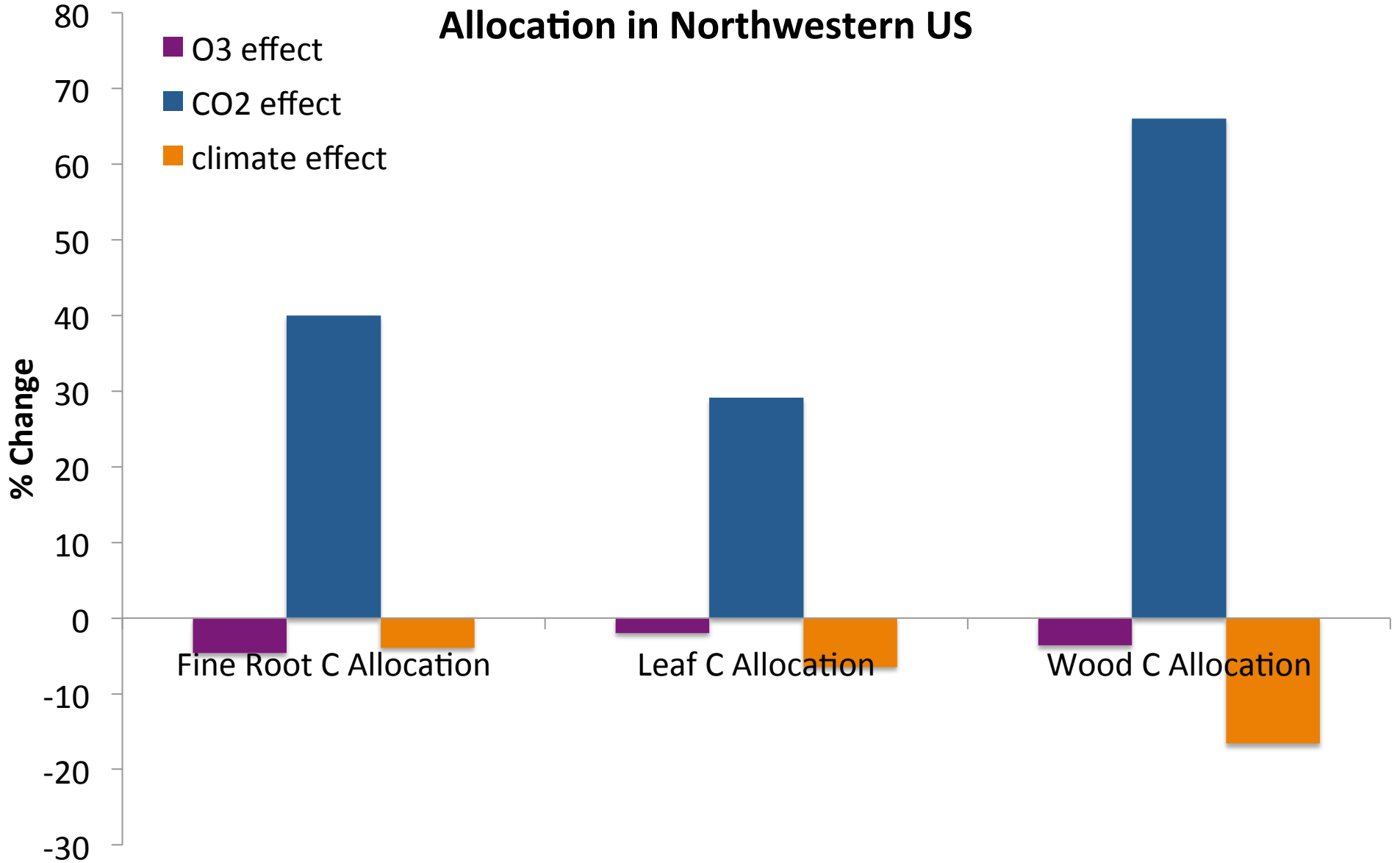
- Grain yield increases (average: 24%)
- Wood C increases (average: 2%)
- CO₂ typically has the largest impact on both wood (37%) and grain (42%)

In this future scenario: grain yield and wood C do not typically increase as much as the 50% expected population increase by 2100.



