INCORPORATION OF CROP GROWTH MODELS INTO CLIMATE WEATHER RESEARCH AND FORECASTING MODEL

Bio-geophysical feedbacks of maize growth to regional climate

Min Xu[1], Xin-Zhong Liang[1,2] and Wei Gao[3,4]

[1]Earth System Science Interdisciplinary Center, University of Maryland at College Park (UMCP)
[2]Department of Atmospheric and Oceanic Science, UMCP
[3]The USDA UV-B Monitoring and Research Program, Natural Resource Ecology Laboratory, Colorado State University (CSU)
[4]Department of Ecosystem Science and Sustainability, CSU

EARTH SYSTEM SCIENCE INTERDISCIPLINARY CENTER
ESSIC
UNIVERSITY OF MARYLAND

UV-B Monitoring and Research Program

UNIVERSITY OF MARYLAND Earth System Science Interdisciplinary Center

Acknowledgement

- Supports from USDA UVMRP USDA-NIFA-2010-34263-21075 and NOAA TE NNH12AU03I
- Computational resources provided by NOAA ZEUS and PNLL Evergreen supercomputers
- WRF development teams
- Members of Earth System Model Research & Development Laboratory (EaSM) in Earth System Science Interdisciplinary Center.

Outlines

- Introduction
- Objectives
- CWRF-Crop coupled system
- Experiments
- Results and conclusions
- Future works

Introduction

Agriculture system and climate are coupled in nature, because:

- Agriculture is an essential part of climate system, occupying about **12**% of Earth land.
- Agriculture is severely influenced by weather and climate.
- Crop growth alters surface characteristics vital to determine various surface fluxes to overlaying atmosphere (bio-geophysical feedback).
- Crop growth also modulates the exchanges of greenhouse gases among atmosphere, soil and plant (bio-geochemical feedback).
- Moreover, the perturbed climate caused by crop growth, in turn, will affect crop development and growth.
- The feedback and response of crop growth to regional climate are uncertain in future climate change.

Objectives

- Implement crop growth models with comprehensive phenology into the regional climate model (CWRF) to understand the complex two way crop-climate interactions under current and future climate
- Study local and regional bio-geophysical feedback from crop growth using the coupled CWRF-Crop system.
- Study the impacts of future climate change and variability on crop growth, development, and final yield.

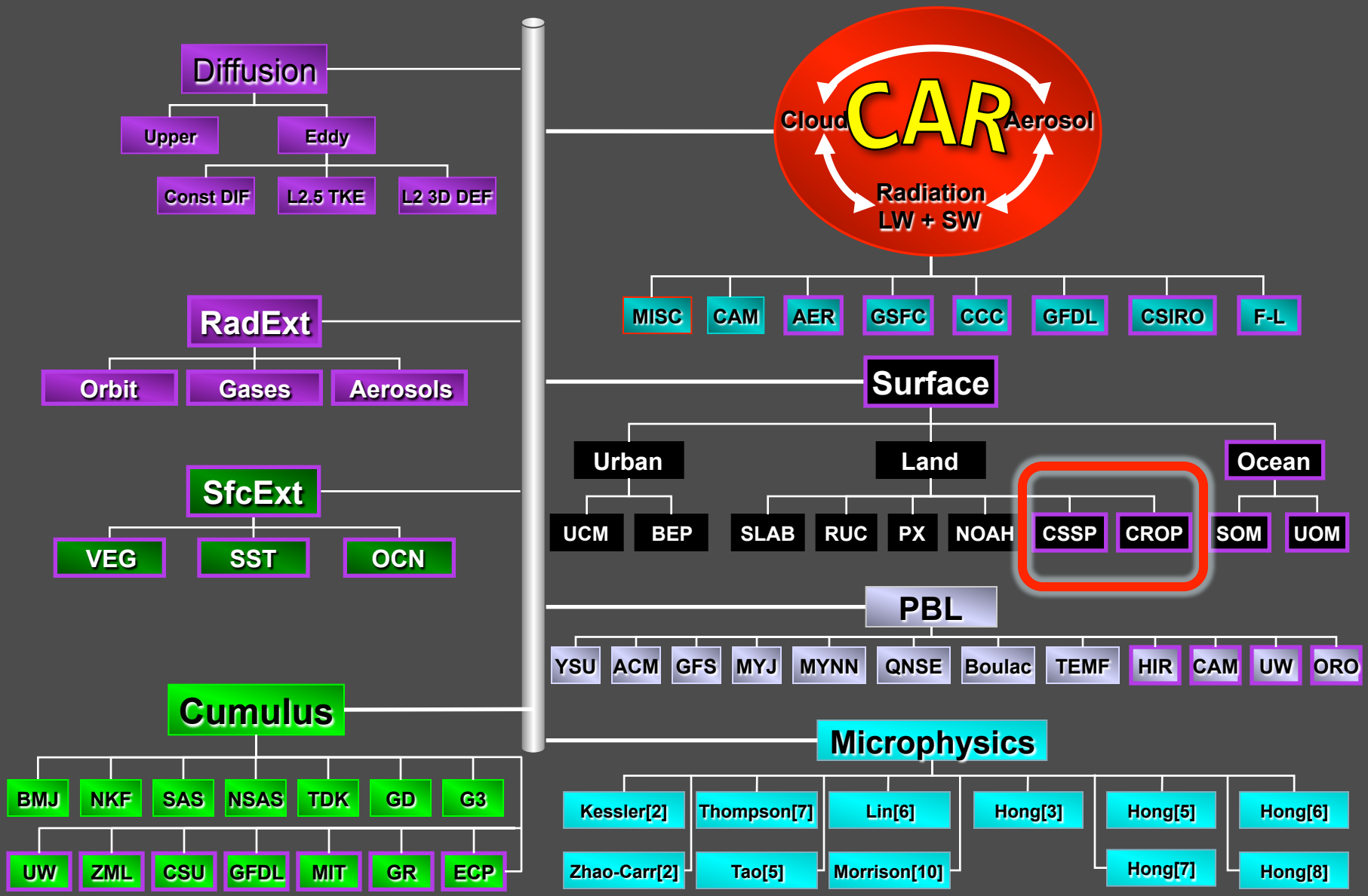
CWRF-Crop system (1)

