Simulating County-Level Crop Yields in the Conterminous United States Using the Community Land Model: the Effects of Optimizing Irrigation and Fertilization

GUOYONG LENG[1], XUESONG ZHANG[1], MAOYI HUANG[2], QICHUN YANG[1], RASHID RAFIQUE[1], GHASSEM R. ASRAR[1], L. RUBY LEUNG[2]
[1]Joint Global Change Research Institute, Pacific Northwest National Laboratory,
[2]Earth System Analysis and Modeling Group, Pacific Northwest National Laboratory

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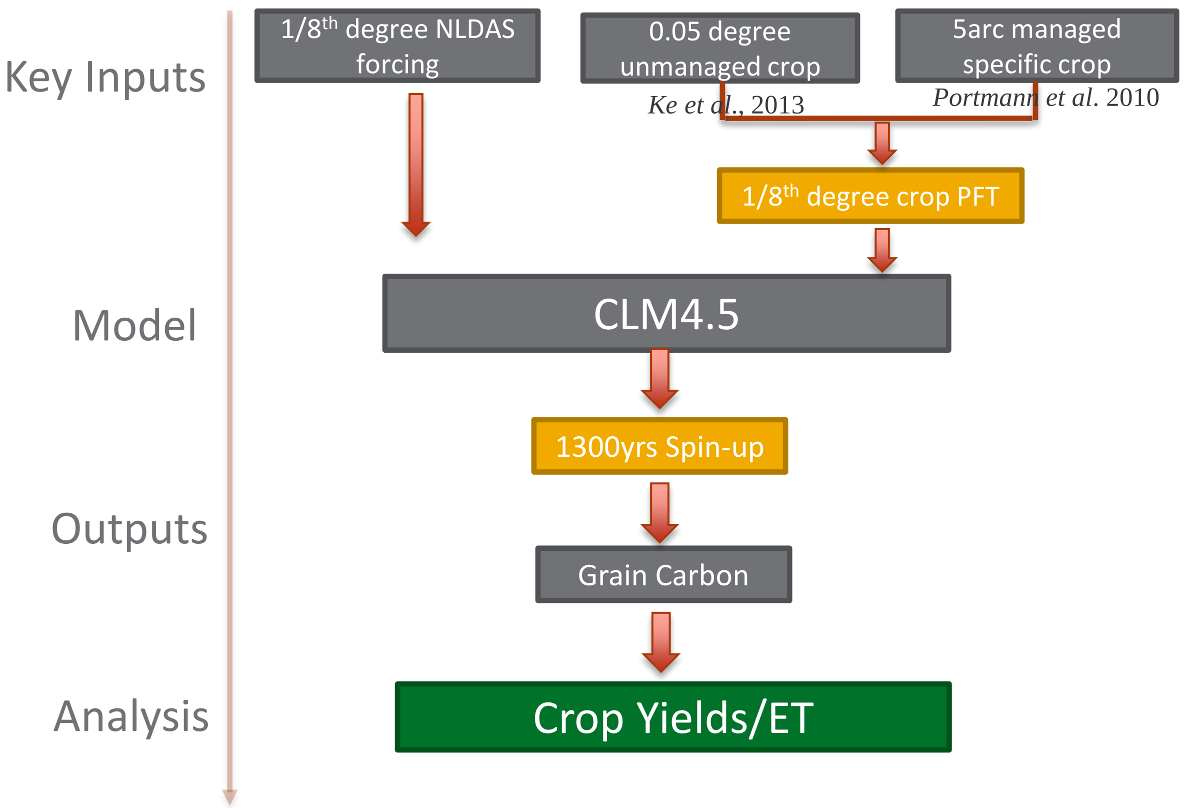
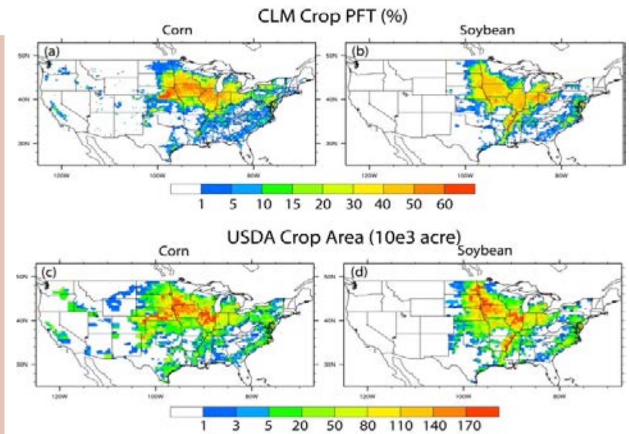
Motivations

- Growing population and rising demand for biofuel identify an urgent need to maximize crop yields on available agricultural land to ensure global food security as well as environment-friendly bioenergy supply:
  - To evaluate the potential of Community Land Model (CLM) as an effective tool for investigating water-energy-food systems interactions under climate change;
  - To evaluate the benefits of incorporating and coupling human activities (e.g. agricultural management practices) into complex ESMs.

