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Effects of Crop Growth and Development on regional climate: A case study over East Asian monsoon area

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Outline

- Motivation
- Model development
- Effects of crop growth on land surface fluxes
- Effects of Crop Growth on regional climate
- Summary and discussion

A.

Motivation

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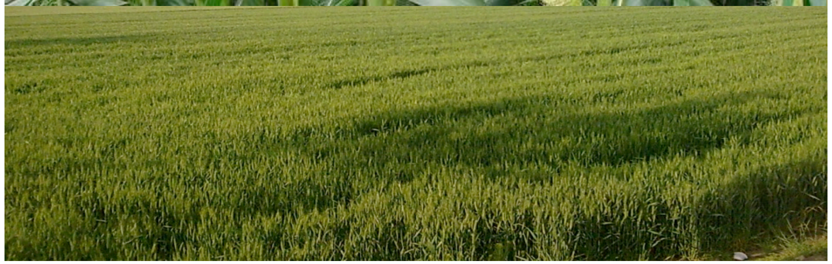
Motivation

- Agricultural crop growth and development processes play significant roles in water and energy balances, and regional climate;
- An integrated regional earth system model requires better representation of crop growth and development processes for evaluating impacts of alternative mitigation and adaptation strategies;

However

- Most of climate models do NOT consider different crop types and agricultural practices such as planting and harvesting schedules;
- do NOT consider crop phenological development.



Motivation

- To represent the interactions between regional climate and crop growth processes，the crop model **(CERES-Maize, CERES-Wheat, CERES-Rice)** was coupled to BATS, and RegCM3 ；

- The effects of crop growth and development processes on regional climate were then studied based on 20-year simulations over the east Asian monsoon area conducted.

B.

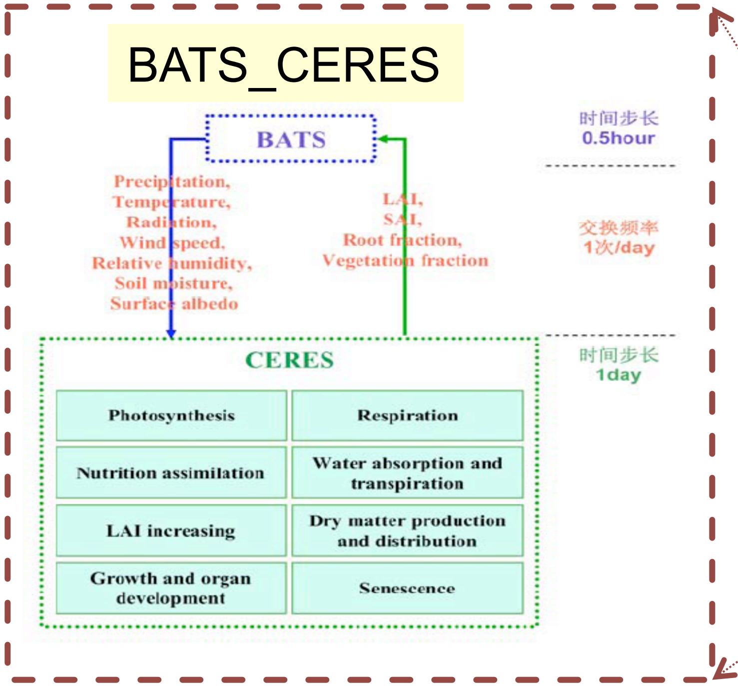
Model development

Contents

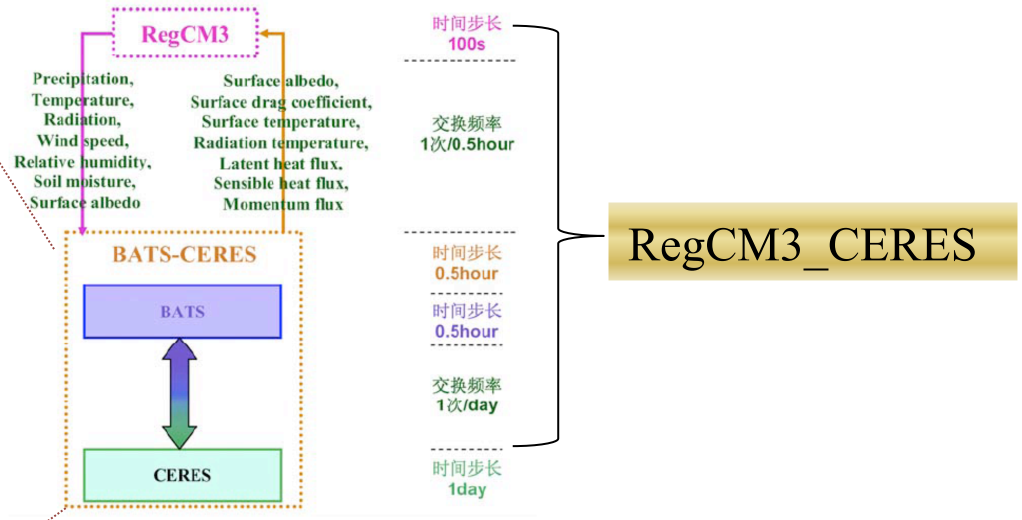
Model development

- The crop growth model CERES v3.0) was coupled into the Biosphere-Atmosphere Transfer Scheme (BATS), which is called BATS_CERES, to represent interactions between the land surface and crop development processes.

- The CERES phenological growth and development functions were implemented into the regional climate model, RegCM3 to give a model denoted as RegCM3_CERES to represent interactions between regional climate and crop growth processes.



Land surface model coupled with crop model CERES

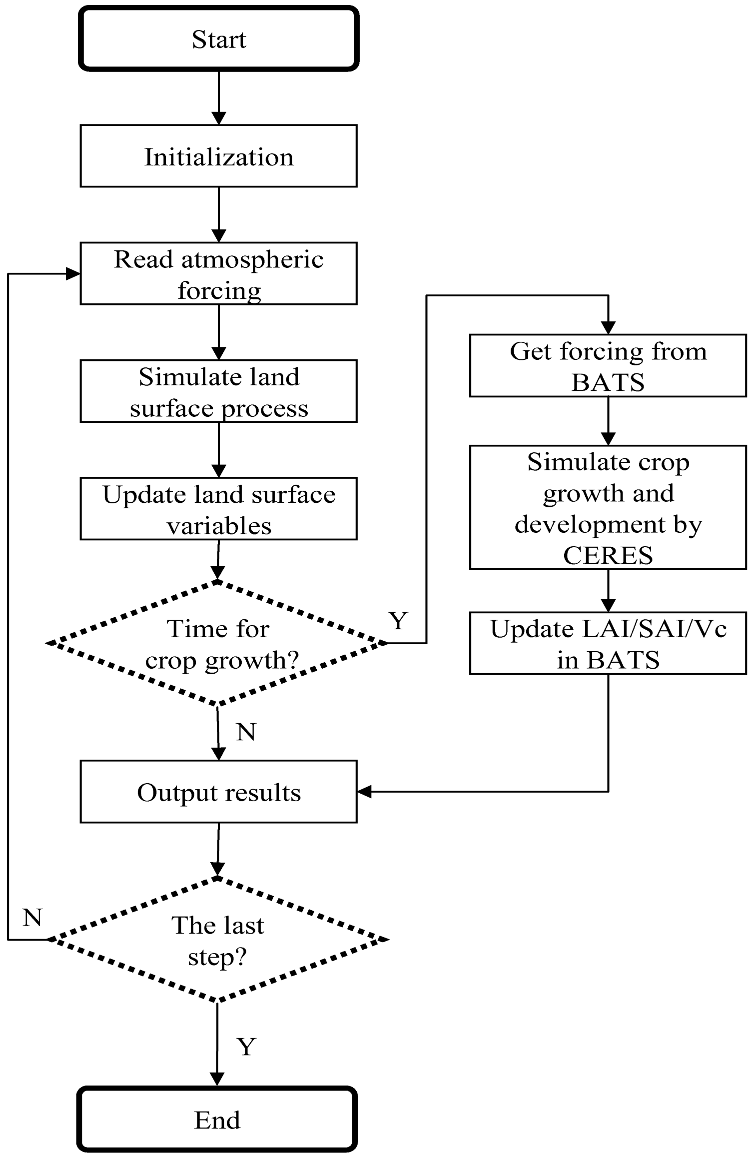


Regional climate model RegCM3 coupled with BATS_CERES i.e. RegCM3_CERES

Model development

- CERES receives weather conditions (minimum temperature, maximum temperature, radiation, etc.), surface conditions (surface albedo, etc.), soil conditions (soil moisture, etc.) from BATS, and calculates crop growth and development in a daily time step.

- BATS takes the output of CERES such as leaf area index, stem area index, root fraction as input, and simulates the surface fluxes.



Contents

C.

Effects of crop growth on land surface fluxes

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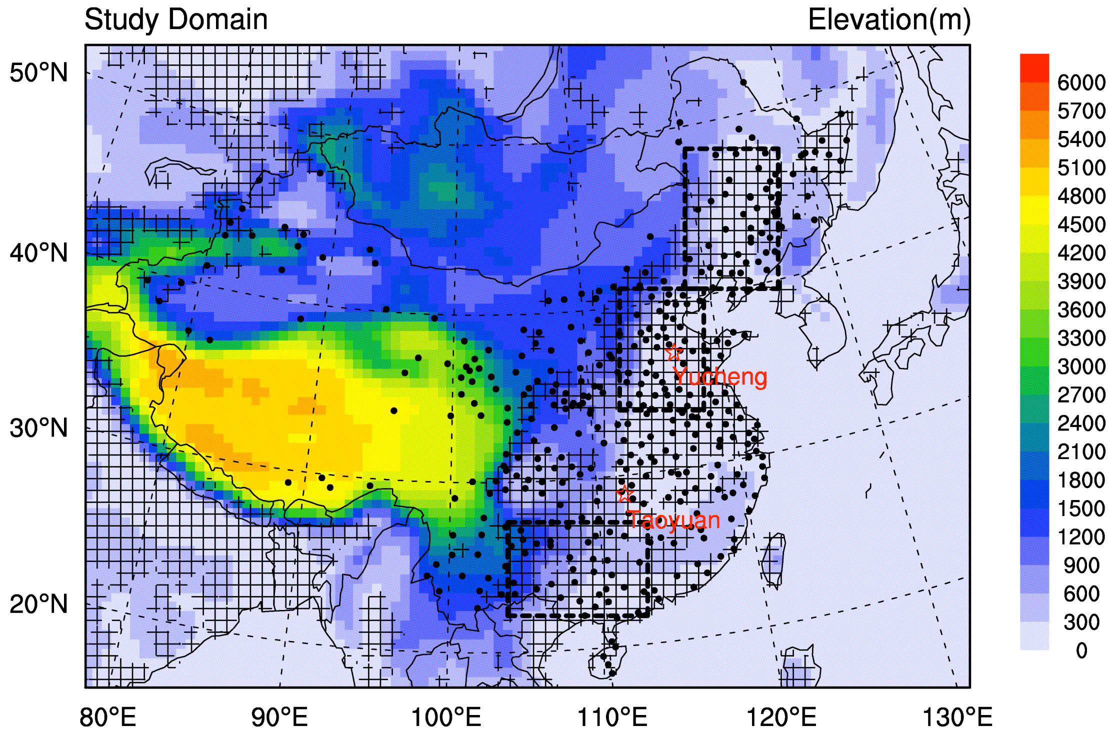
Effects of crop growth on land surface fluxes

- Two experiments were designed: CSM-run (conducted by BATS_CERES) and CTL-run (conducted by BATS).
- Each experiment was conducted from 1991-01-01 to 2004-12-31 with the time step in 30 minutes.