- Couples CWRF and crop growth models in a direct way with a common interface (data exchange using modules and subroutines).
- Includes the following crop growth modules at present:
  - *Cotton module from GOSSYM model (Liang et al. 2012)*
  - *Maize module from DSSAT CERES maize model (Xu et al. 2009)*
  - *Wheat module from DSSAT CERES wheat model*
- Incorporates two soil C/N cycling modules:
  - *CERES based C/N model*
  - *CENTURY based C/N model*

CWRF-Crop system (2)

- **Includes following crop managements:**
  - Planting or sowing date is determined automatically when soil temperature, moisture, and atmosphere temperature satisfied a pre-defined criteria during the range of the most active planting window in state level from USDA NASS data.
  - All above ground biomass is removed in the last day of the most active harvest window in state level from USDA NASS data.
  - Automatic Irrigation scheme follows the method of Liang et al. 2012.
  - A certain amount of ammonium nitrate (50% ammonium plus 50% nitrate) is applied when the plant nitrogen stress factor (0-1) drops below 0.6 (1 if free of nitrogen stress)
  - Tillage management.

CWRF Physics Options



Liang et al. (2012, BAMS)

CERES-maize

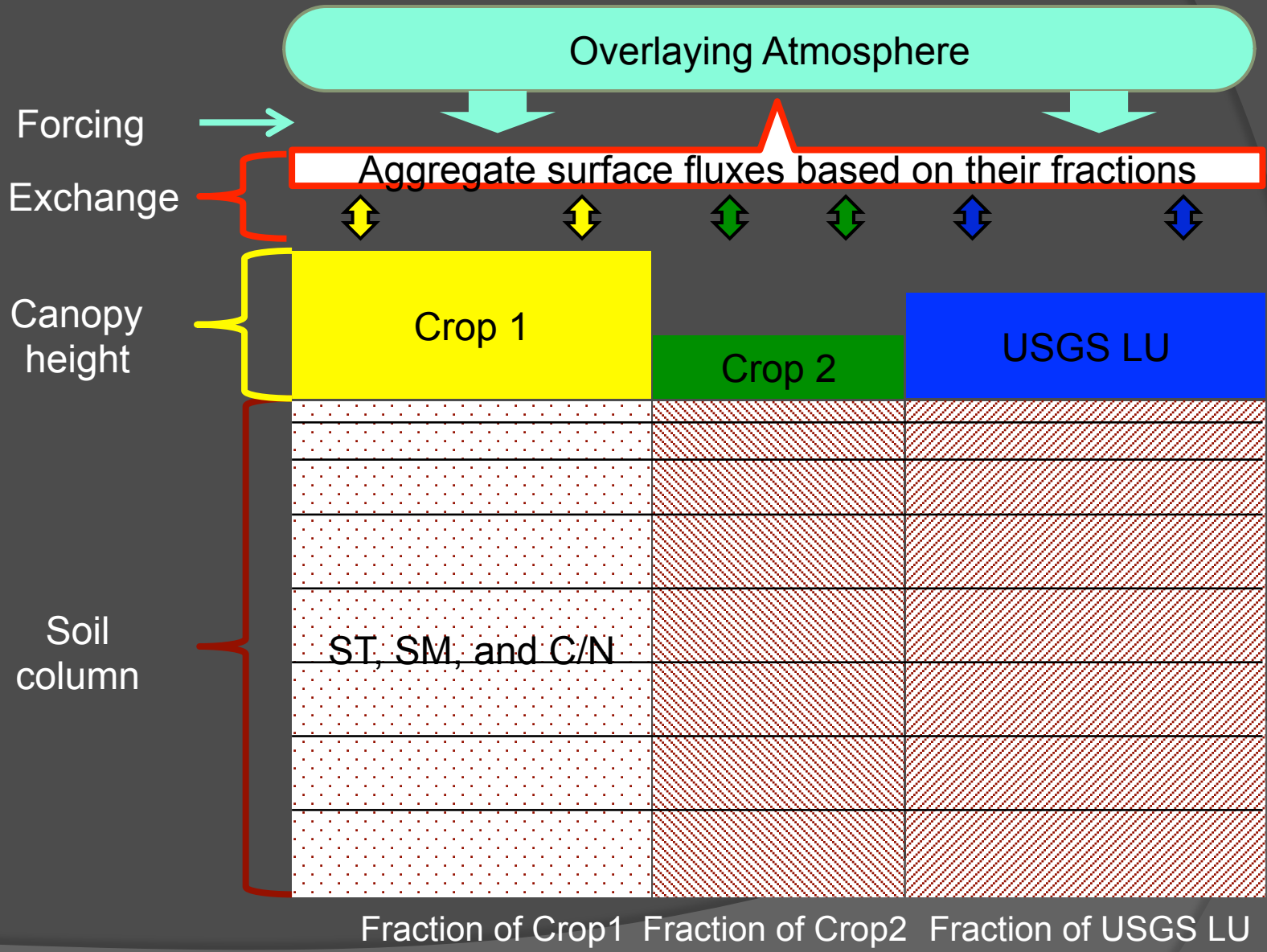
Phenology (nine stages)