Model Setup

- 1/8th degree CLM4.5 over CONUS





- Calculate grain yield (adapted from Agro-IBIS):

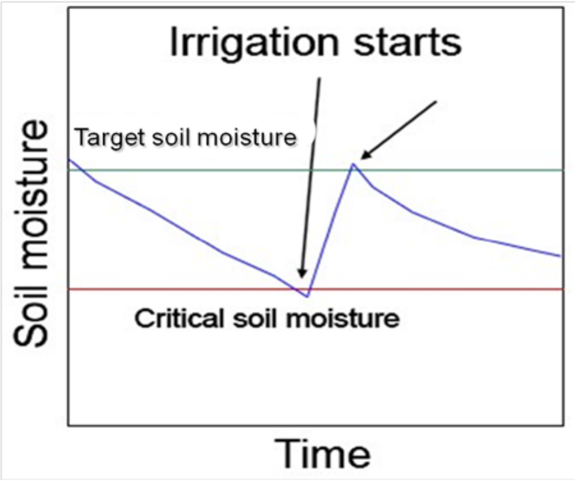
Yield = grainc * fyield * convfact / cgrain

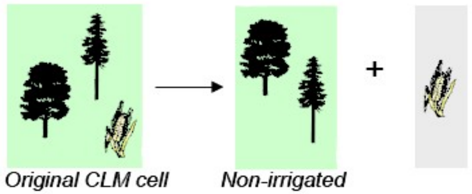
- grainc = grain carbon (g/m^2)
- fyield = adjustment factor for portion of grain that is actually harvested
- convfact = conversion to get from g/m^2 to bu/acre
- cgrain = amount of carbon in grain (0.45)