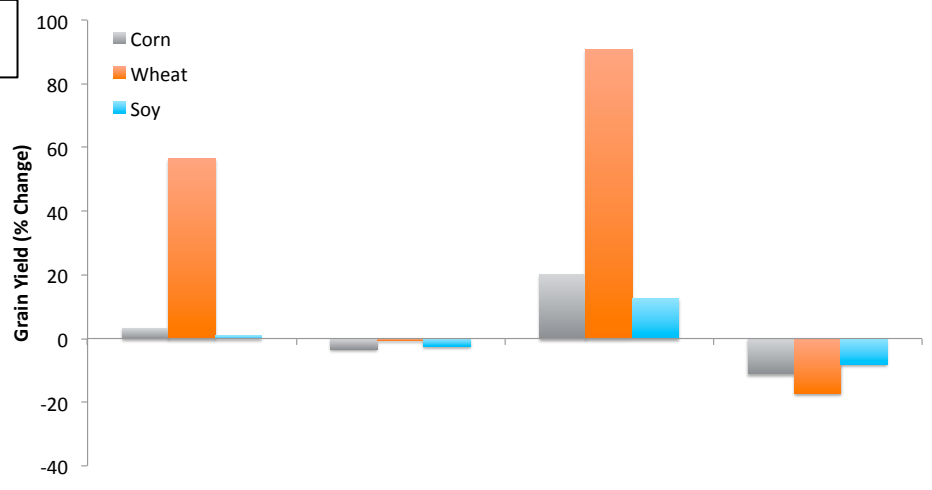
Allocation in Northwestern US

- O3 effect
- CO2 effect
- climate effect

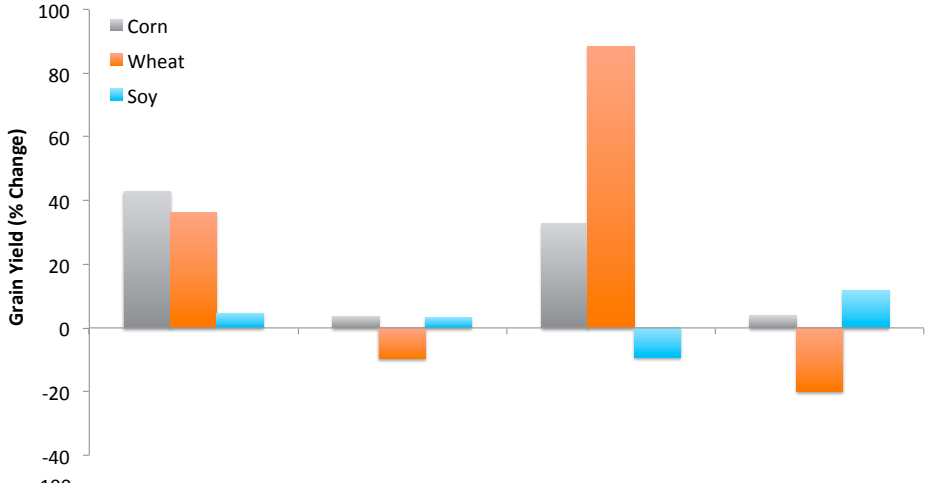


20-year (2080-2100) Averages