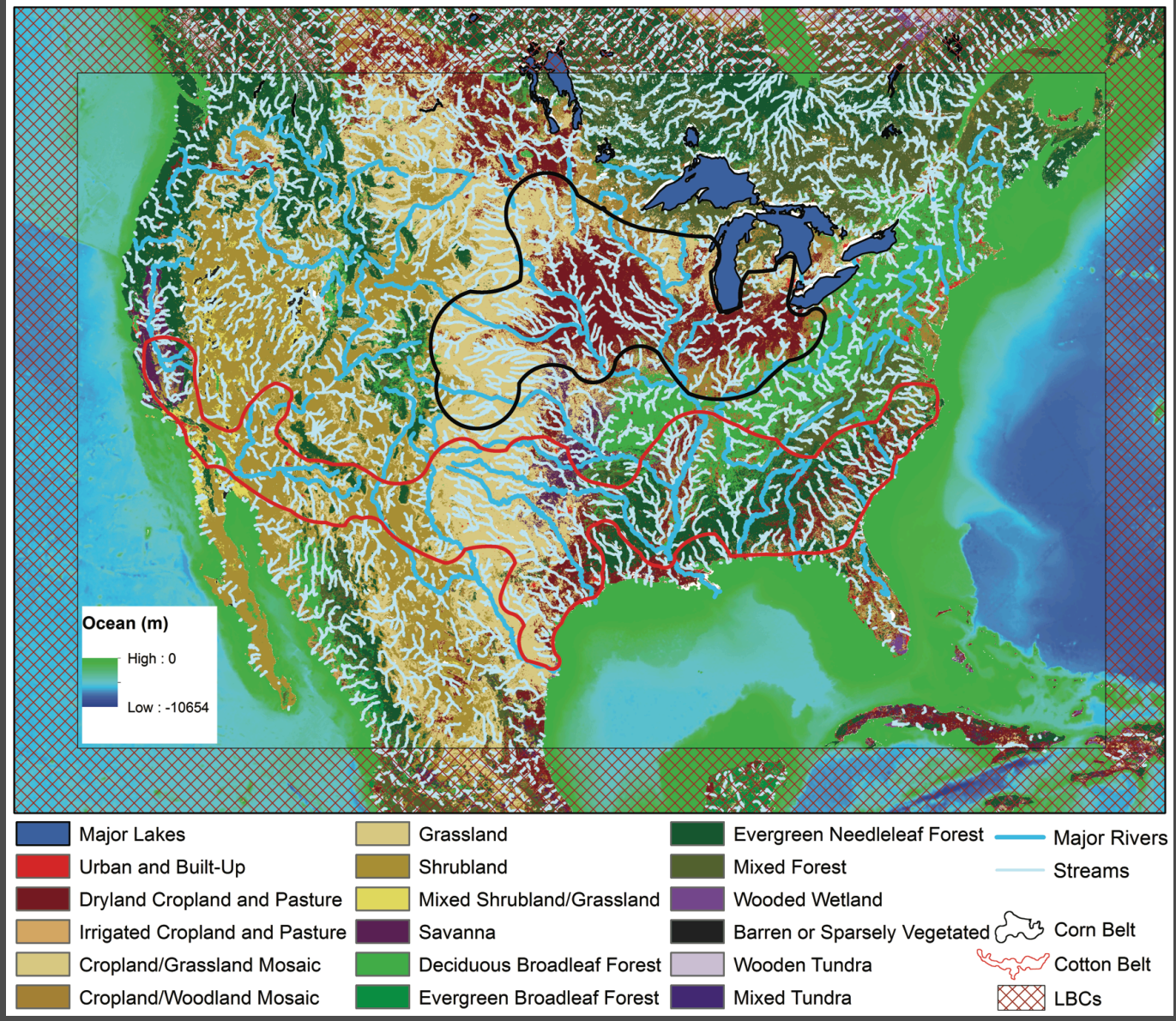
1. Sowing
2. Germination
3. Emergence
4. Emergence to End of Juvenile
5. End of Juvenile to Tassel Initiation
6. Tassel Initiation to End of leave growth and silking
7. Silking to begin of effective grain filling
8. Effective grain filling
9. End of grain filling to physiology mature