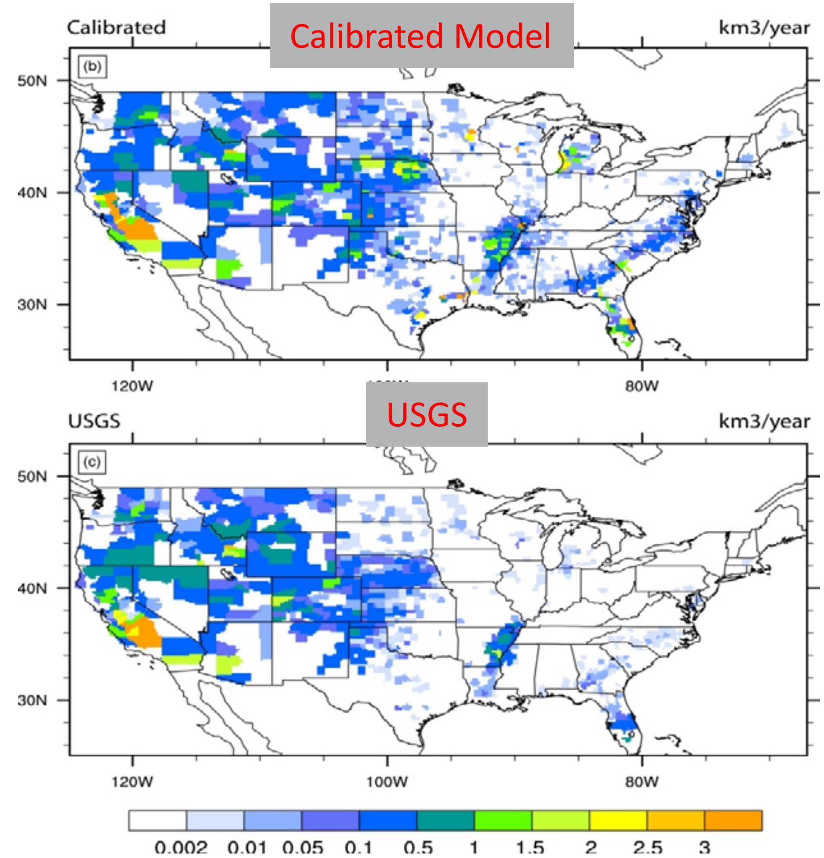
Dynamic Irrigation Scheme

Irrigation Amount

Irrigation Process



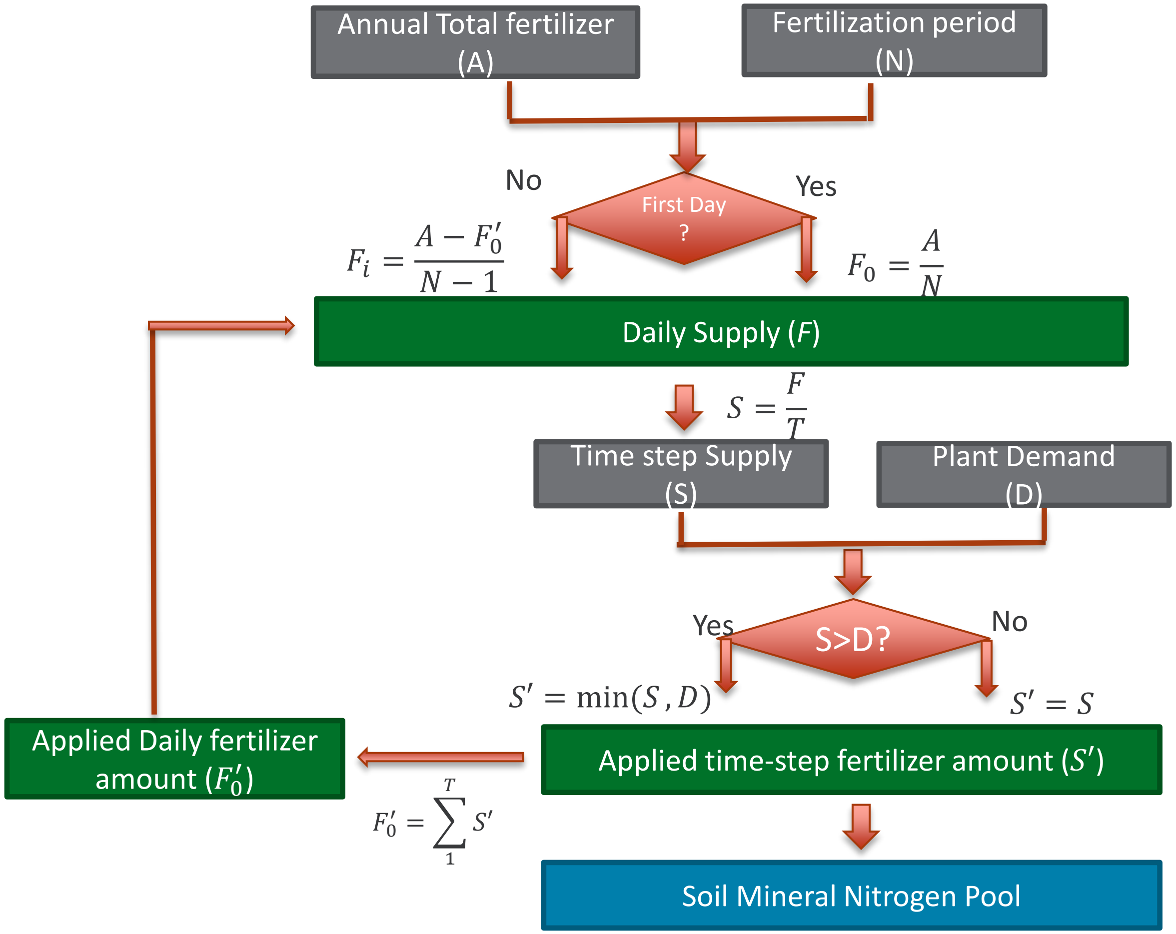




Leng et al. 2013 JGR; Leng et al. 2014 JHM

Optimized Fertilizer Scheme

- Instead of prescribing fertilizer constantly and spatial-uniformly as in default, we propose a optimized fertilization scheme, which is featured with optimized rate and timing with annual total amount constrained by observations



The value of A is determined using the USDA reported State level fertilizer use data. N is calibrated by matching simulated yields with USDA reported county-level yields.