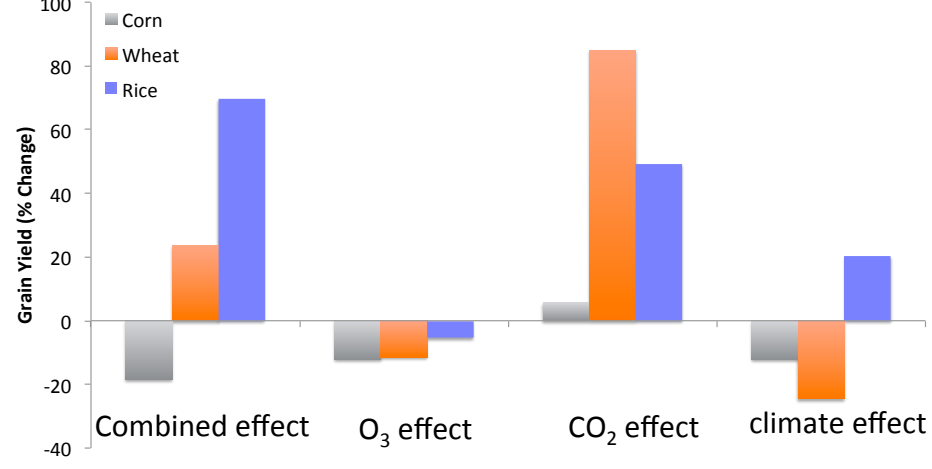
Europe

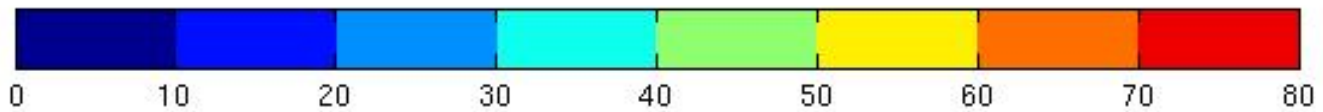
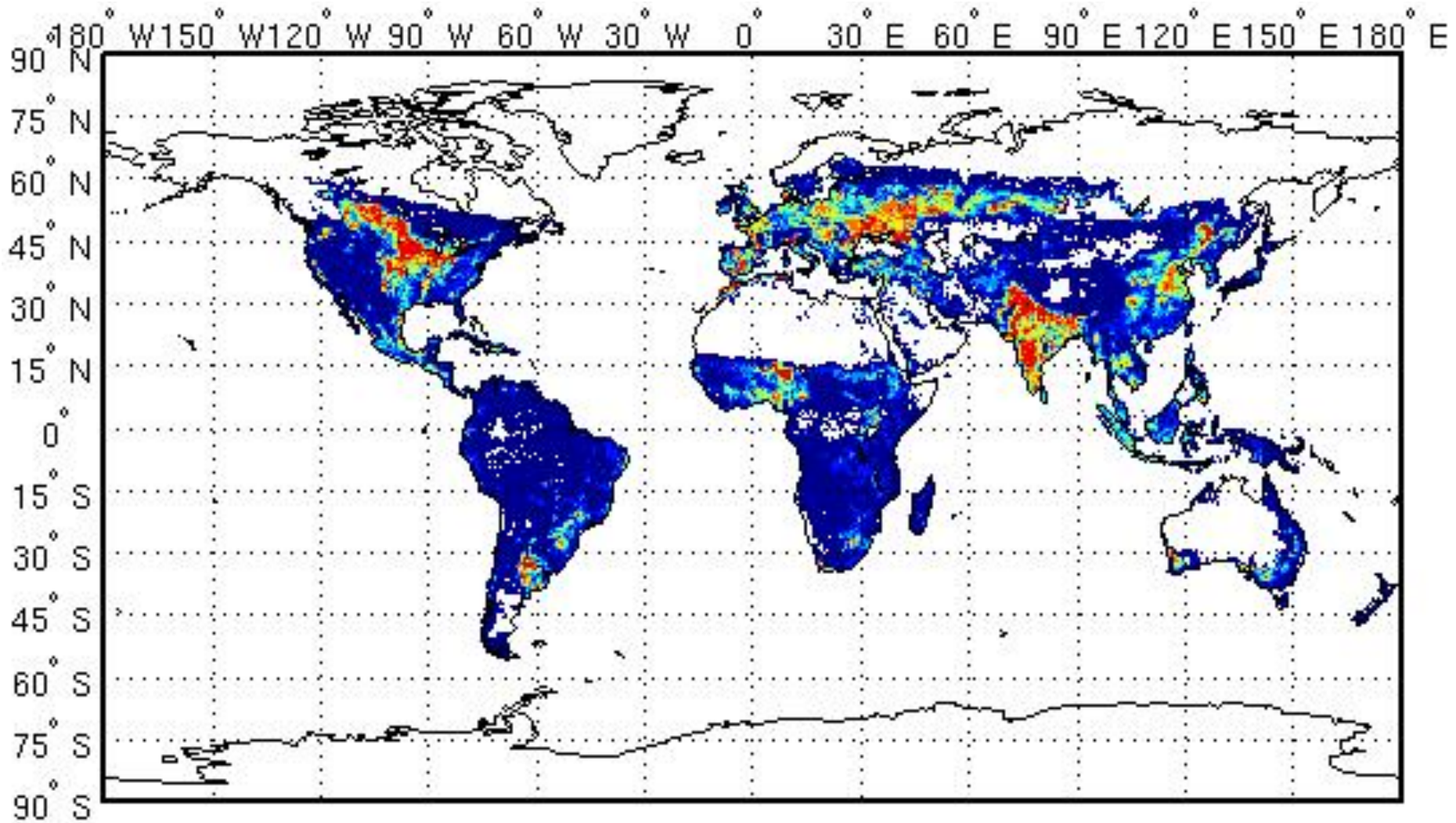


Central US



Eastern China





Managed PFTs (% of grid cell)