- Three sub-regions were selected:
  Northeast China (NE)
  North China (NC)
  South China (SC) .



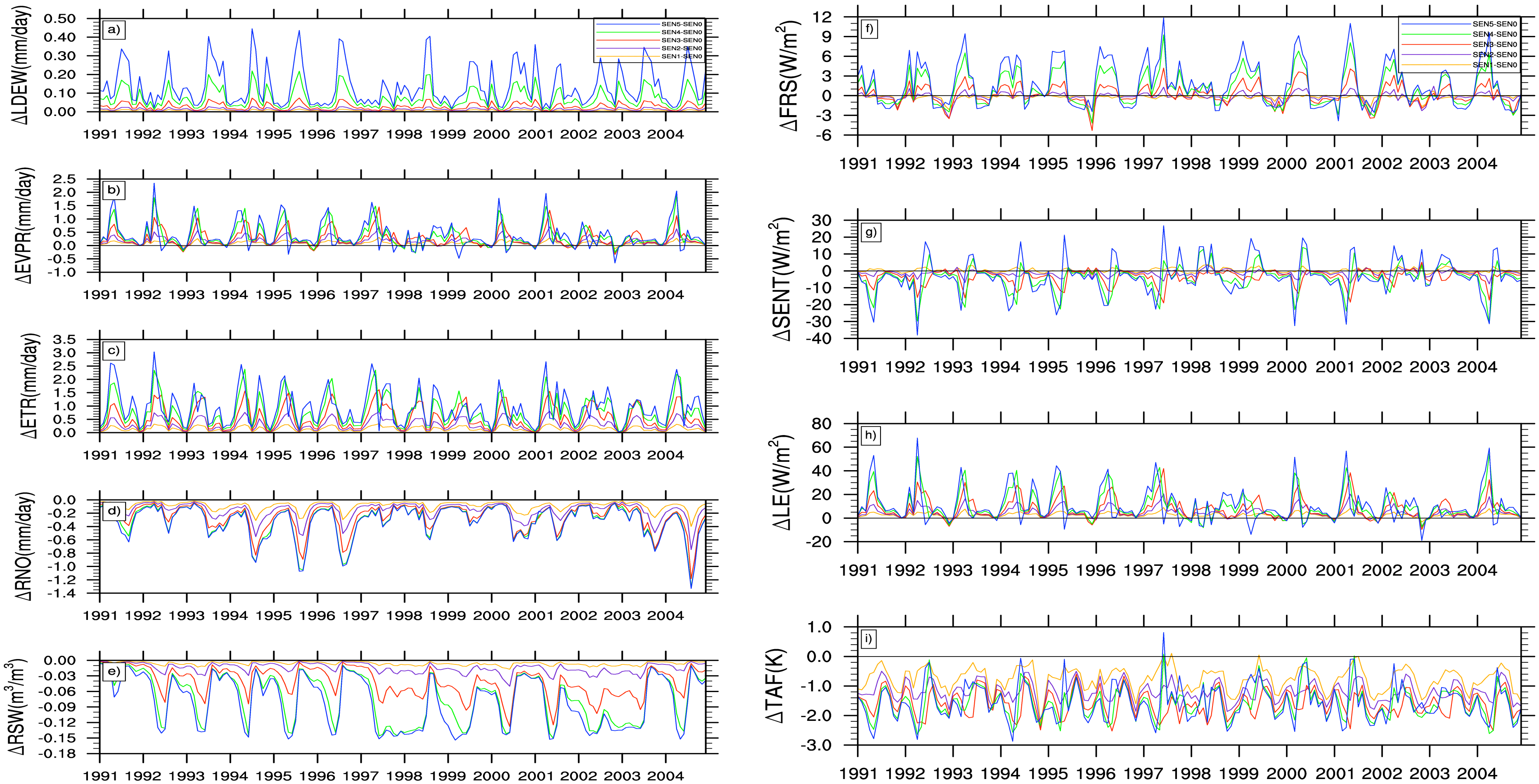
Effects of crop growth on land surface fluxes

- Six numerical experiments at YuCheng Ecological station(116°36′E, 36°57′N) were designed to test the sensitivity of BATS-simulated surface fluxes to LAI.

- For the set of experiments (SEN0-SEN5), LAI was changed incrementally from 0 (bare soil) to 6 (maximum LAI for crops in BATS).

- By comparing the results of six experiments, it is noteworthy that BATS was particularly sensitive at lower values of LAI (less than 4), which is consistent with observations.

Sensitivity of BATS's surface fluxes to LAI

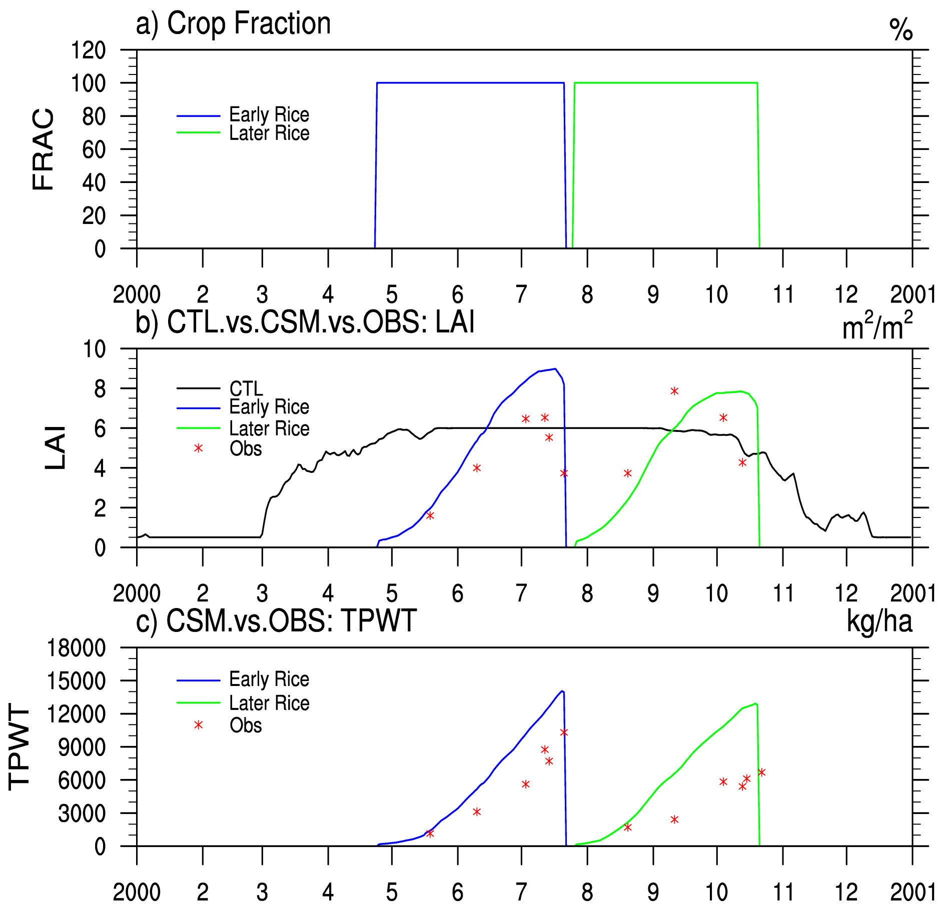


- LDEW - canopy water;
- EVPR - total evapotranspiration;
- ETR - transpiration;
- RNO - surface runoff;
- RSW - soil moisture in root zone;

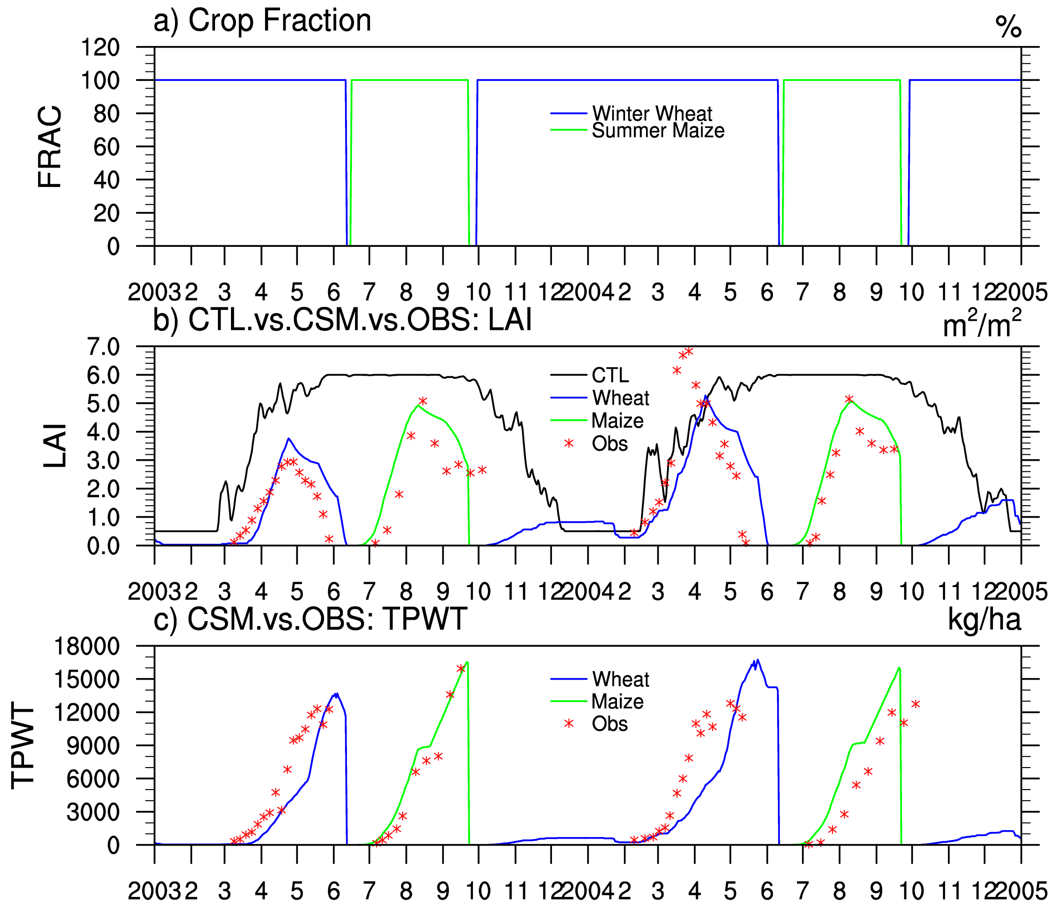
- FRS - net absorbed solar energy flux;
- SENT - sensible flux;
- LE - latent flux;
- TAF – surface temperature within foliage