Simple mosaic scheme

- In CWRF, Land use type dominant with largest coverage in a grid represents the land use type of the grid.
- In CWRF-Crop coupled system, there exist two tiles or mosaics in those grids with crop planted. One is USGS unmanaged land use tile, the other is managed crop tile. The managed crop tiles also can have subtiles for different crops. The phenology of the USGS tile is derived from satellite data, while for crop tile, it is predicted by crop growth model.
- Two tiles have different soil columns, even for crop tile, different crops have different soil columns to incorporate crop management separately.
- Two tiles share same overlaying atmosphere and return surface fluxes by aggregating them over tiles based on their fractions in a grid.

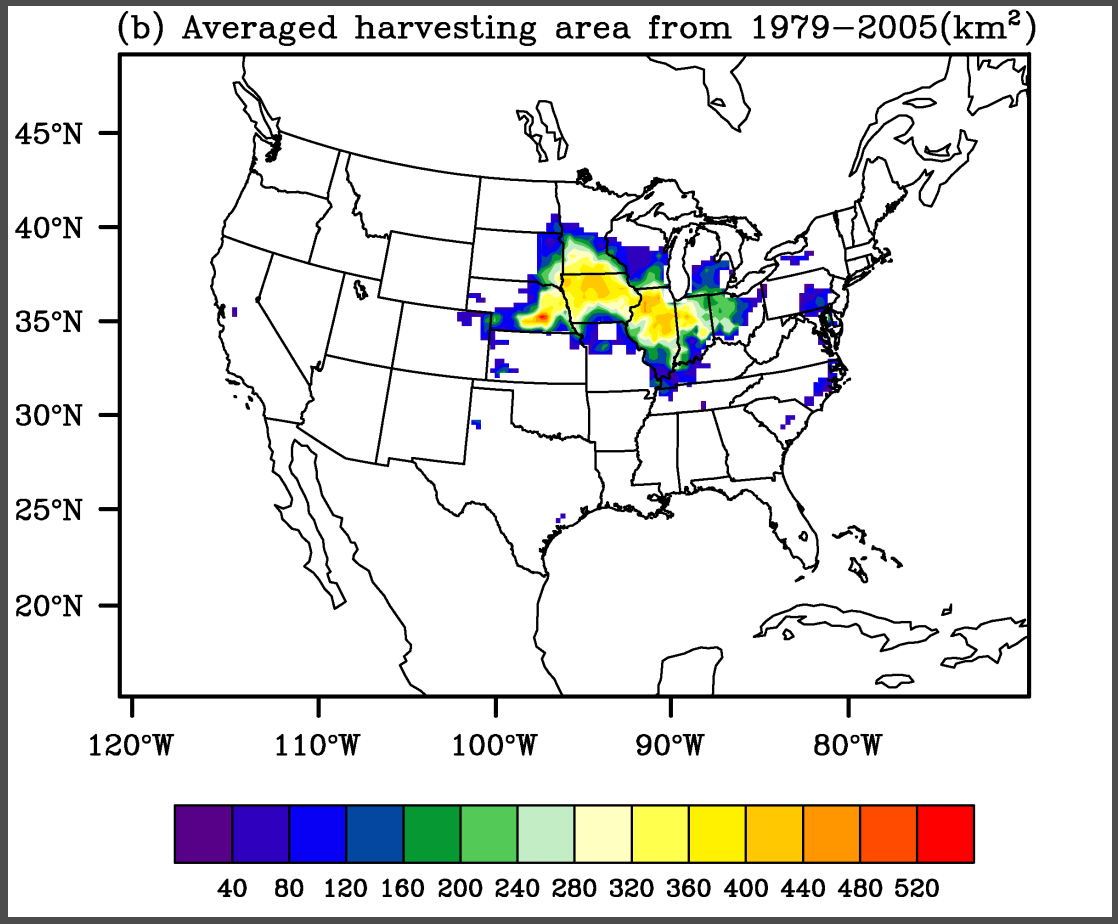
Illustration of the simple mosaic scheme in CWRF-Crop coupled system





the CWRF computational domain for this study. the hatched edge areas are the buffer zones, where LBCs are specified. overlaid are the geographic distributions of land cover (USGS24 categories) and ocean depth (m), lakes, major rivers, and main streams as well as the outlines of the corn/ soybean and cotton Belts. (From Liang et al. 2012 BAMS)