Combined Effect = O_3 - Constant Control

O_3 Effect = O_3 - Transient Control

CO_2 Effect = Transient Control - Constant CO_2

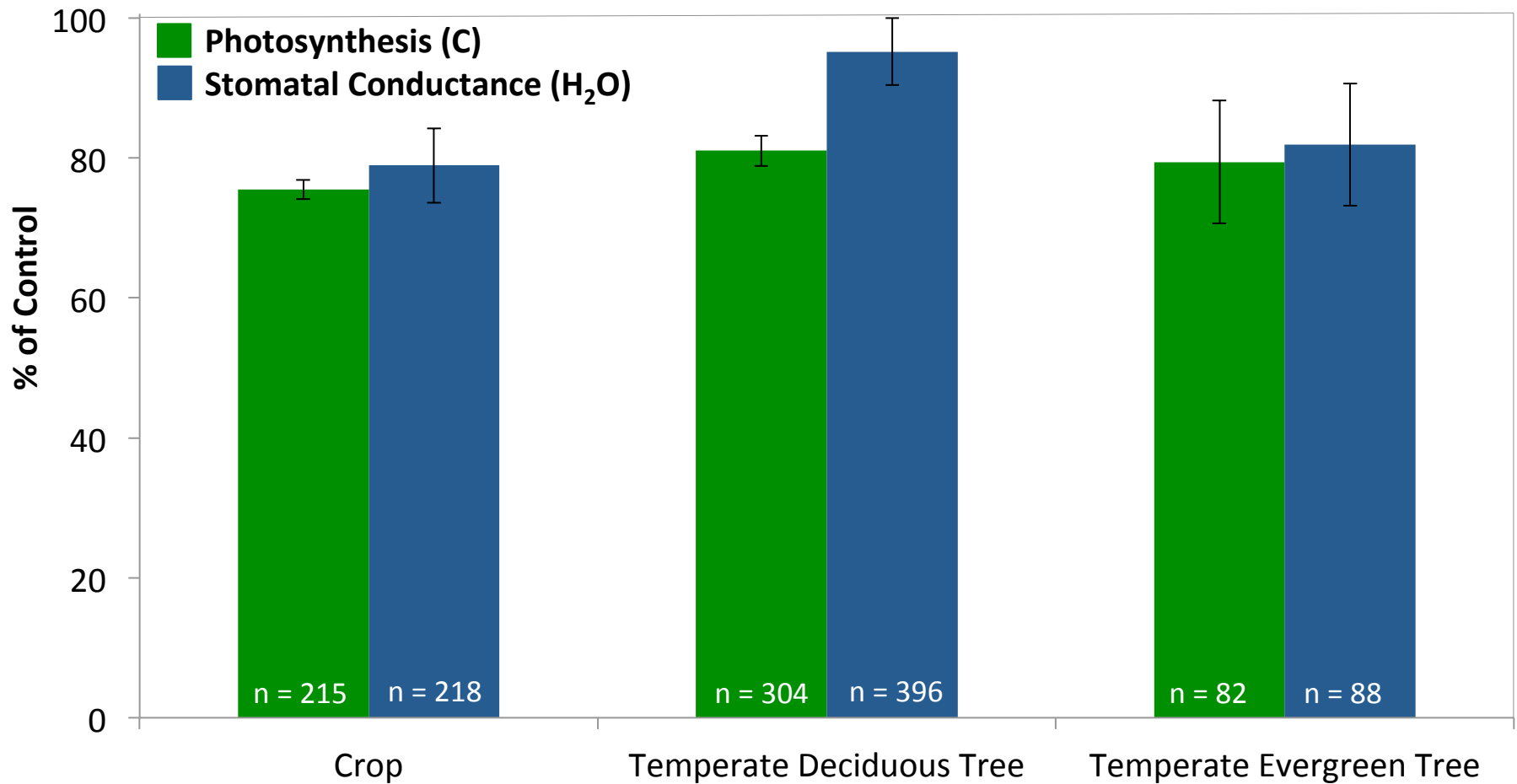
Climate Effect = Constant CO_2 - Constant Control

	climate	CO_2	O_3
Constant Control	2005	2005	None
Constant CO_2	transient RCP8.5	2005	None
Transient Control	transient RCP8.5	transient RCP8.5	None
O_3	transient RCP8.5	transient RCP8.5	2100 RCP8.5