Simulated and observed LAI and aboveground biomass

Taoyuan station

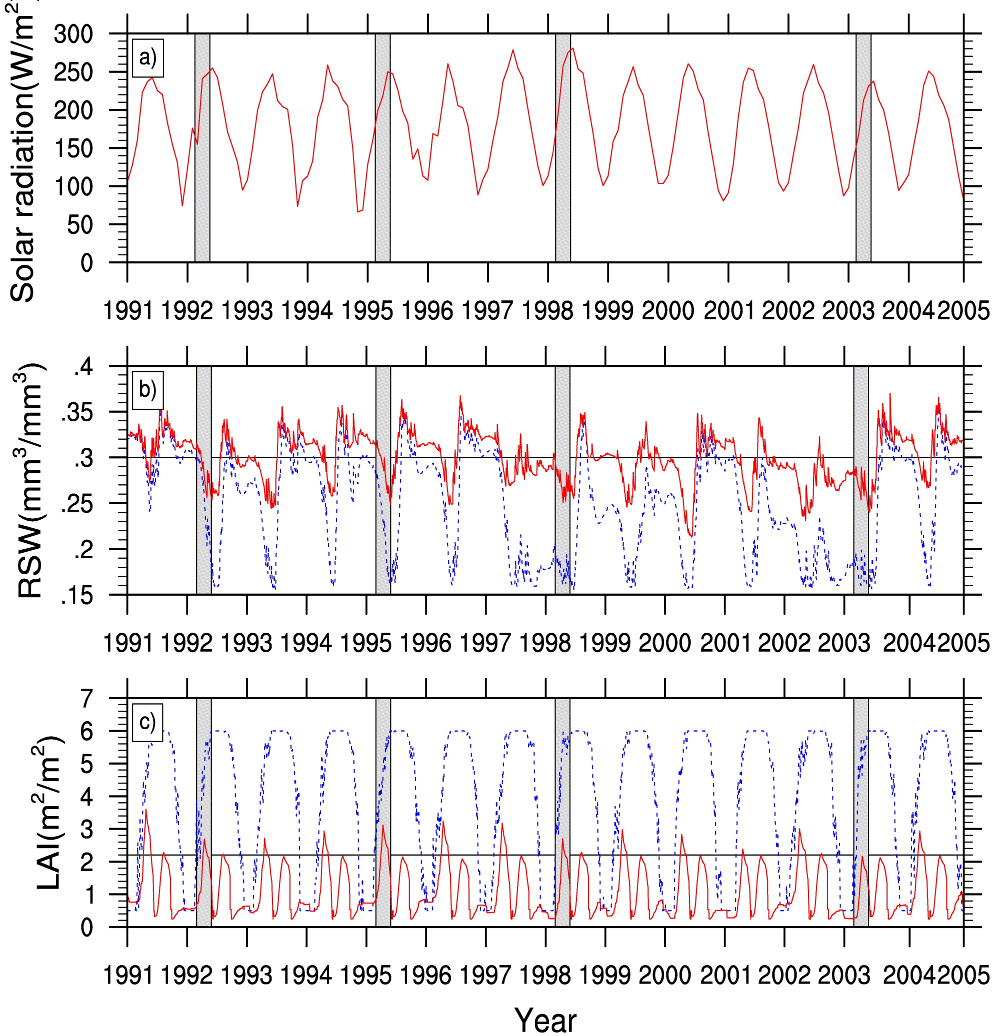


Yucheng station

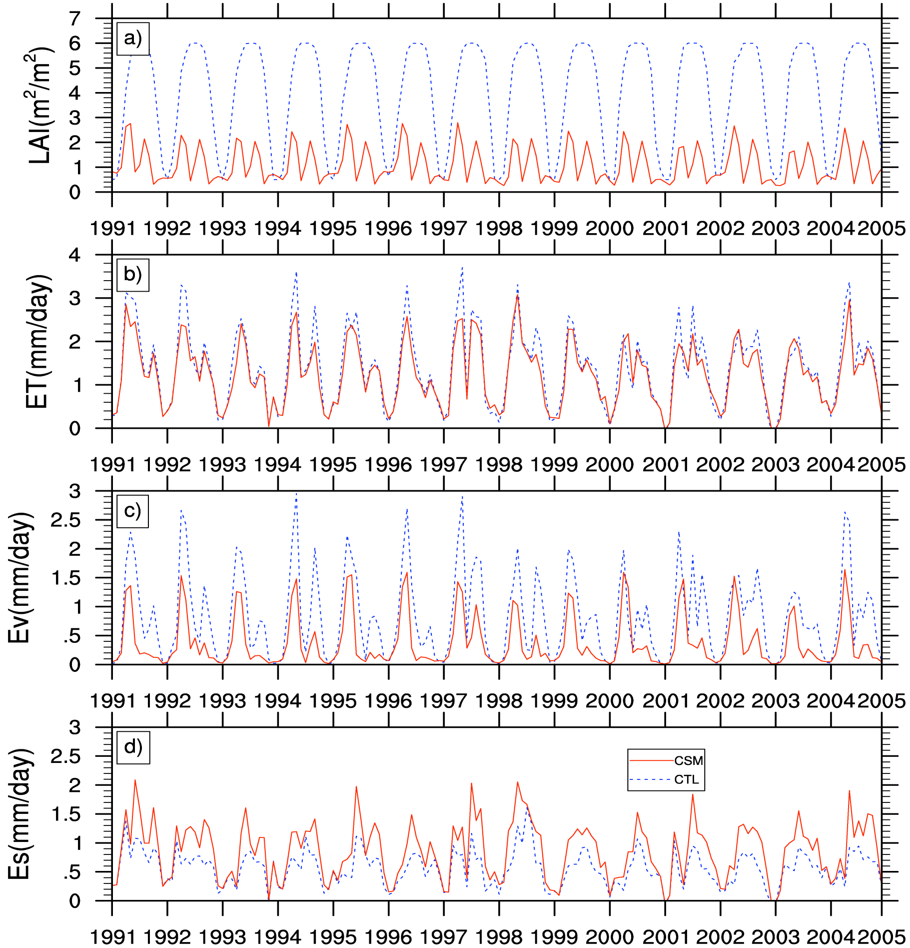


Interaction of crop and land surface in Yucheng station

- Incoming solar radiation, simulated soil moisture of root zone, and leaf area index

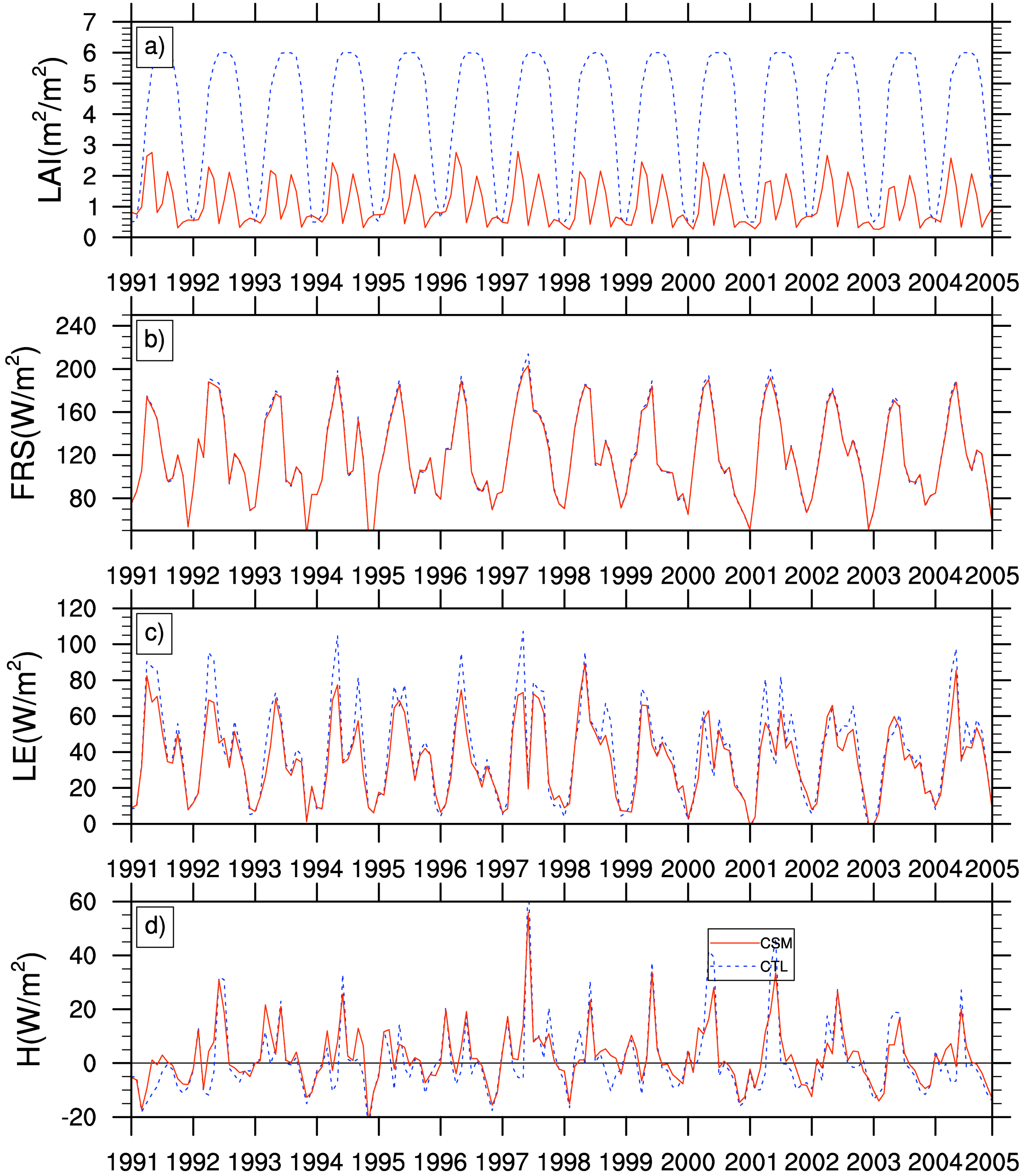


- Simulated leaf area index (LAI), evapotranspiration (ET), transpiration (Ev), and ground evaporation (Es)



