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REGIONAL CLIMATIC EFFECTS OF CROP GROWTH MODELED BY THE COUPLED CWRF-CROP SYSTEM

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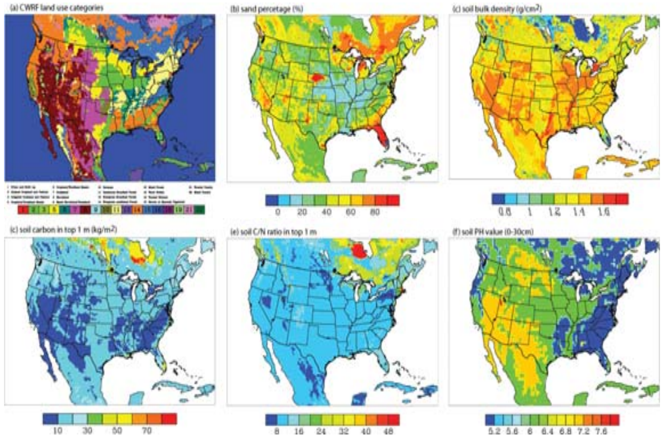
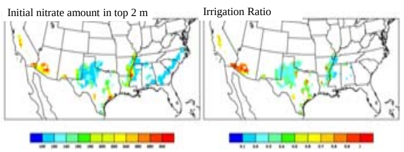
CONSISTENT SBCS AND CROPPING PRACTICE DATA



The CWRF currently uses the USGS land use/cover classification, which consists of 24 categories based on 1-km AVHRR satellite measurements. Modifications to the CWRF vegetation have been made to ensure consistency with the crop dominance in these regions. The geographic distribution of soil properties, including sand/clay percentage, bulk density, PH value, carbon and nitrogen density required by the crop growth models are obtained from satellite retrievals and remapped onto the CWRF 30-km grid. The other soil hydrological properties such as volumetric water content at saturation, field capacity, permanent wilting point, and air dry, water potential at field capacity and water diffusivity or conductivity at permanent wilting point are parameterized in terms of sand, clay and organic matter profiles as Saxton and Rawls (2006).

PARAMETER OPTIMIZATION AND MODEL VALIDATION

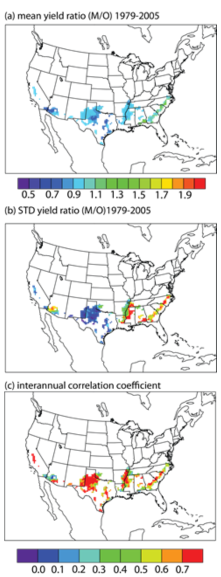


GOSSYM optimized key parameters

The nitrate amounts in California, Arizona and the areas along the Mississippi River are larger than 220 kg/ha, and are less than 140 kg/ha in other regions of the Cotton Belt. The heavy irrigations with the ratio of irrigated water amount larger than 0.8 occur in the Arizona and California border on Arizona, moderate irrigations (irrigated ratio about 0.6-0.7) in the Sacramento and San Joaquin Valleys in California, and small irrigations in other regions.

Given the data specifications in the CWRF-SBCs, the new crop models still require additional parameters that lack the observational basis as distributed over the U.S. Cotton and Corn Belt. These parameters include initial soil nitrogen condition, fertilization rate and irrigation water amount that are usually related to complex crop management practices. Since there is no credible source for a correct specification, they can be determined through an inverse modeling that minimizes local root-mean-square error of annual lint yields modeled under realistic climate conditions. This is accomplished following the optimization procedure of Liang et al. (2005). For the new GOSSYM model, we choose ratio of the irrigated water amount to potential evapotranspiration (only over irrigated lands) and the initial nitrate amount (everywhere) as the key adjustable parameters that vary in space and remain invariant over time.

The new GOSSYM well produce long-term mean cotton yields within $\pm 10\%$ of observations over virtually the entire U.S .Cotton Belt. The modeled year-to-year variability is in reasonably good agreement with observations. Assuming that yearly records are independent, having 25 degrees of freedom, modeled and observed deviations are not statistically different at the 90% significance level if their ratios are within 0.71-1.4. By this measure, the modeled yield interannual variability close to observations over 91% harvest areas for the new GOSSYM. The crop yields modeled by the GOSSYM is positively correlated with observations over the majority of the Cotton Belt. Significant correlations at the 95% confidence level are found over 79% (irrigated), 83% (non-irrigated) 87% (all) of the harvest cotton grids. This result demonstrates the important contribution of climate variations to cotton yields over these areas, and explains greater than 50% of the observed interannual variance in 53% of the harvest grids.