Mean **photosynthetic** change = **-21% ***

Mean **conductance** change = **-11%**



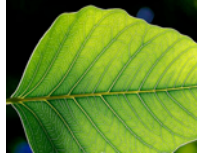
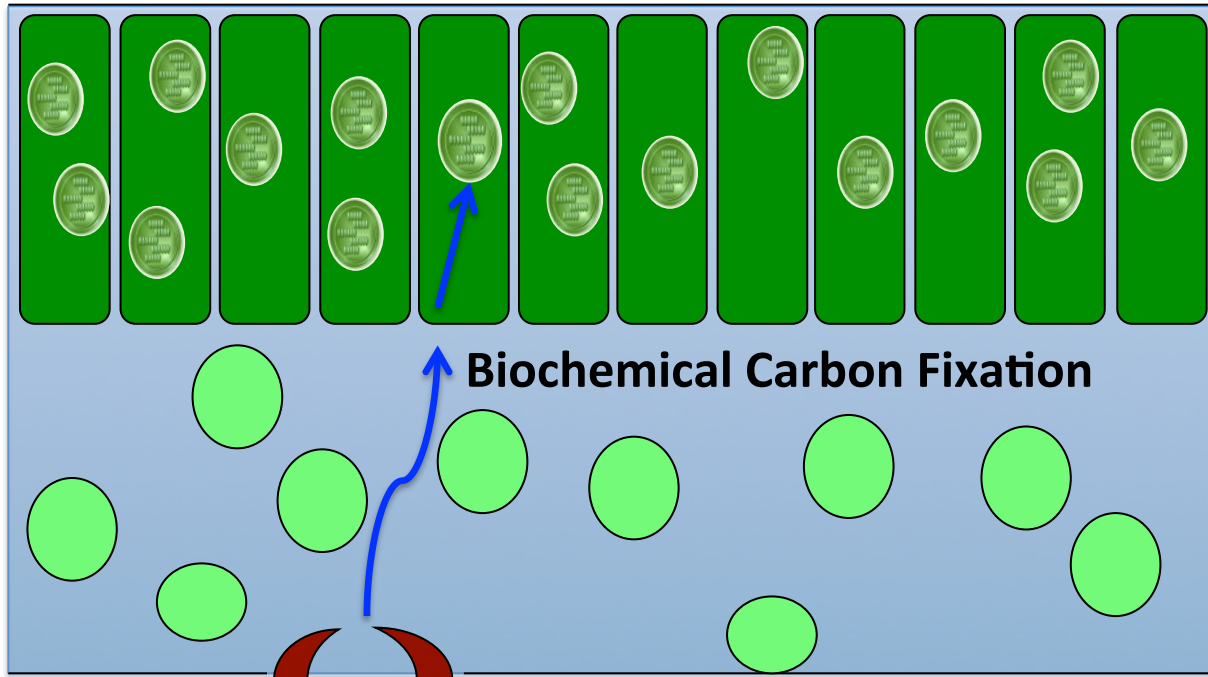
Data adapted from Lombardozzi et al., 2013 *BGS*

* Similar to Wittig et al. 2007, *Plant Cell Environ*; Feng et al. 2008 *GCB*; Morgan et al. 2003, *Plant Cell Environ*

Plant Group	Photosynthesis		Conductance	
	Slope	Intercept	Slope	Intercept
Broadleaf	0	0.7985	0.0033	0.8413
Needleleaf	0	0.8748	0	0.9161
Crop	0	0.7624	0.0004	0.7881

Table 1: The slopes and intercepts used to parameterize the responses of each plant functional type in CLM simulations based on values presented in Lombardozzi et al. (2013).

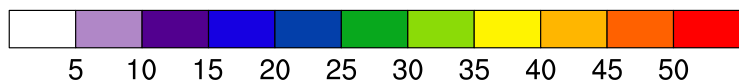
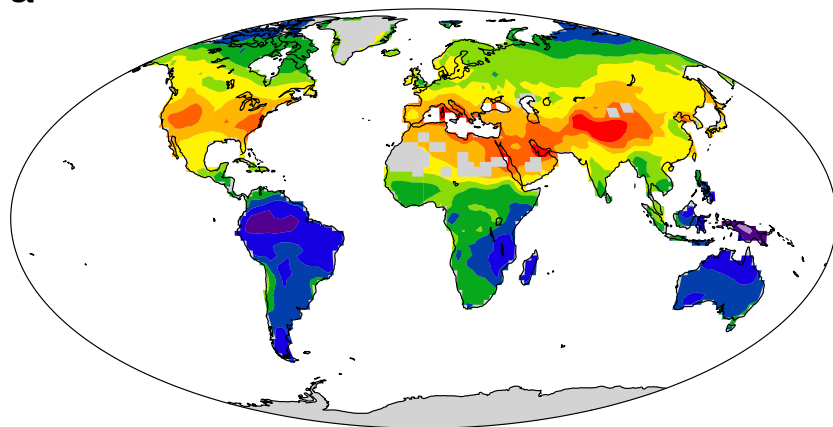
Leaf Cross-section