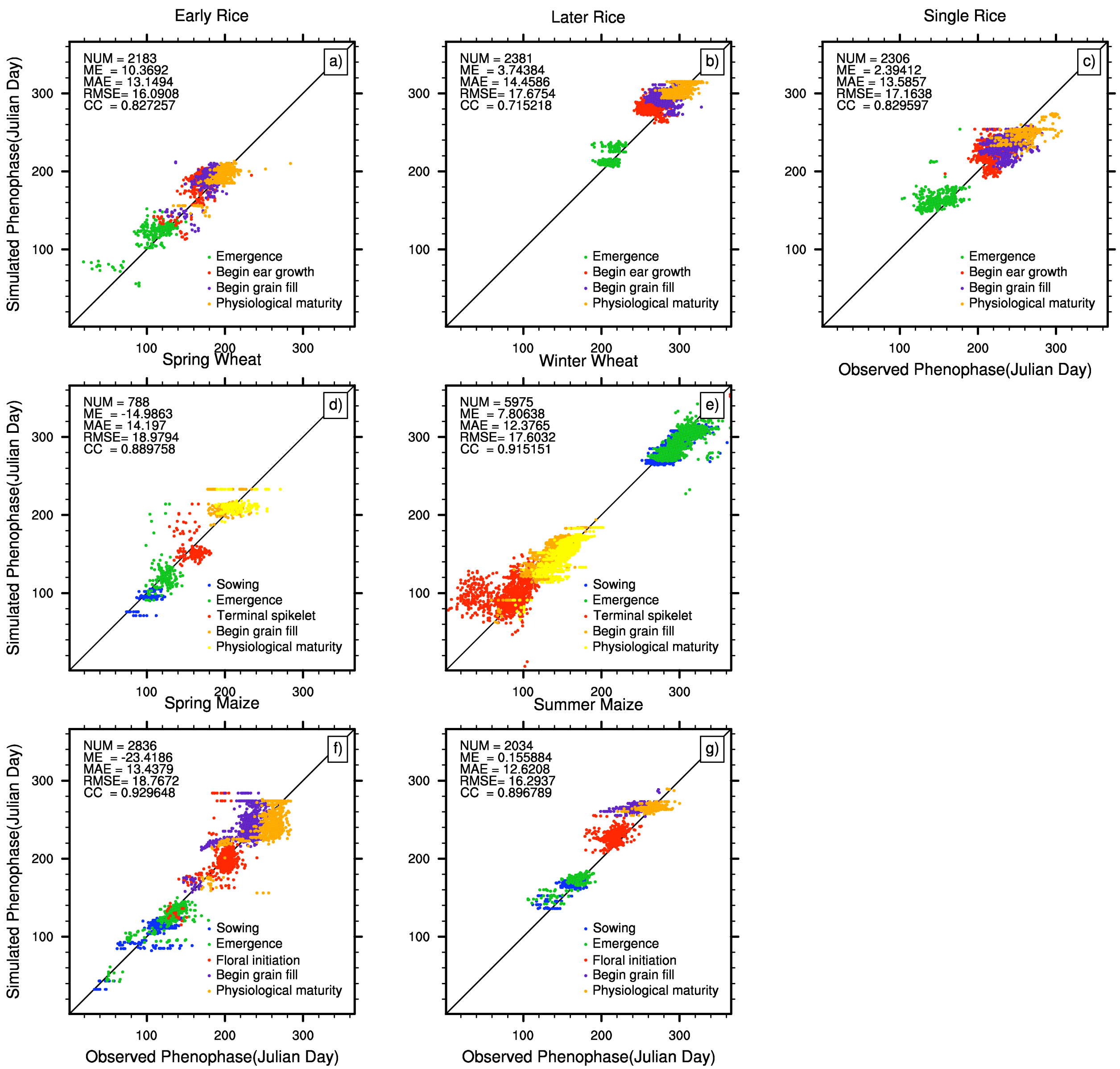
Interaction of crop and land surface in Yucheng station

- Simulated leaf area index (LAI),
- Net absorbed solar energy flux (FRS), latent heat flux (LE);
- Sensible heat flux(H)



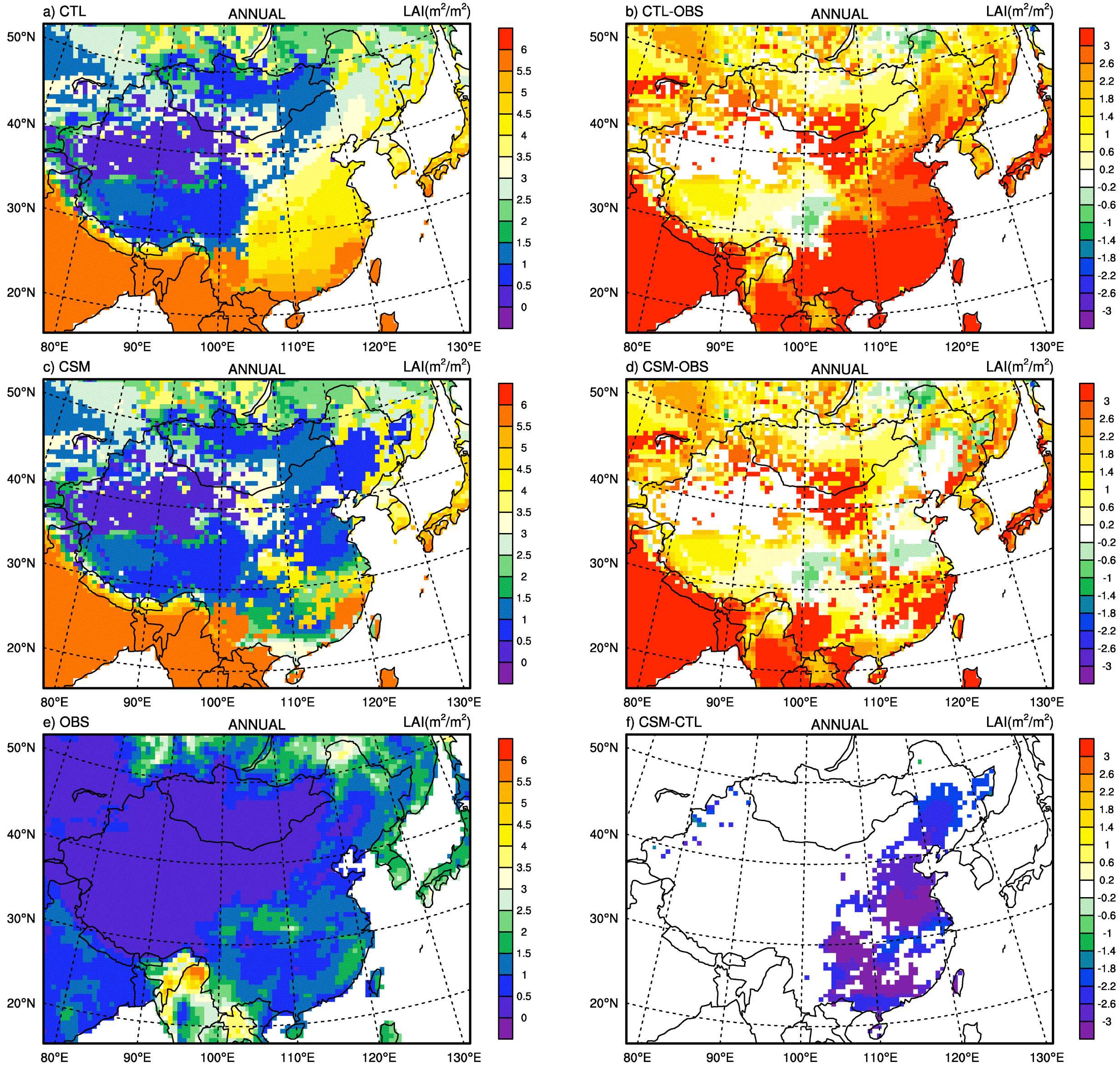
Effect of crop growth on surface fluxes in China

- Comparison of simulated and observed phenological date of main crops in China (early rice, later rice, single rice, spring wheat, winter wheat, spring maize, and summer maize);
- It was shown that it represents the crop growth and development process accurately, and matched the observed data well.



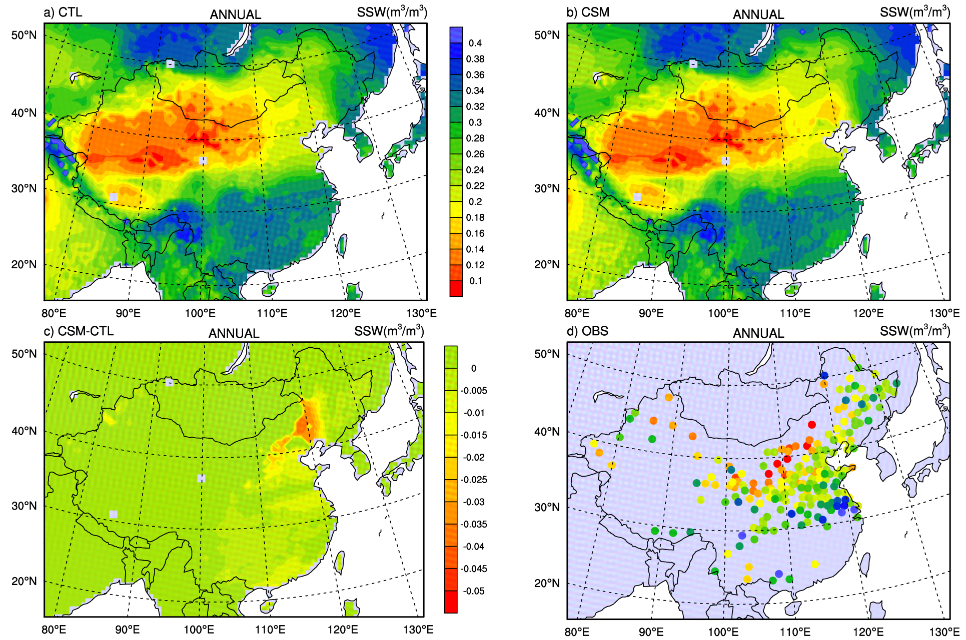
Effect of crop growth on surface fluxes in China