Fertilization Scheme Parameters: Amount and Period

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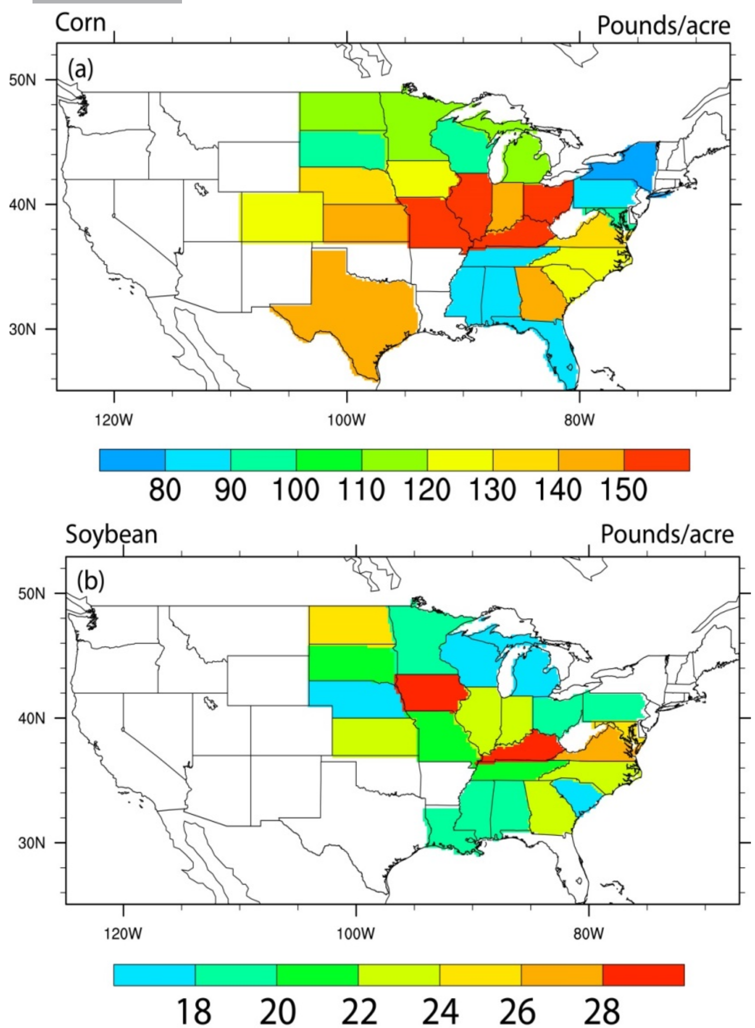
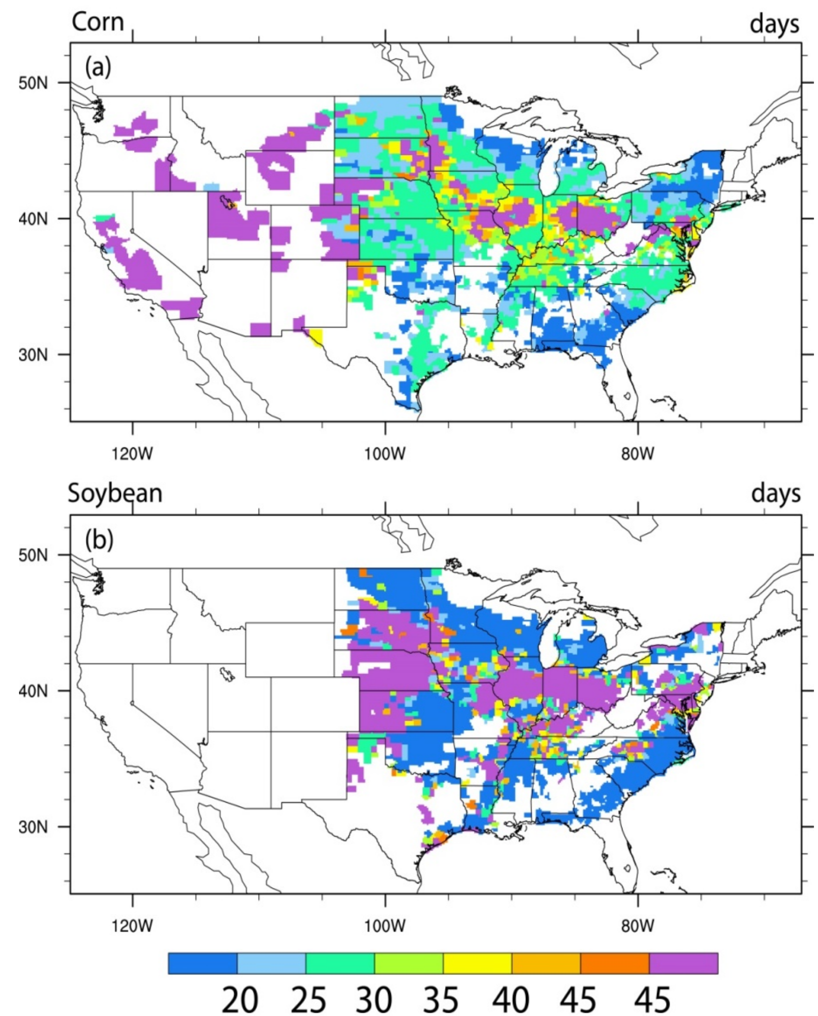
USDA