Left is the geographical distribution of 1979-2005 cotton ratios for (a) means; (b) standard deviations of simulated and observed yields; ; and (c) their interannual correlation.

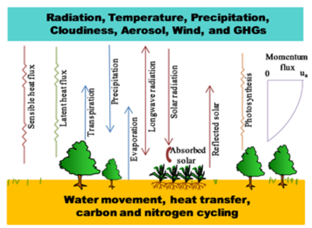
OBJECTIVES

- **To develop a fully coupled CWRF-Crop modeling system by incorporating the crop growth models into the CWRF framework, aligning their consistency in SBC data and formulations, and programing their interfaces.**
- **To evaluate the crop growth feedback to regional climate using the coupled modeling system.**

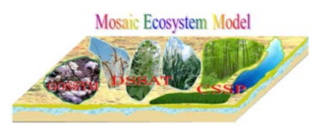
CONCLUSION

This study focuses on developing and validating a coupled CWRF-Crop modeling system, and then simulates the cotton growth feedback to regional climate using the developed modeling system. It includes the model recoding/reconstruction, interface development, physical improvement, yield validation and climate-crop interactions, all of which are made in the context of geographically distributed modeling. In particular, consistency in model formulation between new GOSSYM and CWRF is incorporated for the physical representation of vegetation and soil properties, soil temperature and moisture, evaporation and transpiration, and photosynthesis radiation. Also the optimization method is applied to determine the key parameters that lack the observational basis as distributed over the Cotton Belts through an inverse modeling. The initial standalone evaluation shows encouraging results, where modeled 1979-2005 mean yields are within $\pm 10\%$ of observations over virtually the entire Cotton Belts. The modeled yields are significantly correlated with observations at the 95% confidence level over 87% of cotton grids. This lays a solid foundation for current study on the crop growth feedback to climate. Preliminary simulated results in 1993 show that the crop growth has substantial effects on regional and local climate. Using the realistic cotton area fraction, the cotton growth will increase (decrease) surface temperature in Mississippi River Delta (U.S. Southeast and Texas), precipitation in Texas coast and U.S. Southeast (Arkansas), humidity in eastern Texas and U.S. Southeast (Arkansas). For surface albedo, because the simulated leaf and stem area index has more significant seasonal evolution and much smaller value than the prescribed one in CWRF, the surface albedo decreases over most area in U.S. Cotton Belt.

METHODS



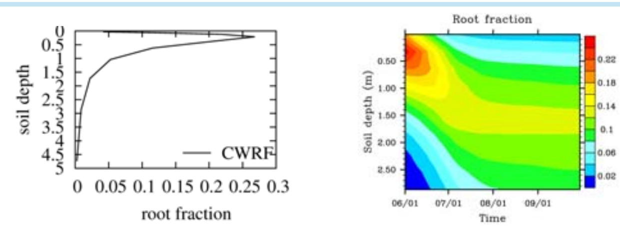
Schematic representation of surface energy and water exchange between land and atmosphere adopted from Bonan et al. (2001)



Schematic representation of the coupled CWRF-Crop modeling system and the mosaic modeling of land surface processes by crop models and the CWRF conjunctive surface-subsurface process (CSSP) model rooted from Common Land Model (CoLM)

The crop model, GOSSYM, that simulates the cotton growth, has been incorporated into CWRF as a module with programming and physical improvements as following:

- Reengineered in software by implementing the FORTRAN90 features, including modular designation, dynamic memory allocation, and derived data type.
- Incorporated the consistency of the coupled system both using same horizontal grid, the land surface properties and the computation sequence and parallelism to improve computational efficiency.
- Implemented an interactive interface with CWRF and a standalone interface with NARR reanalysis.
- Computed the soil hydrological coefficients by the soil texture and organic matter using Saxton et al. (1986, 2006).
- Implemented the biogeochemical photosynthesis model of Farquhar et al. (1980) using the latest temperature dependent parameterizations from Bernacchi et al. (2001, 2003) and the Ball-Berry stomatal conductance model (Ball et al., 1987; Collatz et al., 1991)
- Incorporated the collimations of day length and leaf nitrogen content on the photosynthesis parameters following CLM4 (Bonan et al., 2011).
- Incorporated a new automatic irrigation model on the basis of the daily water stress and potential evapotranspiration.
- Implemented the mosaic method to compute the land surface variables and land-atmosphere exchanges.
- Added an independent soil profile for crop to flexible implement the crop management practices.
- Incorporated the dynamic roughness and zero-plane displacement height parameterization from canopy width, plant height, and leaf and stem area index (Raupach, 1994; Jasinski et al., 2005).