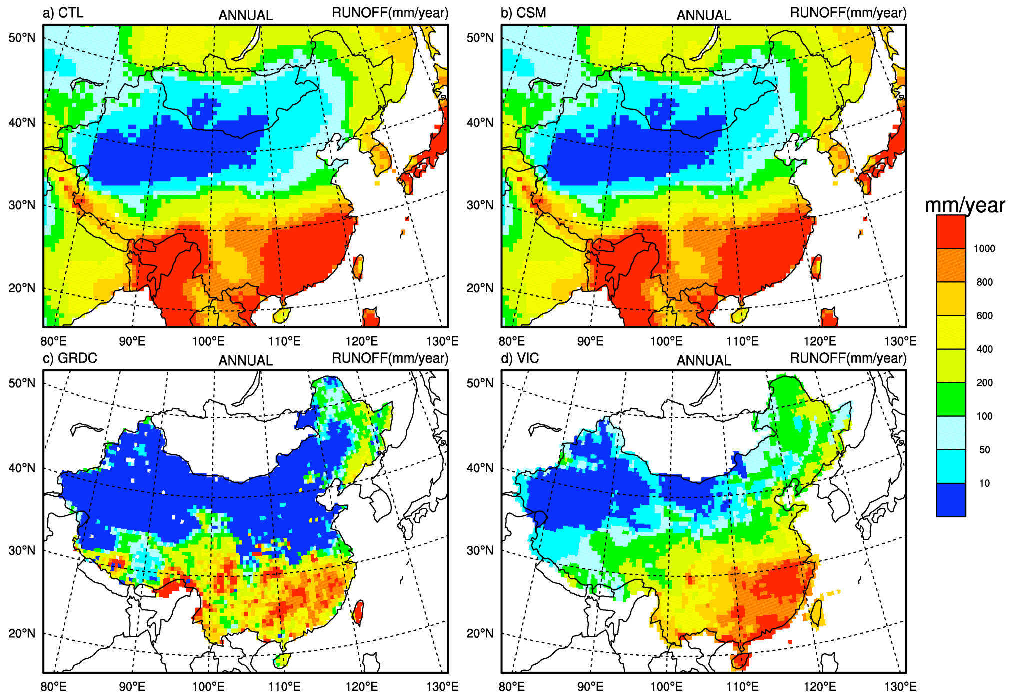
- Simulated and observed mean annual LAI and their differences in China (CTL-control run, CSM-coupled run, OBS-MODIS observation)



Effect of crop growth on surface fluxes in China

- Mean annual soil moisture (0-10cm) and their differences in China (CTL-control run, CSM-coupled run, OBS-observation data)



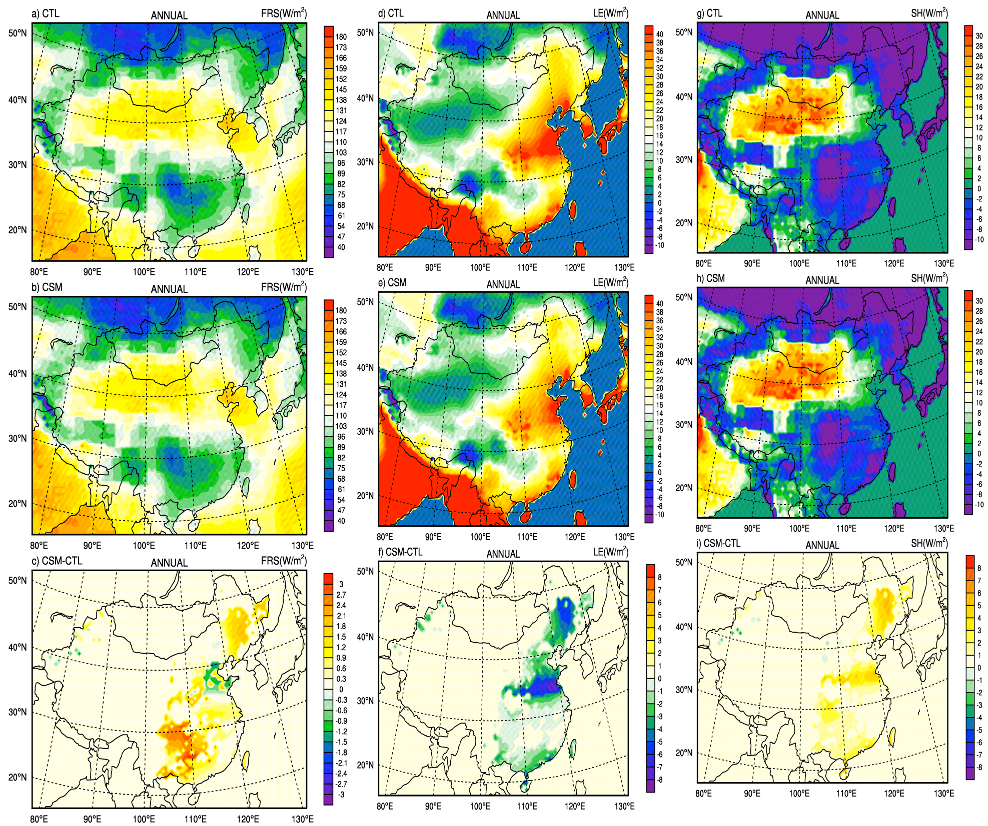


- Mean annual runoff in China
- (CTL-control run, CSM-coupled run, GRDC-observation from GRDC data, VIC-results from VIC-3L model)

Effect of crop growth on surface fluxes in China

- The coupled land surface model could capture the responses of crop growth and development to incoming solar radiation, soil moisture, temperature, etc., and the feedback of crop growth and development to land surface processes.
- The decrease of leaf area index and fractional vegetation cover leaded to less canopy interception, vegetation transpiration, total evapotranspiration, top soil moisture, and more soil evaporation, surface runoff, root zone soil moisture.
- These changes were accompanied by increasing latent heat flux and decreasing sensible heat flux in the cropland region.

- Mean annual net absorbed solar energy flux (FRS), latent heat flux (LE), and sensible heat flux (SH) in China (CTL-control run, CSM-coupled run)



D.

Effects of Crop Growth on Regional Climate

Contents

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Simulation by RegCM3_CERES

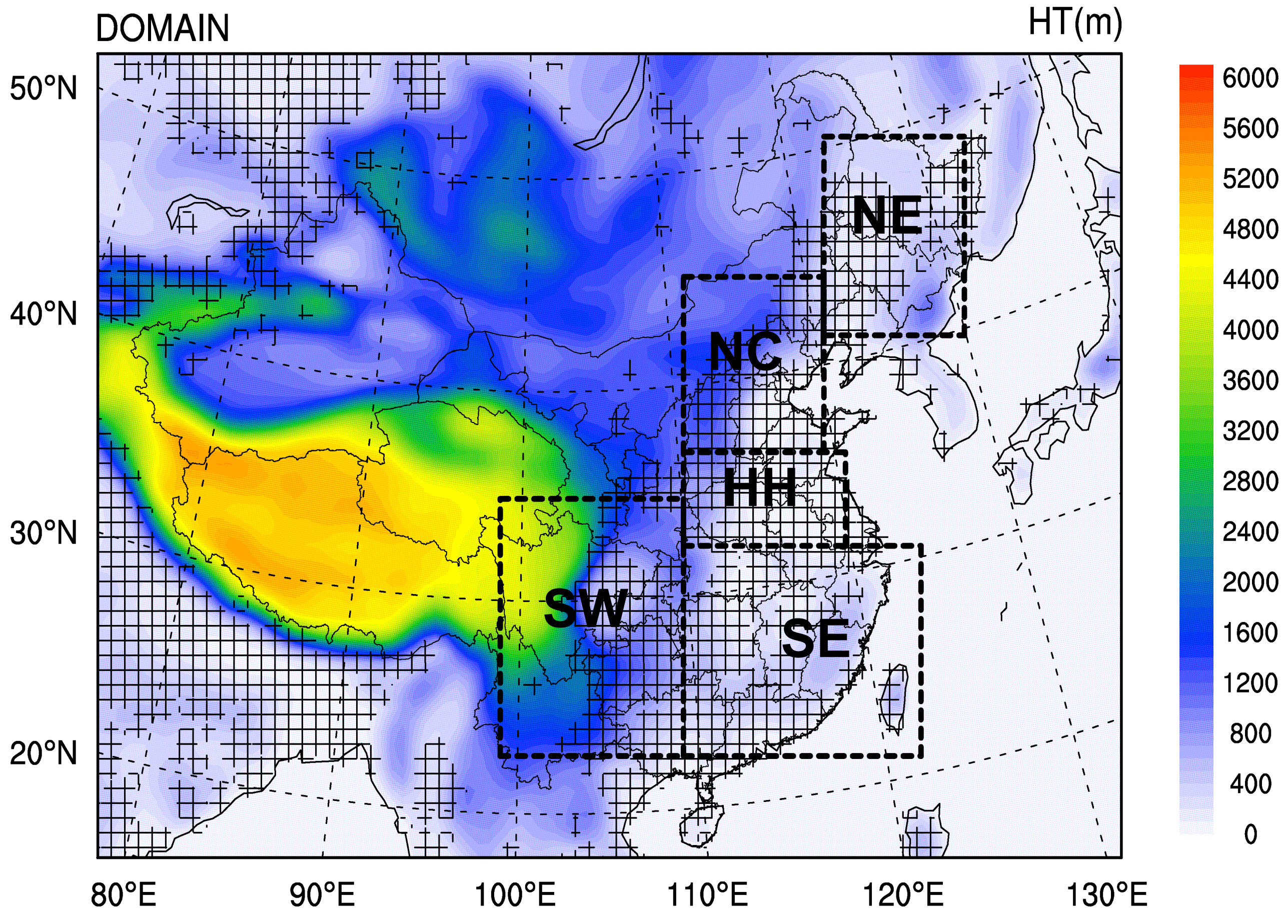
- Horizontal resolution : 60 km， 120x90 grid points
- Lateral boundary conditions: ERA40 and OISST
- Two simulations:

Two simulations :

1) RegCM3 (CTL);
2) RegCM3_CERES(CSM).