Fertilization Amount



Calibrated

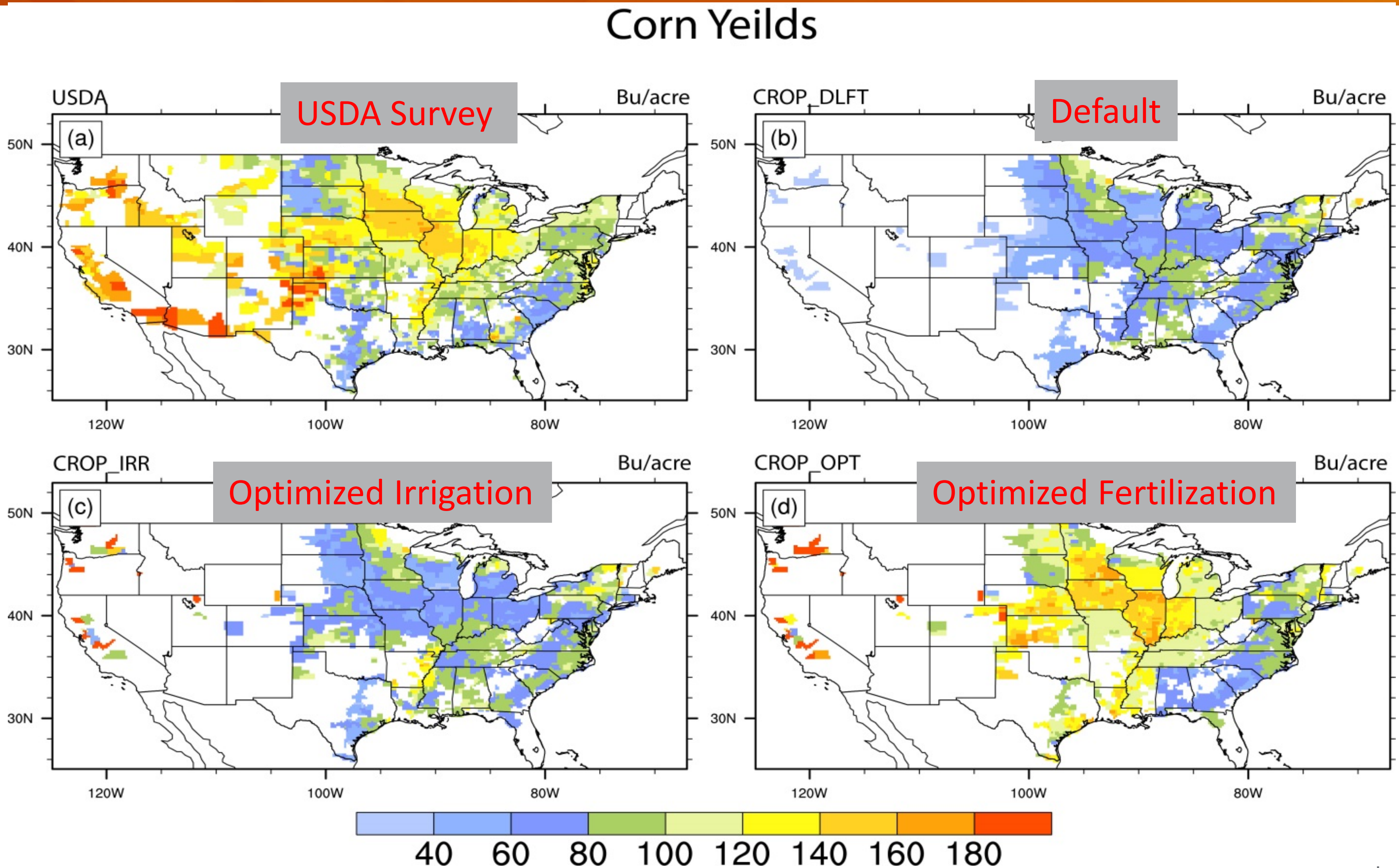
Fertilization Periods



Experimental Design

Name	Crop Types	Fertilization	Irrigation
GRASS	No	No	No
CROP_DLFT	Yes	Yes (Default)	No
CROP_IRR	Yes	Yes (Default)	Yes (Optimized)
CROP_OPT	Yes	Yes (Optimized)	Yes (Optimized)

Comparison of Model Performance: Spatial Pattern



Gridded results are aggregated into county-level for comparisons with USDA reports

Comparison of Model Performance: Spatial Pattern

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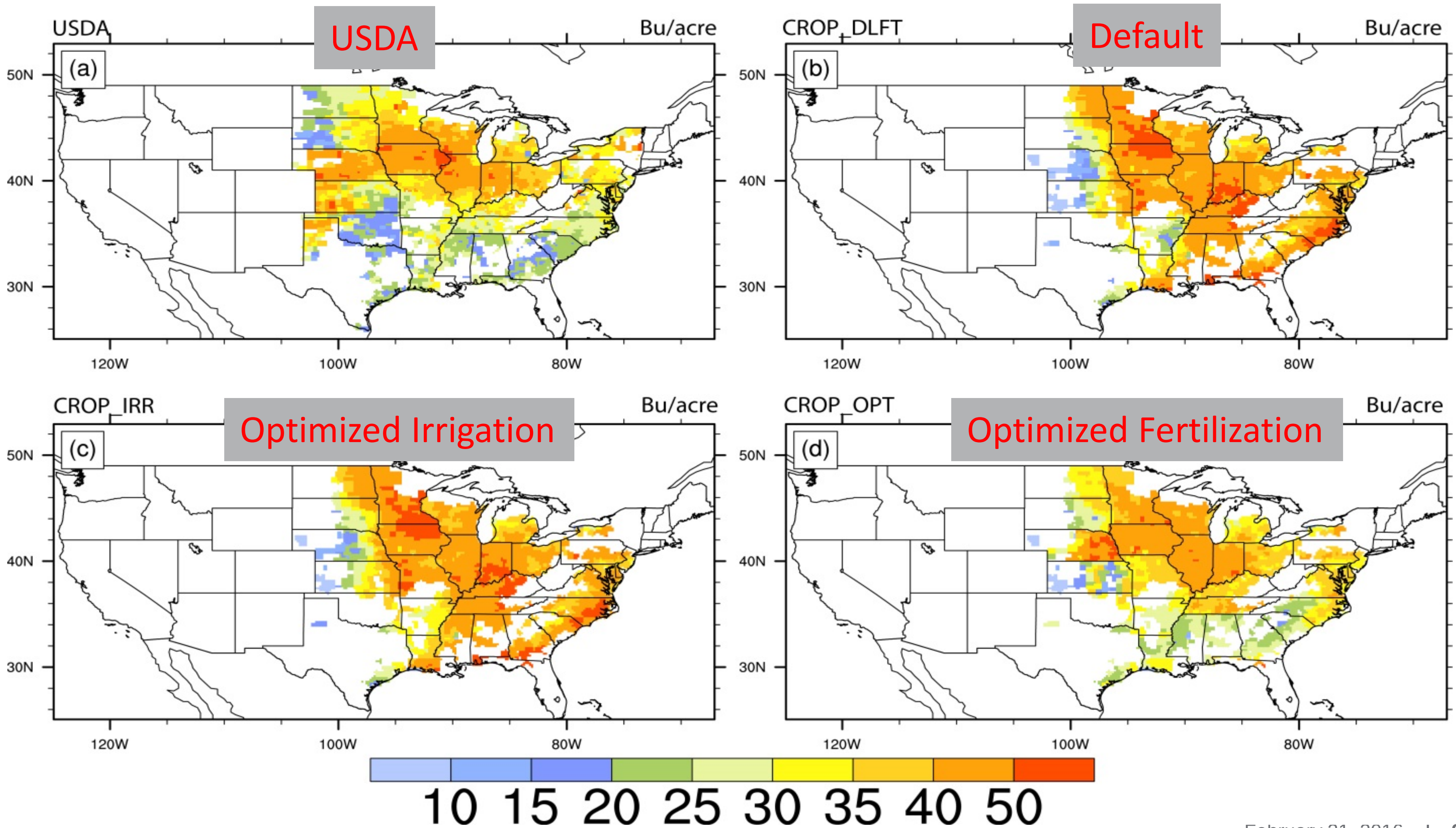
Soybean Yeilds