Photosynthesis

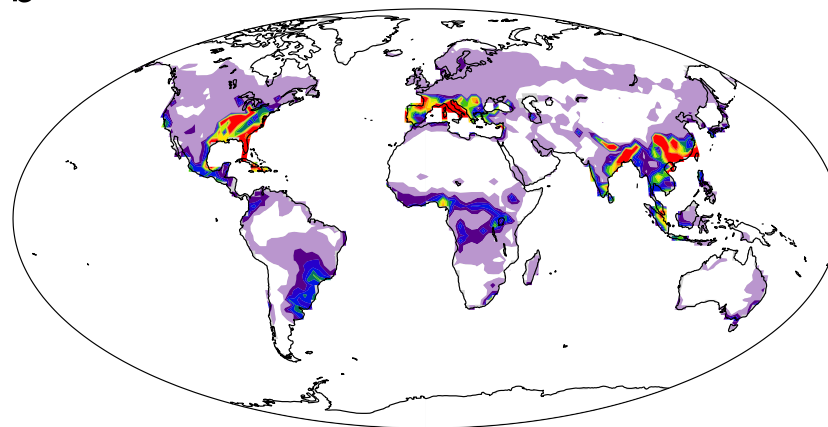
Transpiration

a

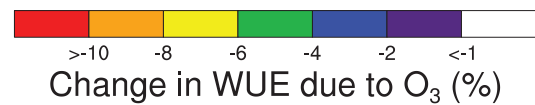
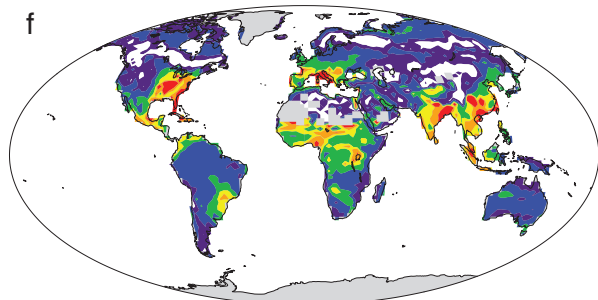
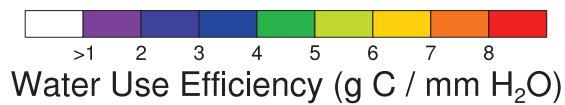
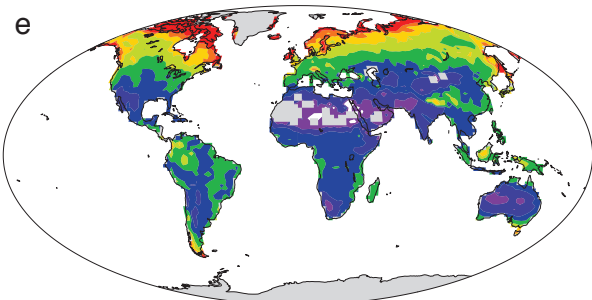
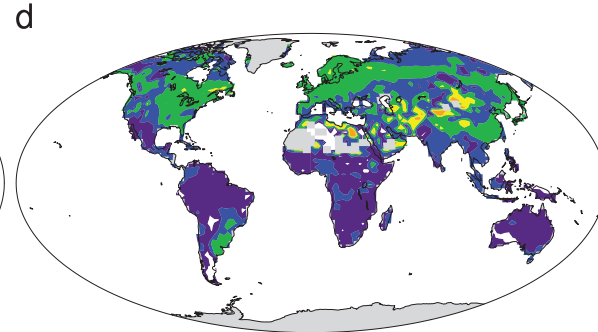
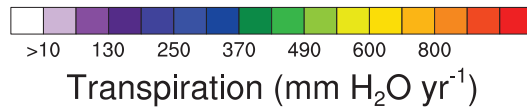
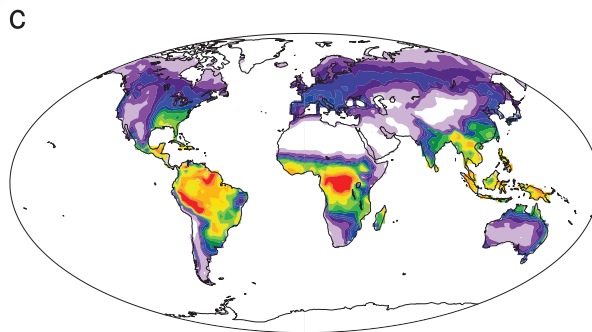
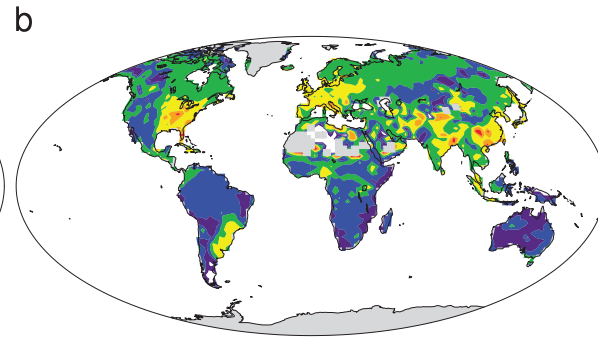
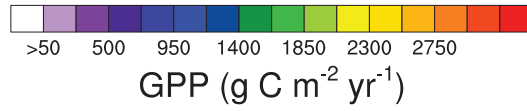
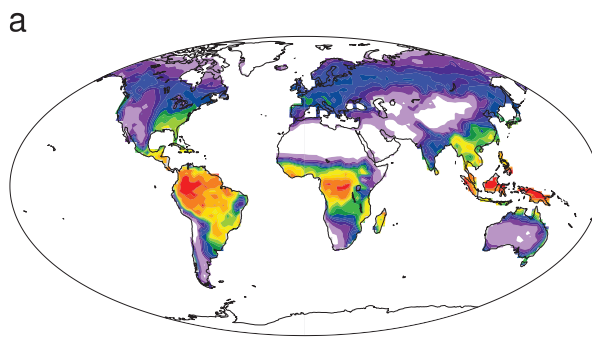