■ Both experiments were conducted from 1982-01-01 to 2001-12-31 with a time step of 180 seconds

■ The first year was used for spin-up



Precipitation

■The mean precipitation and its error in JJA:

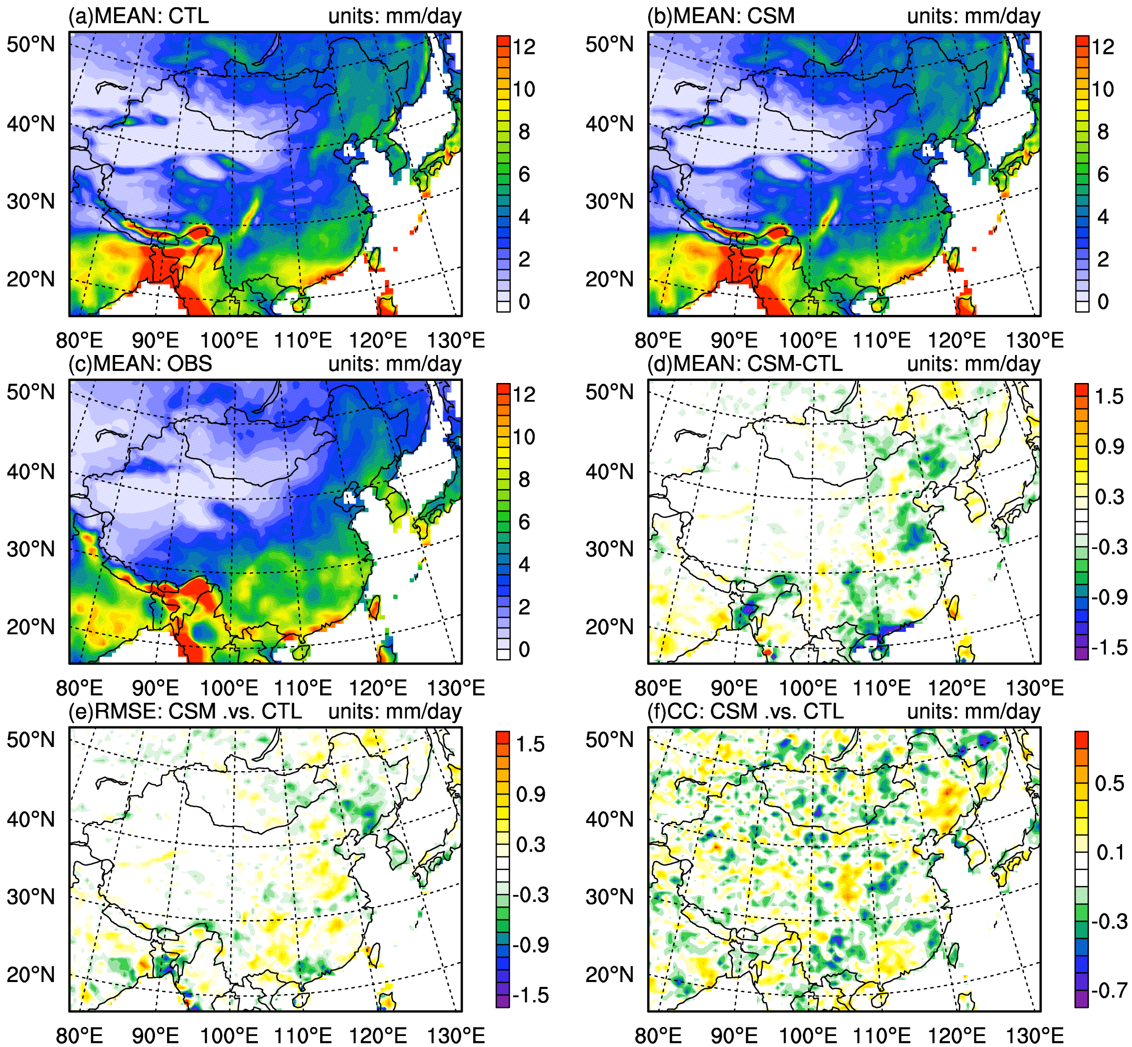
◆(a-c) mean precipitation for CTL-run, CSM-run, and observation;

◆(d) the differences between CSM-run and CTL-run;

◆(e) the differences in Root Mean Square;

◆(f) the differences in Correlation Coefficient

■The RegCM3_CERES alleviated the overestimation in northeast China (especially in sub-region NE and NC).



Temperature

The 2m temperature and its error in JJA:

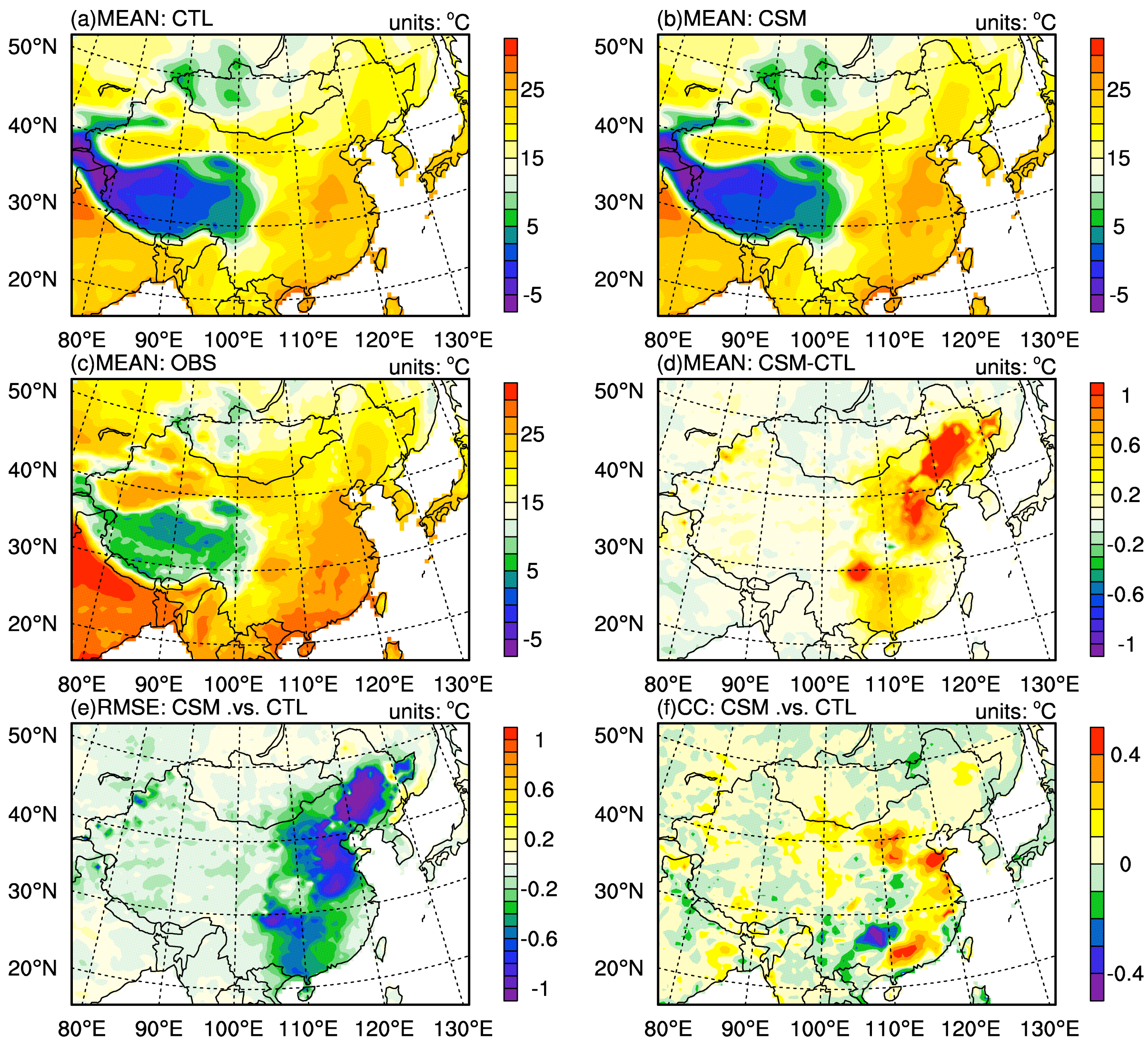
■(a-c) mean 2m temperature for CTL-run, CSM-run, and observation

■(d) the differences between CSM-run and CTL-run;

■(e) the differences in Root Mean Square;

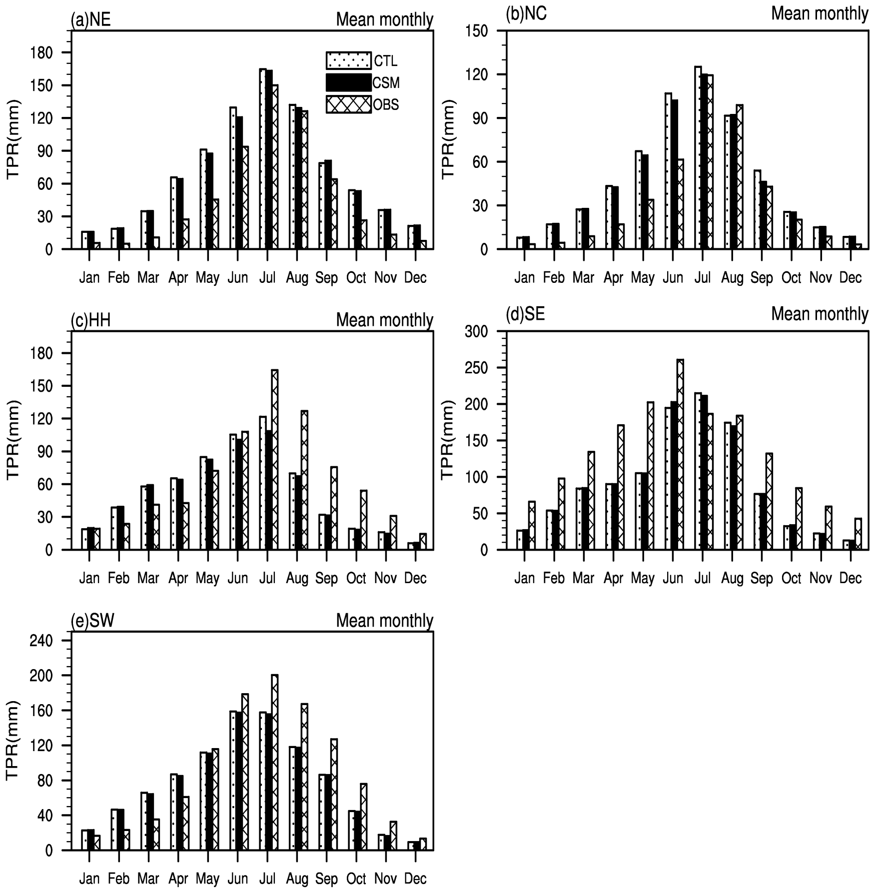
■(f) the differences in Correlation Coefficient

Alleviated the underestimation obviously, especially in the cropland of east China.