Maize distribution

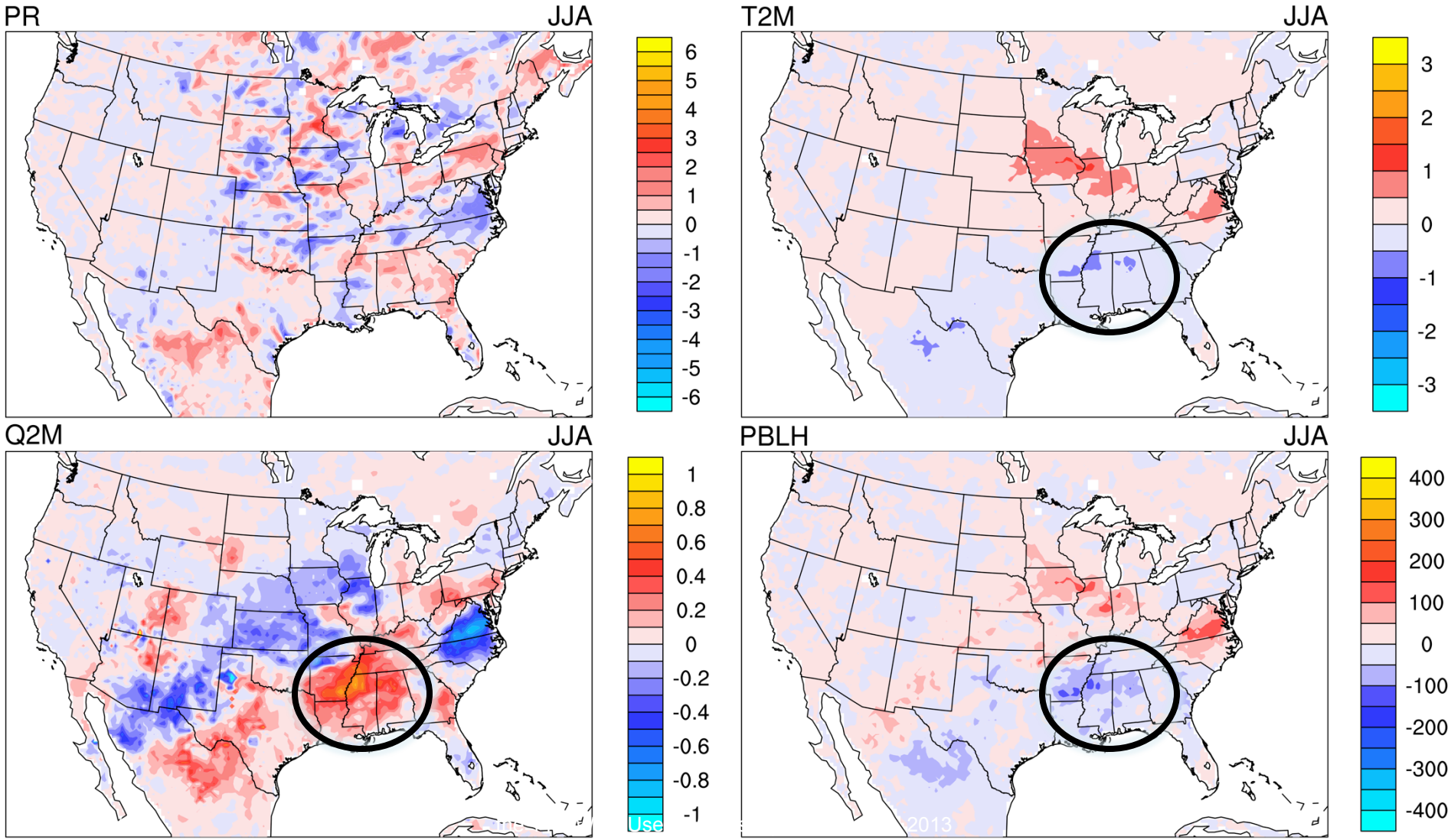


Experiments

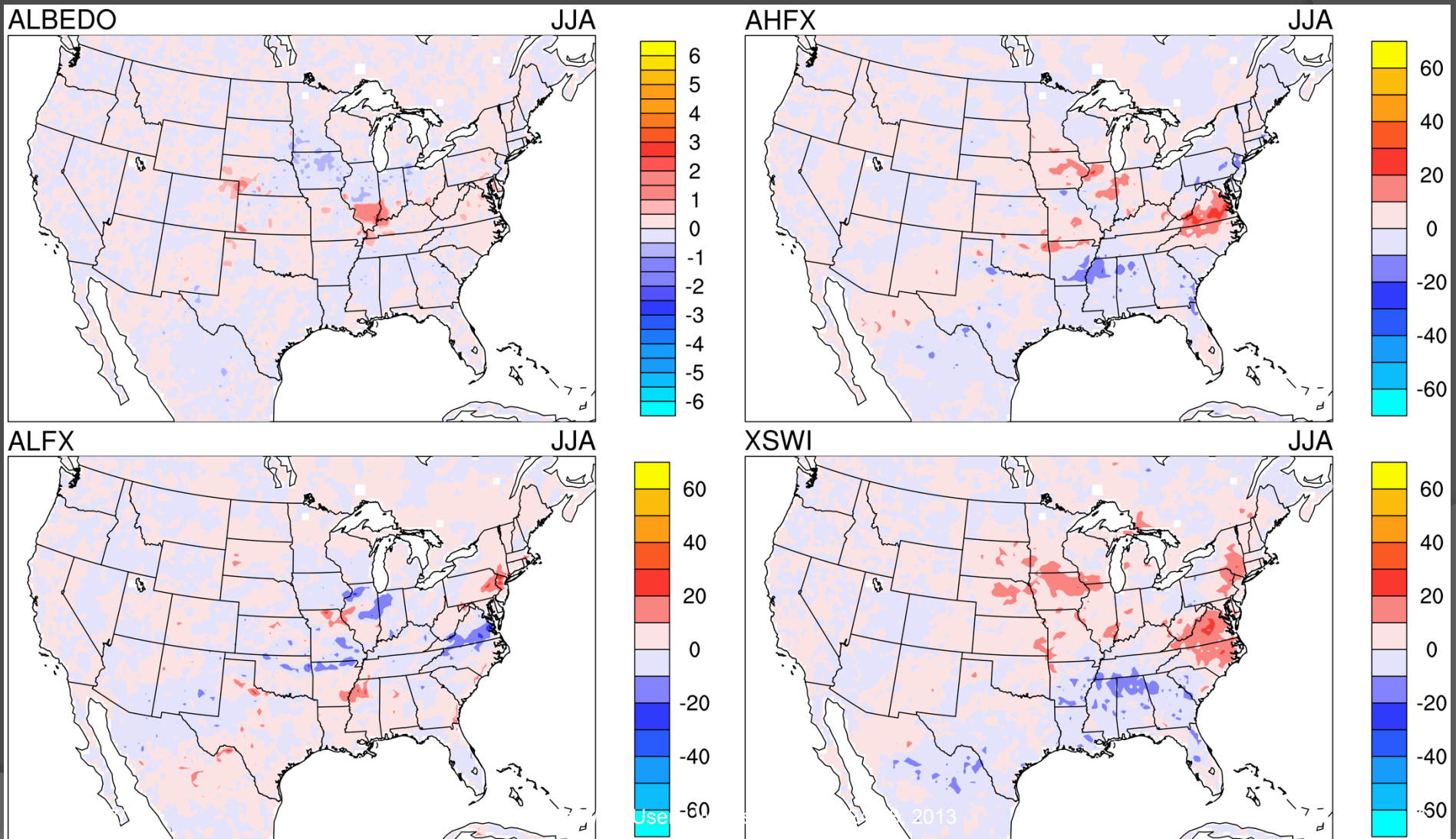
- CNTL: NO feedback, one-way coupling.
- REAL: feedback, two-way coupling with observed planting area from USDA NASS in a grid.