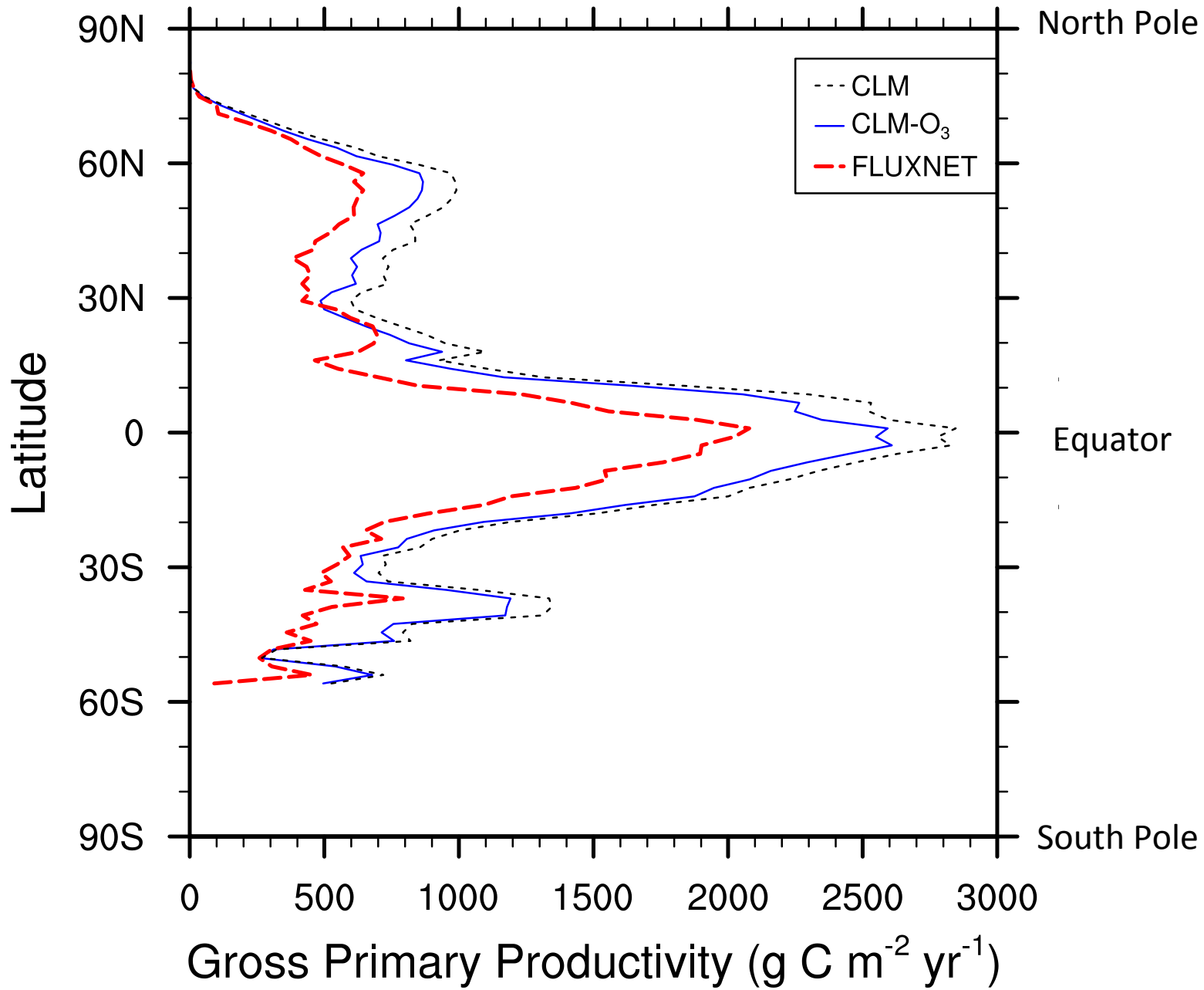
Growing Season [O_3] (ppb)