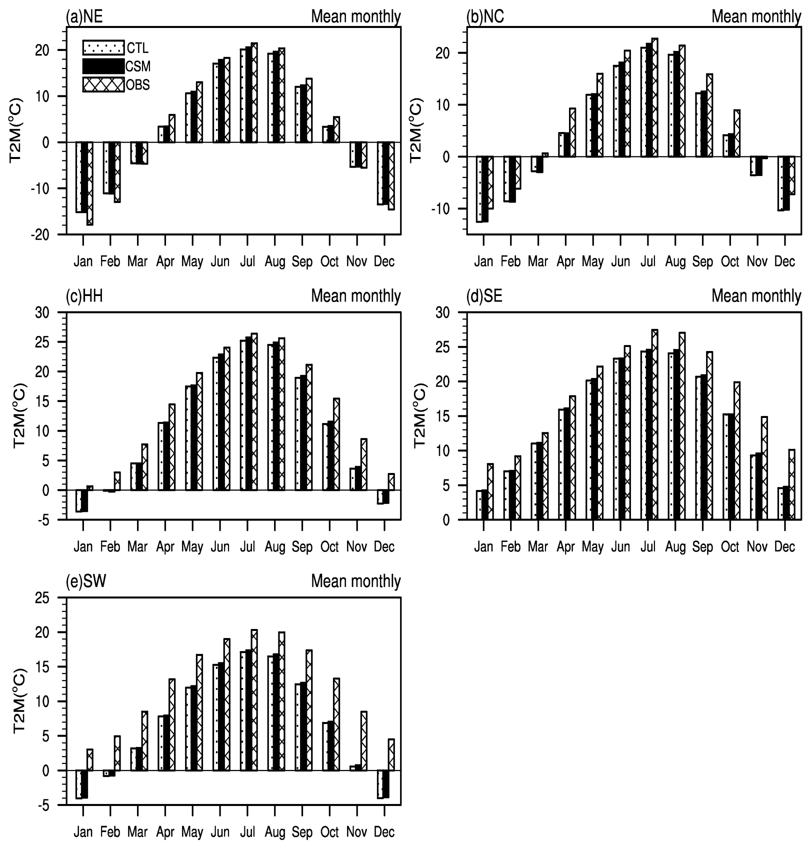


Mean annual monthly precipitation for sub-regions

Precipitation



Temperature



RegCM3_CERES had a better performance during most months than the RegCM3 over all five sub-regions. The largest improvement appeared between May and October over sub-region NE and NC, while appeared between May and November over sub-region HH, SE, and SW.

Effect of crop growth on regional climate

Mean differences between the CSM run and CTL run in JJA:

■(a) LAI - leaf area index (b) RSW - root zone soil moisture

■(c) LE - latent heat flux

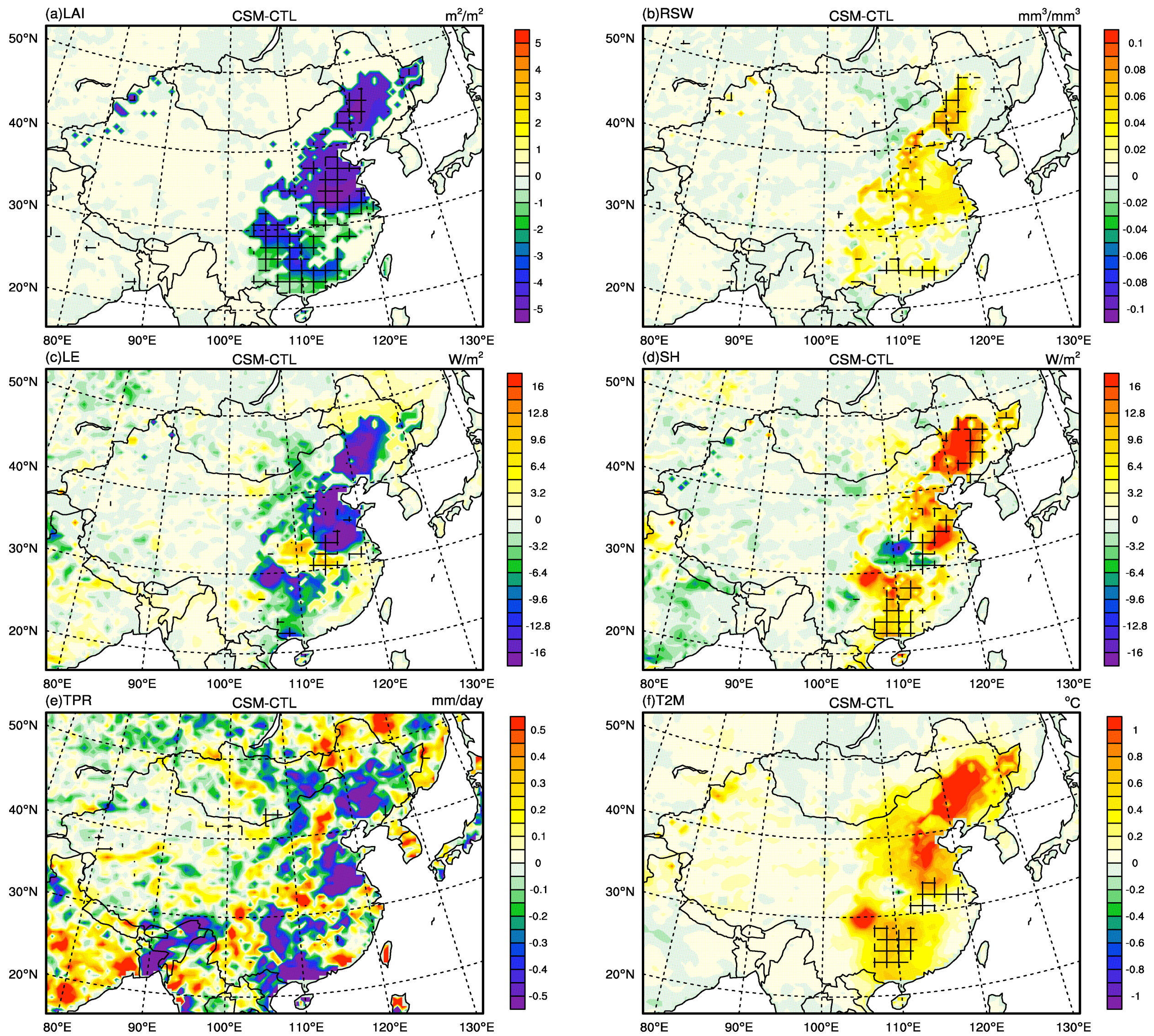
■(d) SH - sensible heat flux

■(e) TPR – total precipitation

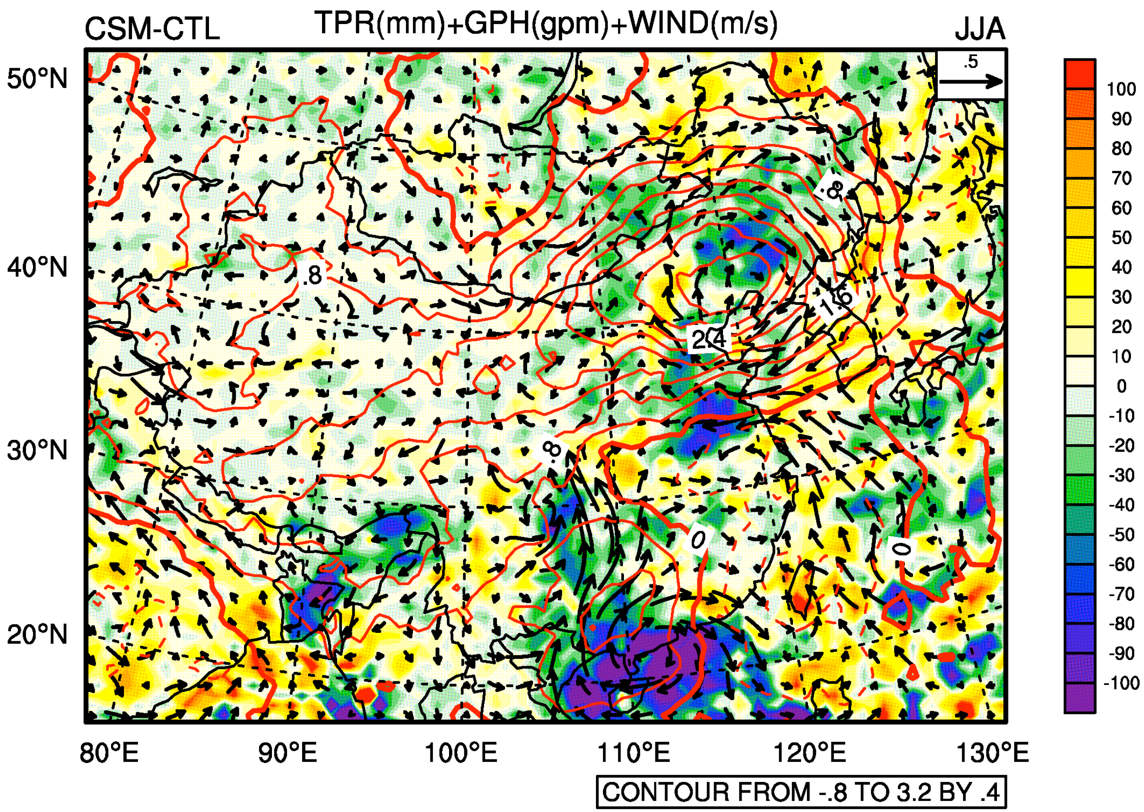
■(f) T2M - 2m mean air temperature

■The differences in leaf area index mainly appeared in the monsoon region in eastern China, where has widely distribution of cropland.

■Corresponding to decrease in leaf area index, the largest differences in root zone soil moisture, latent heat flux, sensible heat flux, and 2m mean air temperature also occurred in the monsoon region in eastern China