- SENS: feedback, two-way coupling with the planting area assumed to be whole land area in a grid.

We examine the differences in surface climate respectively for REAL and SENS cases to CNTL case to study the feedbacks of crop growth to regional climate.

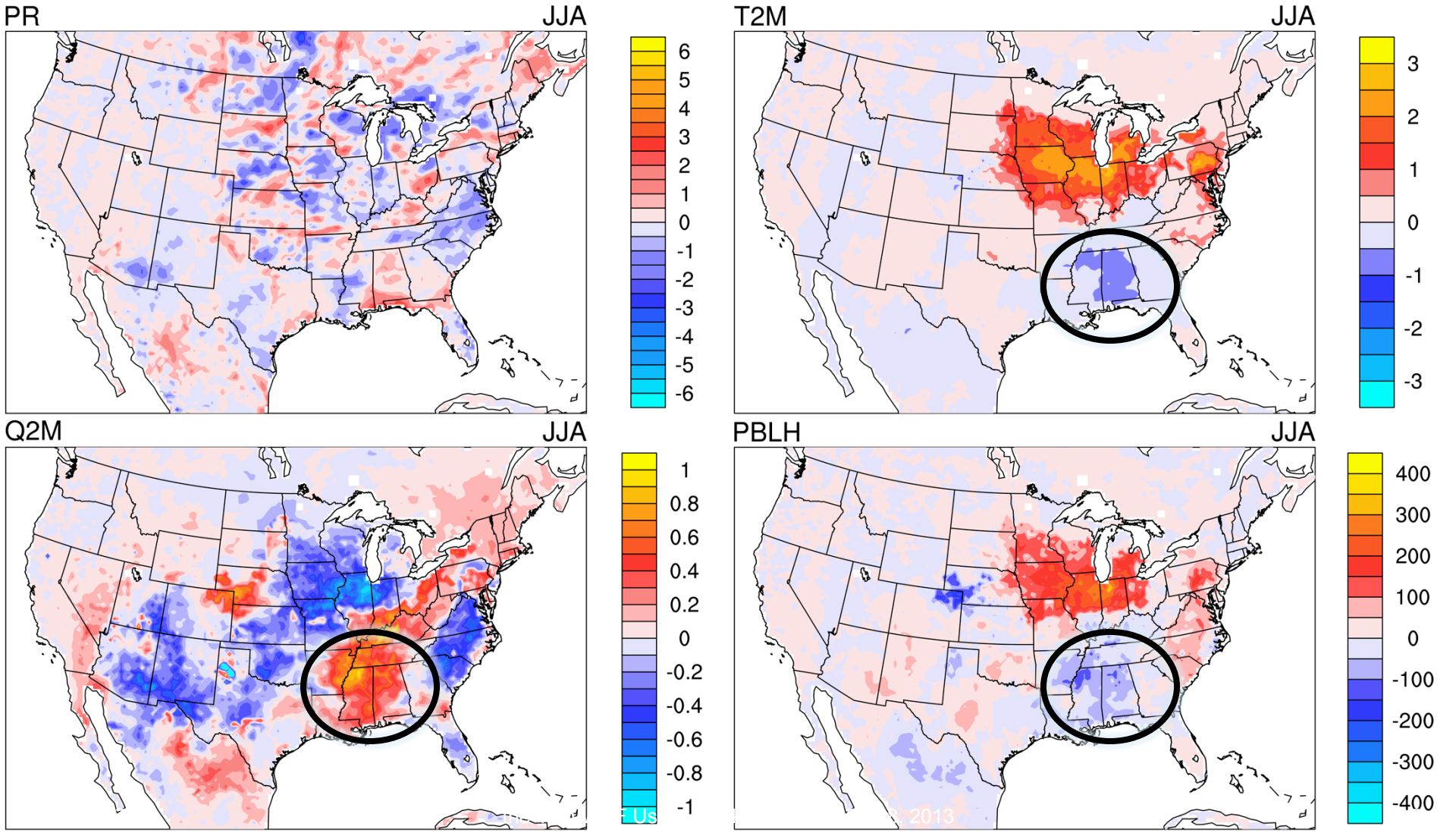
Difference (REAL-CNTL) (1)