Gridded results are aggregated into county-level for comparisons with USDA reports

Comparison of Model Performance: County-level Crop Yields

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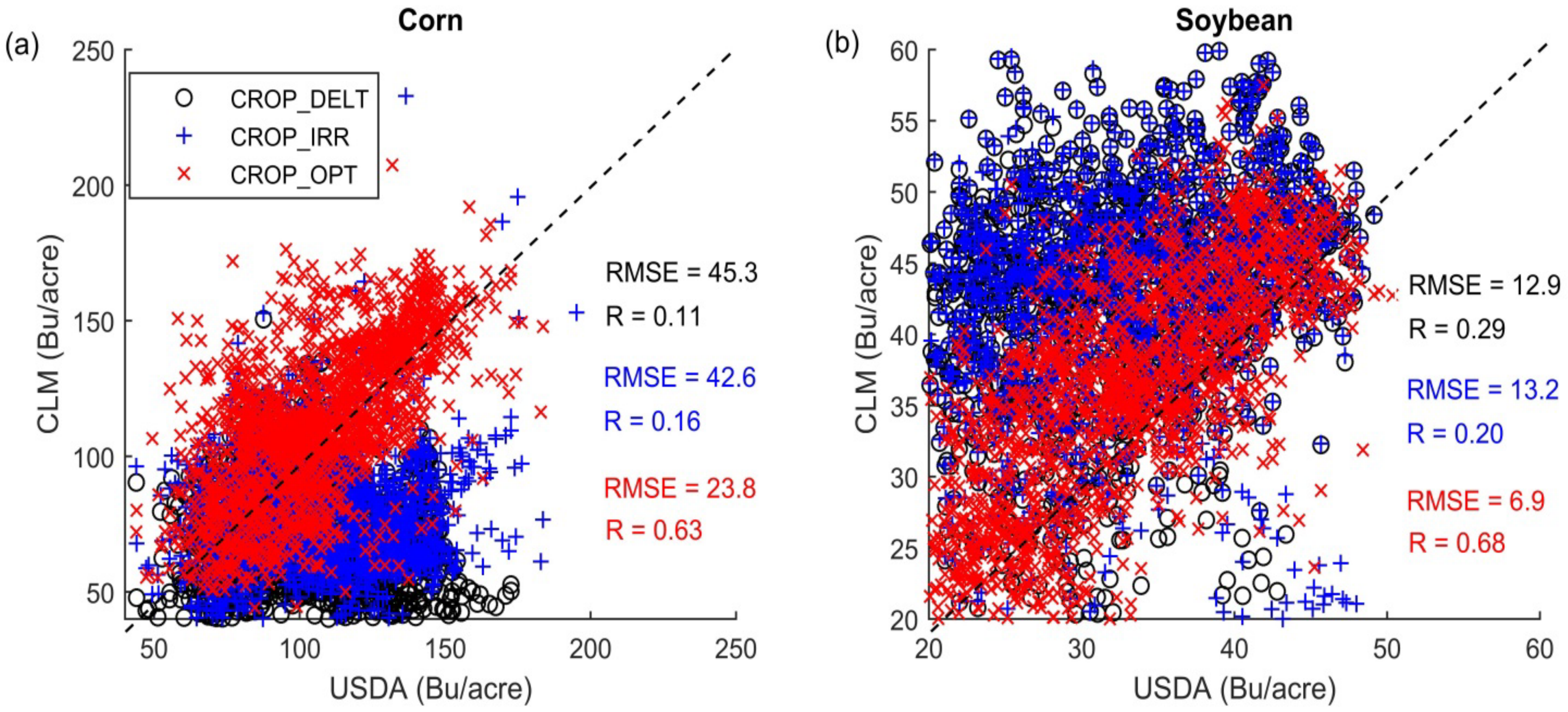

Significant improvements for simulating corn and soybean with optimized fertilization and irrigation.