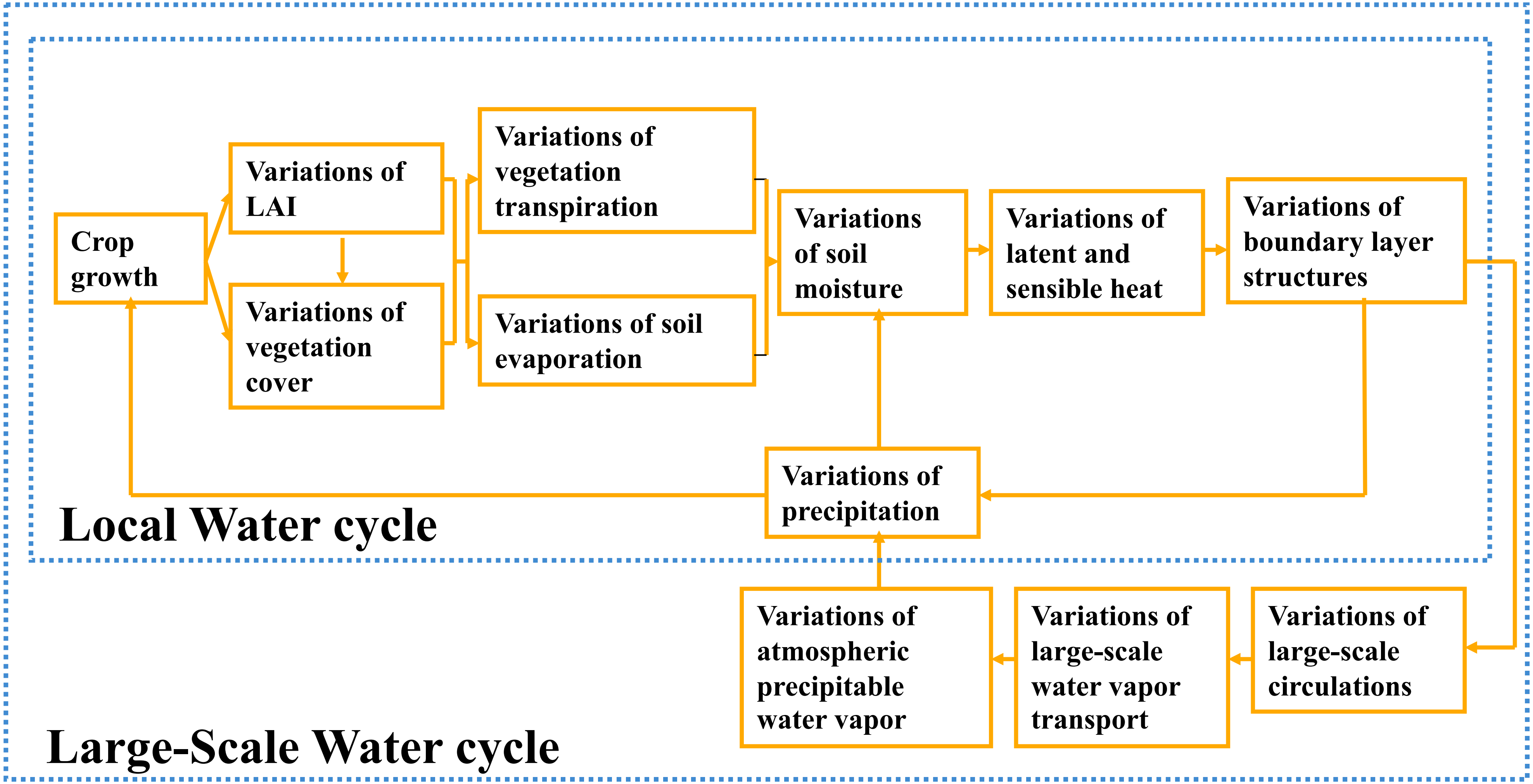
Effect of crop growth on regional climate



Mean differences in total precipitation, 500hPa geopotential height and 850 hPa wind between the CSM and CTL run in JJA.

There were two positive anomaly center of 500 hPa geopotential height located at Liaoning and Guangxi provinces, and a negative one located at Taiwan province. These anomalies enhanced the southerly wind of Qinling Mountain and brought more water into this region.

Effect of crop growth on regional climate



■Chen, F., and Z. Xie (2011), Effects of Crop Growth and Development on Land Surface Fluxes, *Advances in Atmospheric Sciences,* DOI: 10.1007/s00376-010-0105-1.

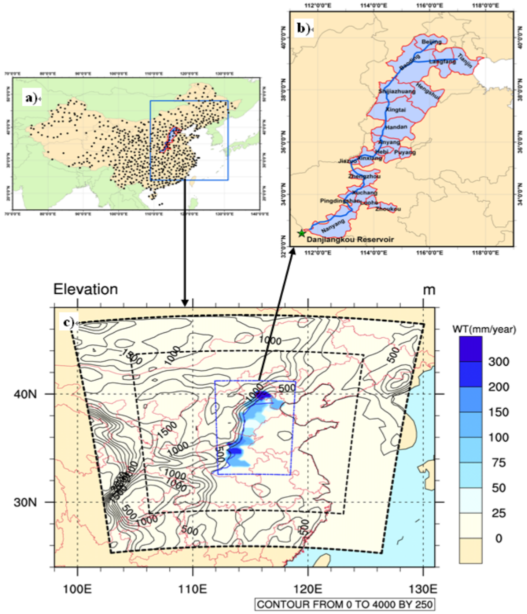
■Chen, F., and Z. Xie (2011), Effects of Crop Growth and Development on Regional Climate：A case study over east Asian monsoon area, Climate Dynamics, DOI 10.1007/s00382-011-1125-y.

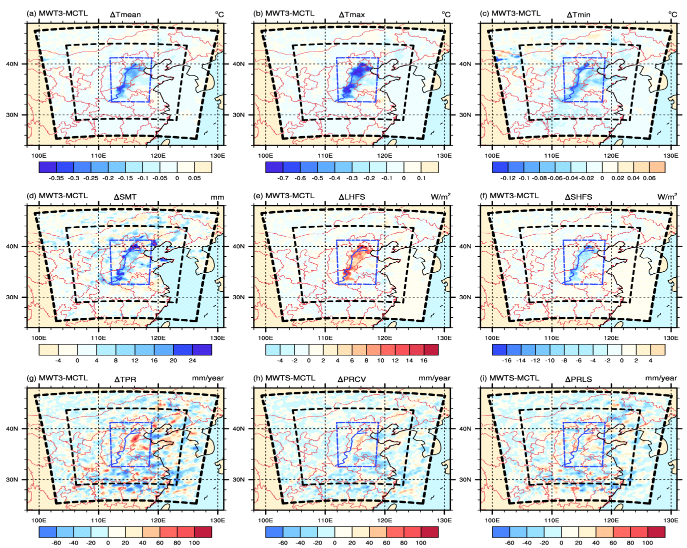
Summary and discussion

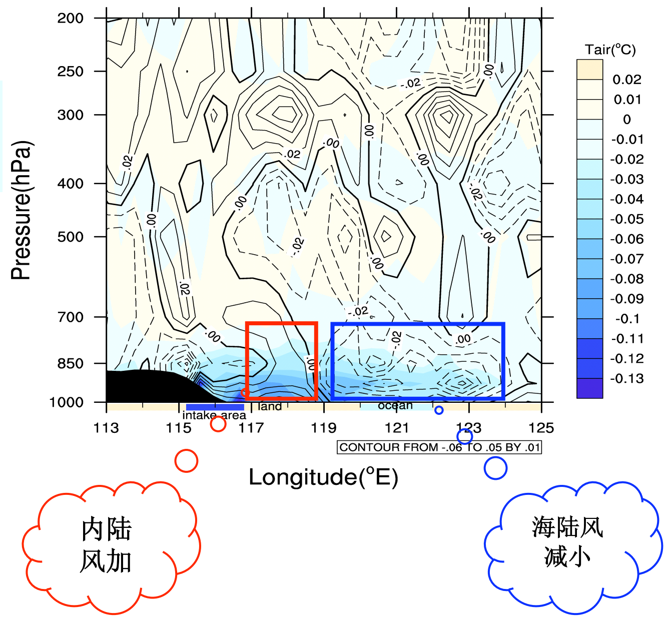
- The CERES phenological growth and development functions into the RegCM3/BATS configuration to investigate the effect of crop growth and development on land surface fluxes and regional climate;
- We found a 5.7%-11.8% decrease in the systematic error of precipitation simulation over north China, and a 3.2%-41.0% decrease in the systematic error of temperature simulation over the monsoon region in eastern China;
- These findings suggested that it is necessary to incorporate the crop growth and development processes into a regional climate model;
- A representation of seasonal changes in plant growth and development in RCM changed the surface heat and moisture fluxes through modifying the vegetation characteristics;
- The variations in leaf area index and fractional vegetation cover changed the distribution of evapotranspiration and heat fluxes, which led to anomalies in geopotential height, and consequently influenced the overlying atmospheric circulation;
- These changes will redistribute the water and energy through advection.

Interbasin water transfer, groundwater on regional climate

Effects of interbasin water transfer on regional climate







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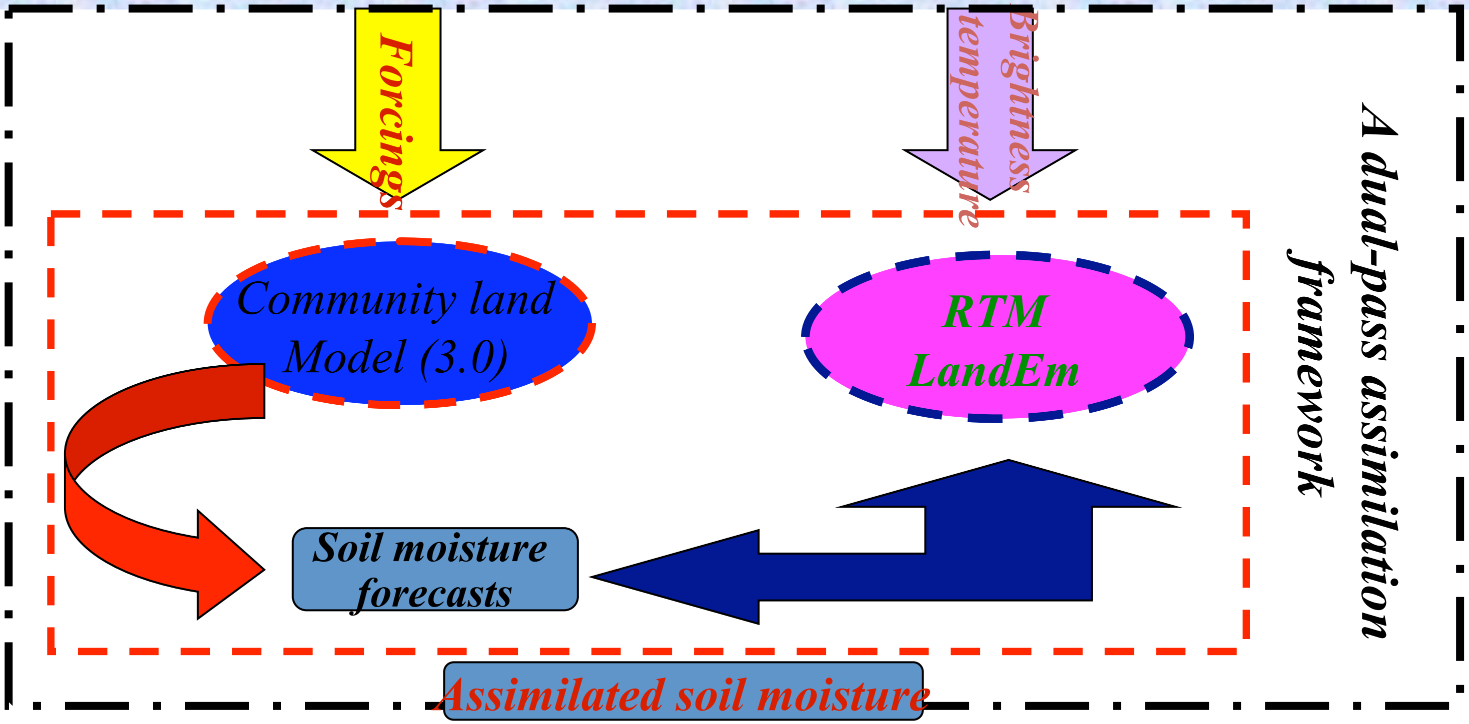
Effects of Water Table Dynamics on Regional Climate

The Global Microwave Land Data Assimilation System of IAP/CAS (GLDAS-IAP)



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THANKS

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