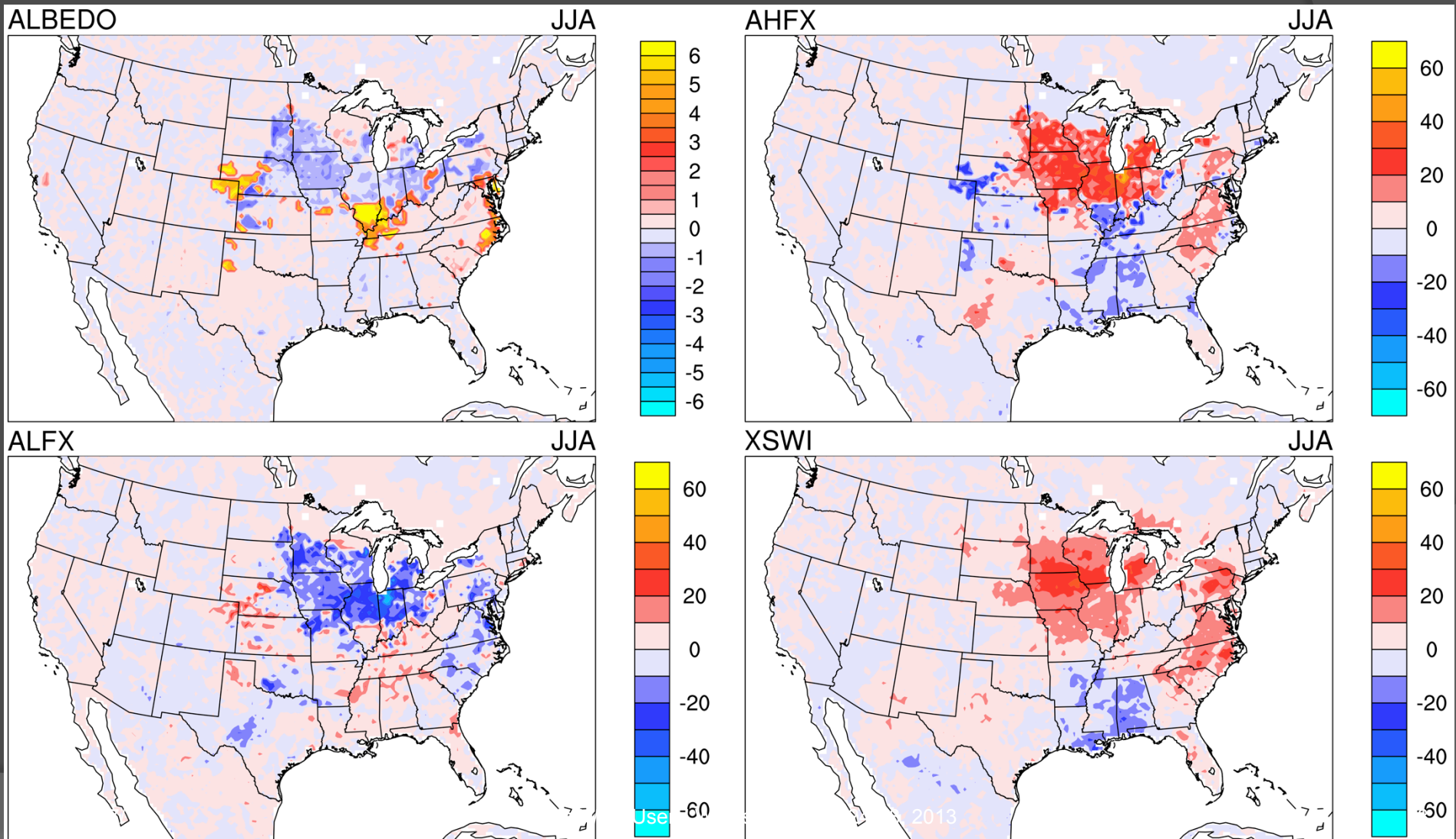
Difference (REAL-CNTL) (2)