Comparison of Model Performance: Temporal Pattern

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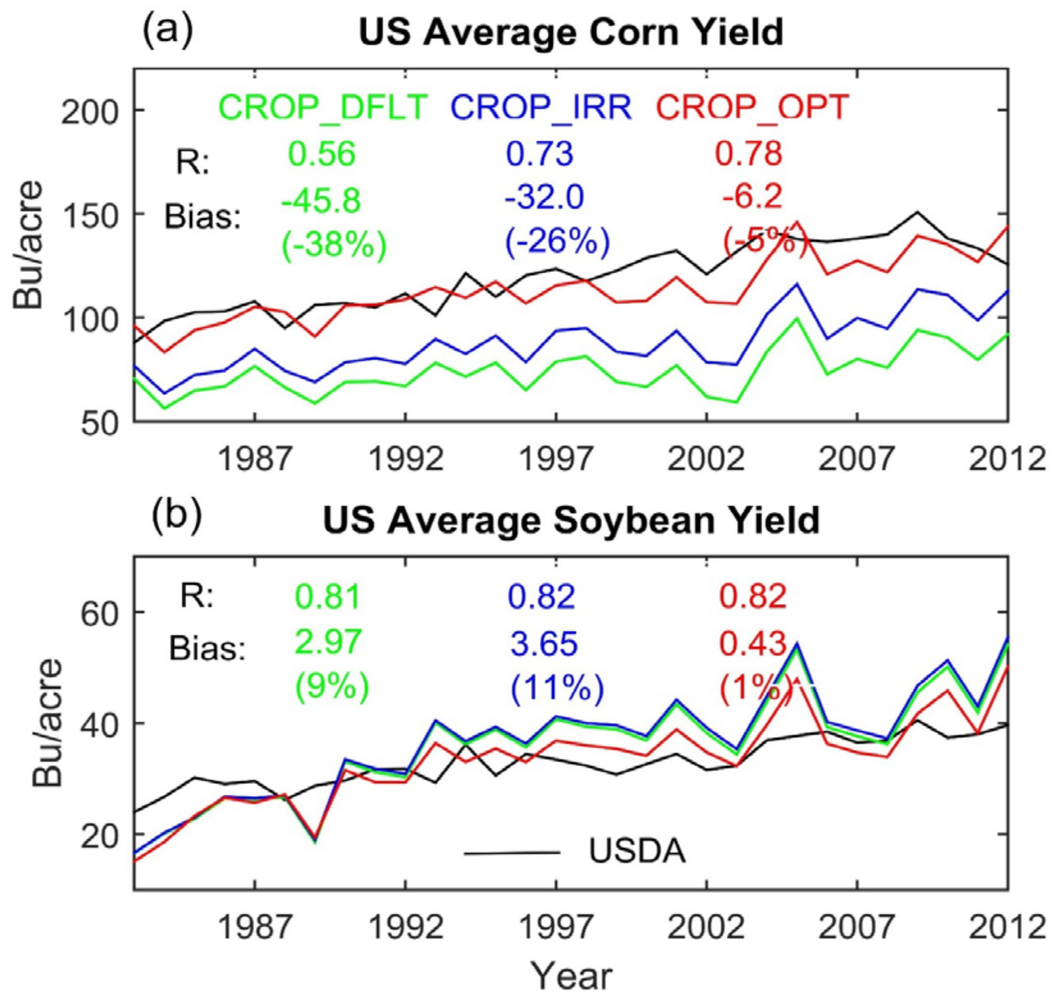
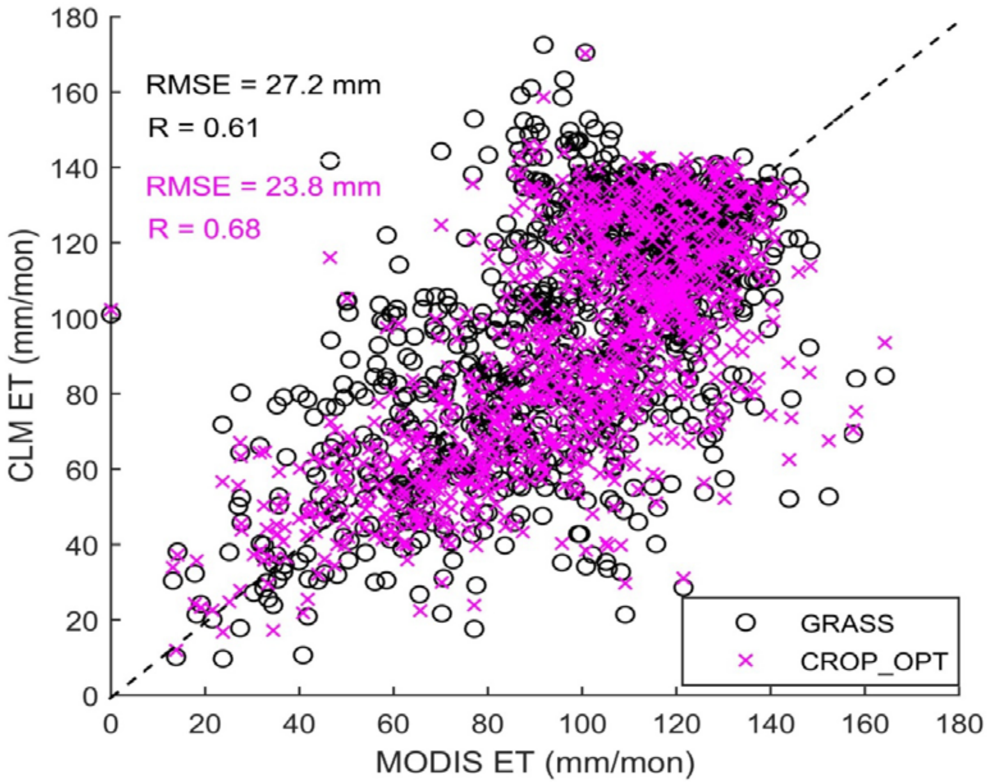


Implication for ET Estimates



Improvements in the representation of crop growth and management translate into better match between simulated and MODIS observed ET.