b

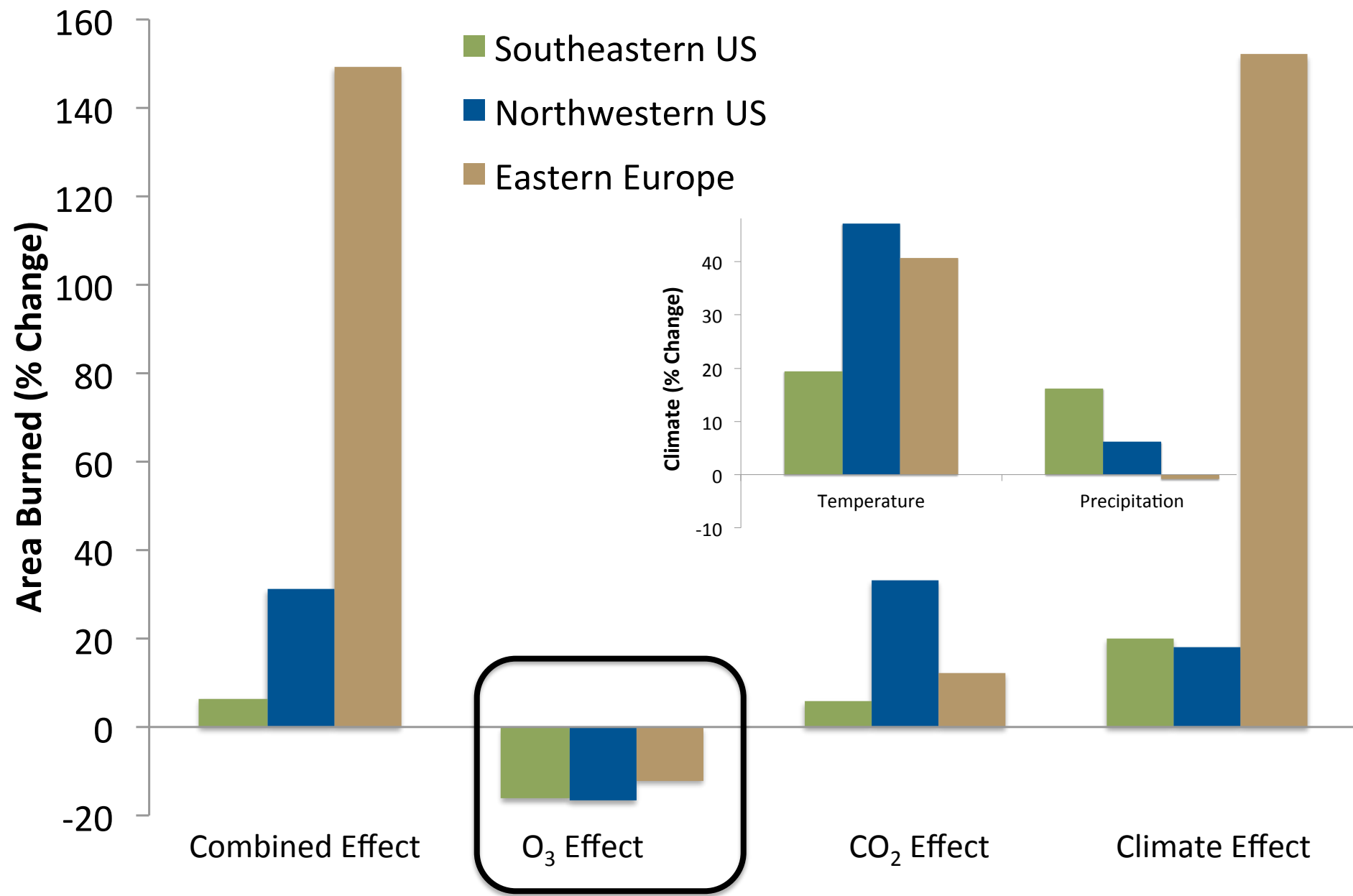


Cumulative O_3 Uptake ($mmol O_3 m^{-2}$)





20-year (2080-2100) Averages



Crop Summary

Future Climate, CO₂, and O₃ Effects:

- Combined: generally increases grain yield
- O₃: smallest effect, decreasing grain yield
- CO₂: largest effect, increasing grain yield 85-90% in wheat
- Climate: variable responses, decreases typically larger than increases

Notable Regional Differences:

- China: strong increase in rice yield (70%), decrease in corn yield (-18%)
- US: yield increases for corn (42%) and wheat (36%)
- Europe: increases only in wheat (56%)