ACKNOWLEDGEMENT

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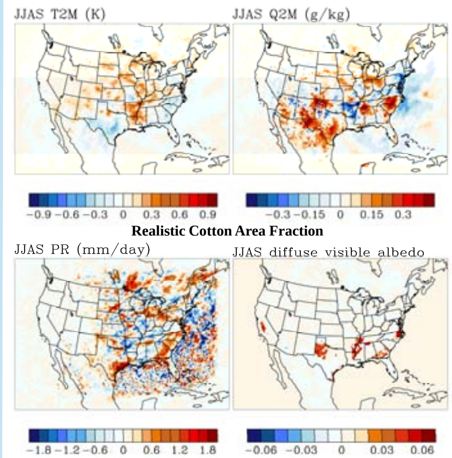
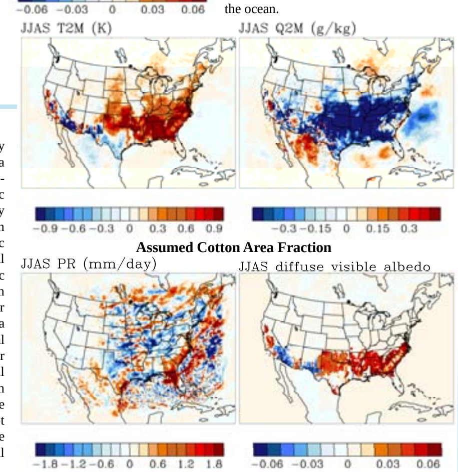
CROP GROWTH FEEDBACK TO REGIONAL CLIMATE



Realistic Cotton Area Fraction

Right is geographical distributions of differences of 2-m temperature, humidity, precipitation and surface albedo simulated with feed back and w/o feedback of crop growth by the coupled system averaged from June to September in 1993. The fraction of cotton cover in each grid is derived from USDA NASS county data. Results show that cotton growth substantially impacts regional and local climate, and their variability through altering the prescribed surface physical prosperities to accurate and dynamic simulations from GOSSYM. By incorporating the feedback of cotton growth, the surface albedo increases 0.04-0.06 in the cotton planted grids. The surface temperature has slight decrease (about -0.4 K) in U.S. Southeast and Texas and increase (0.3-0.6) in the area covered from Mississippi River Delta to Midwest. The surface humidity increases in the regions with decreased surface albedo. The precipitation is enhanced by 0.8-1.2 mm/day over U.S. Southeast, Texas coast and eastern Canada. There is no apparent trend for precipitation over the ocean.

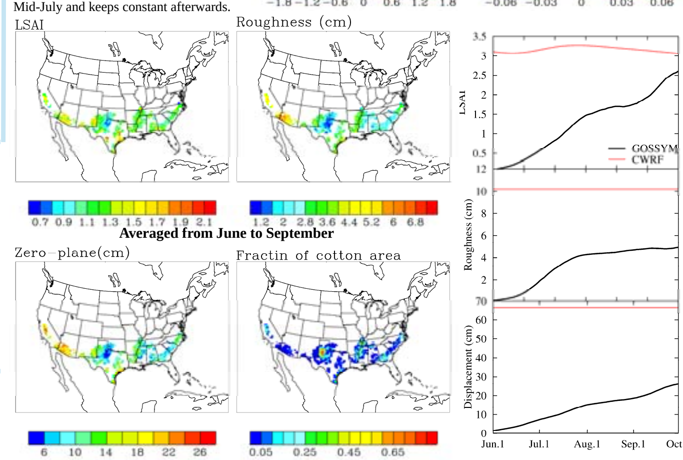
Left is same as above, except increasing the fraction of cotton cover in a grid to 100%.



Assumed Cotton Area Fraction

DYNAMIC VEGETATION

The simulated vegetation parameters by GOSSYM, including leaf and stem area index (LSAI), surface roughness, zero-plane displacement height are dynamic and evolve with the crop growth. They are much different to those prescribed in CWRF for cropland that either are static and time invariant or have weak seasonal cycle. For example, the LSAI for realistic cotton growth is nearly zero in emergence and continuously rises over the entire season because cotton is a perennial crop. The prescribed seasonal cycle of LSAI is weak and only for annual crop. The CWRF vertical distribution of root fraction is fixed with the maximum fraction at 0.5 m for the whole season, while the simulated root fraction varies with time and the maximum fraction depth deepens until Mid-July and keeps constant afterwards.



Averaged from June to September