Conclusion and Discussion

- Better treatments of fertilization and irrigation that incorporate observed information from USDA and USGS results in pronounced improvements in simulating mean, variability and spatial distribution of crop yields, especially for the Midwestern region of US;
- Estimates of ET are also improved by constraining model parameters against agricultural census data, demonstrating the value of continued model improvements and coupling of processes among ESM components for improved climate simulations and projections;
- This study demonstrates the capability of CLM to be used as an effective tool for integrated assessment of cropping systems at a scale meaningful for decision-making.

Acknowledgement

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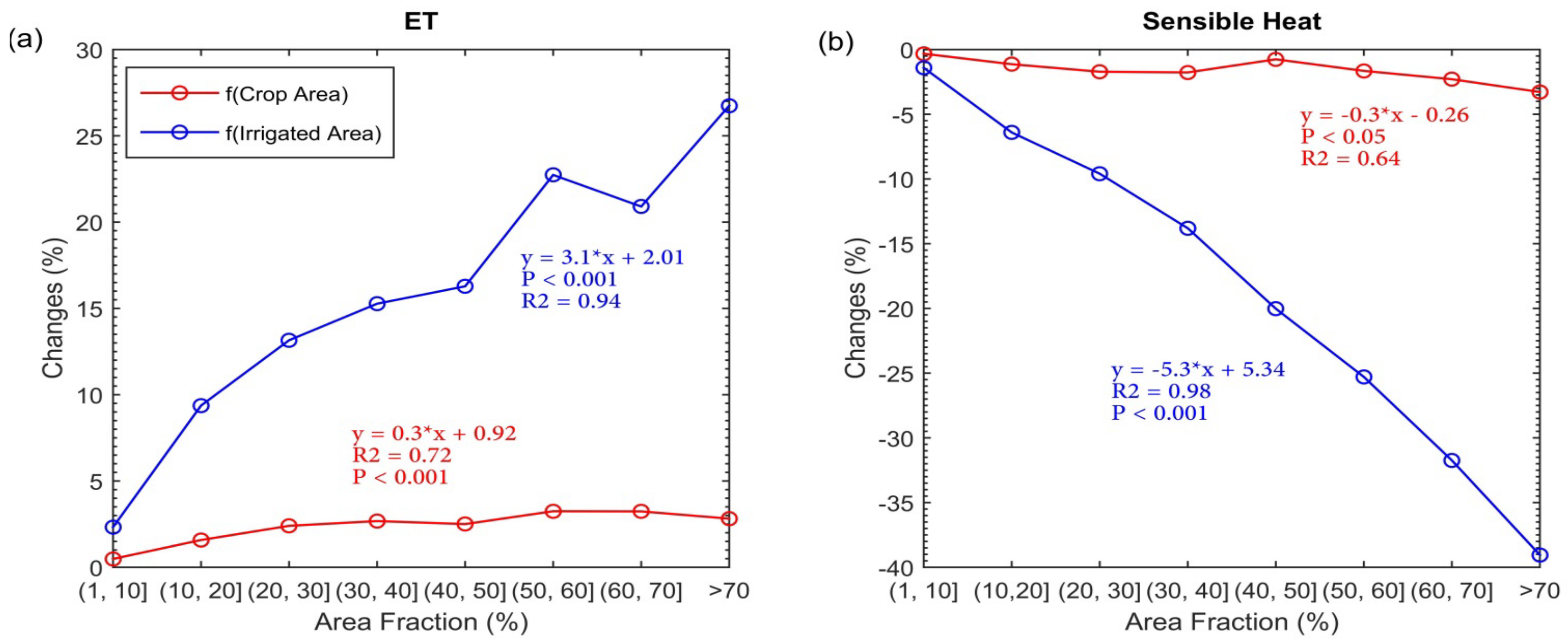
- DOE BER Integrated Assessment Research program:

  The Regional Integrated Assessment Modeling Project
- DOE Energy Efficiency and Renewable Energy:

  The Great Lakes Bioenergy Research Center
- NASA Terrestrial Ecology Program
- Pacific Northwest National Laboratory:

  Laboratory Directed Research and Development Program

Agricultural Management Effects on Water and Energy fluxes



The changes in ET and reduction of SH depend linearly on the crop growing areas and irrigated areas with largest increase of ET by up to 27% and decrease of sensible heat by up to -38%, demonstrating the importance of considering crop types and efficient representation of agricultural management practices.