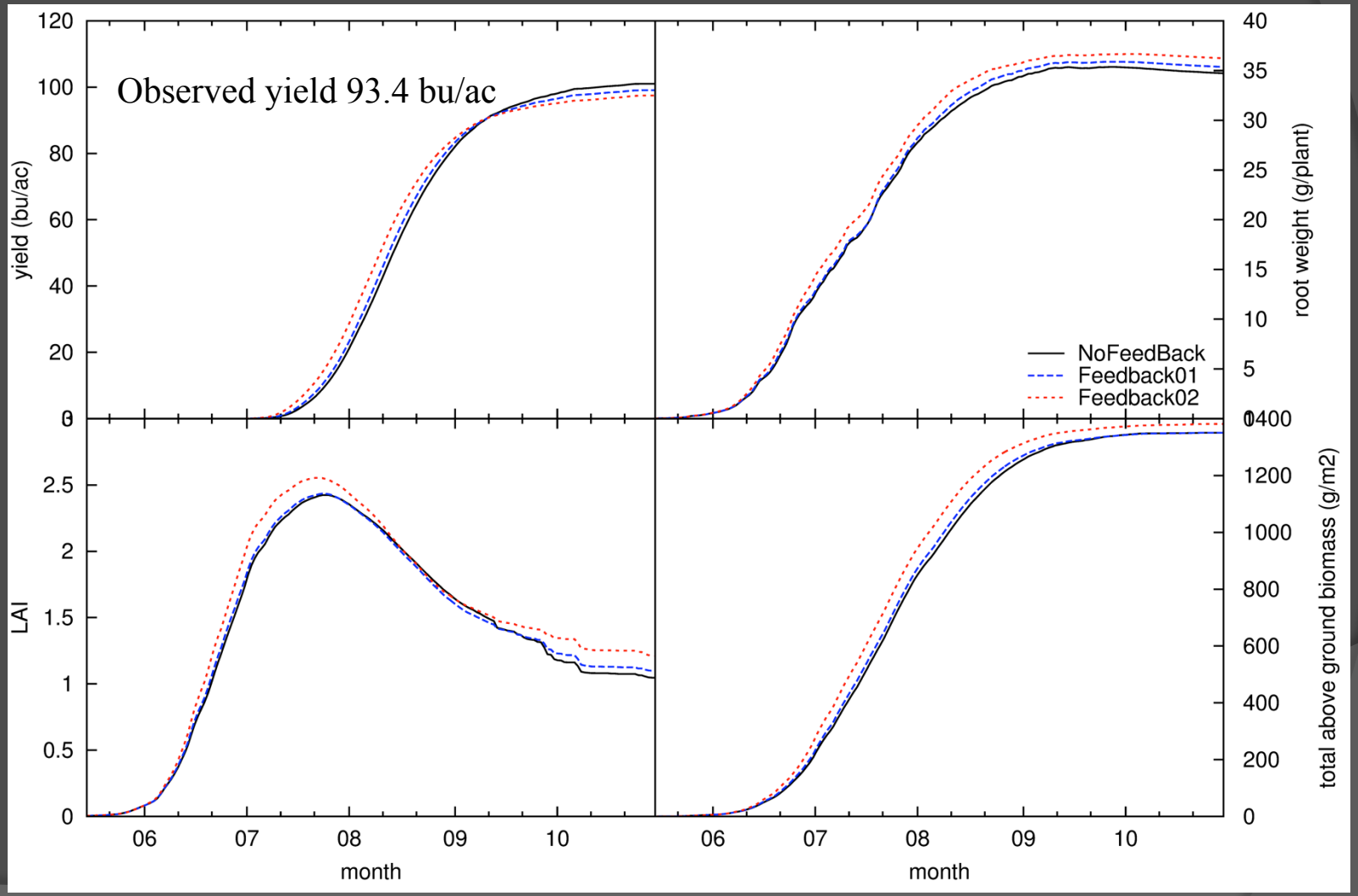
Difference (SENS-CNTL) (1)



Difference (SNES-CNTL) (2)



Impacts on crop growth



Conclusion

- Crop growth apparently has important impacts on the regional and local climate.
- The influenced climate by crop growth, in turn will affect crop growth.
- A fully coupled climate and crop model is needed in projection of future crop productions, and for policy and decision makers in crop adaptation and mitigation under future climate.

Future plans

- The crop growth modules are plan to implement into WRF.
- More crop growth models are planed to implemented into CWRF, including:
  - Soybean (generally planted with maize in alternative years)
  - Rice (an important food crop in Asia)
  - Biofuel/bioenergy crops (energy security)
- More comprehensive and robust soil carbon and nitrogen scheme over cropland is under development by combining the CENTURY model and widely validated C&N cycling algorithm from EPIC model (collaboration with Dr. Xuesong Zhang in PNNL)
- A unified photosynsthesis and stomatal conductance model both for crop growth models and climate models is under development.

Questions?

Thanks