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Neglecting irrigation contributes to summertime warm-and-dry biases in climate model in the central United States

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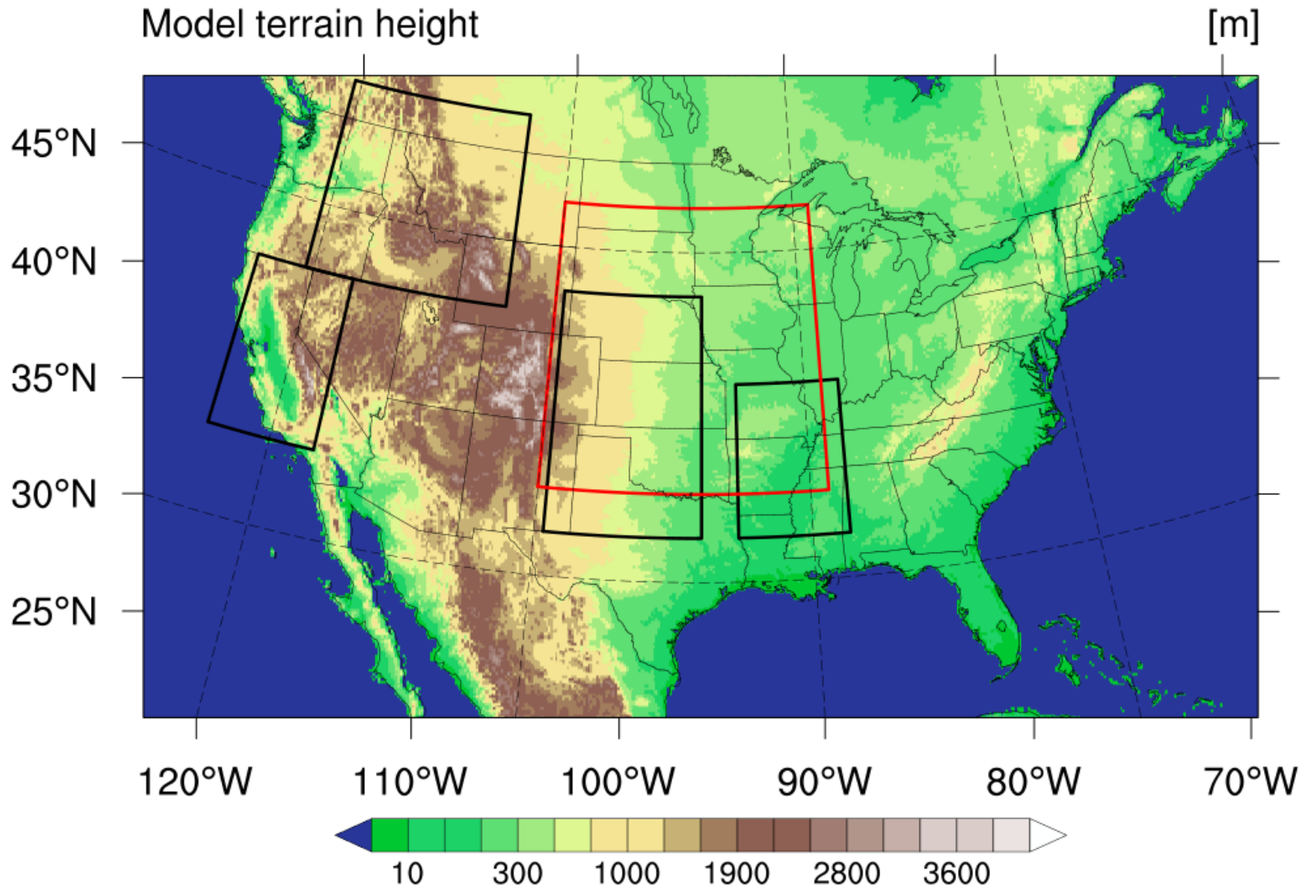
Motivation

- A vast number of weather forecast and climate models have a common warm-and-dry bias, accompanied by the underestimation of evapotranspiration and overestimation of surface net radiation, over the central U.S. during boreal summer.
- Various theories have been proposed to explain this bias, but no studies have linked the bias with the missing representation of human perturbations, such as irrigation.
- Total irrigation withdrawals account for 42% of total freshwater withdrawals and over 80% of water consumptive use is for irrigation purposes in the US in 2015.
- Here we argue that the neglecting irrigation's impact contributes to the longstanding warm-and-dry bias over this region.

Model Configuration



Configuration

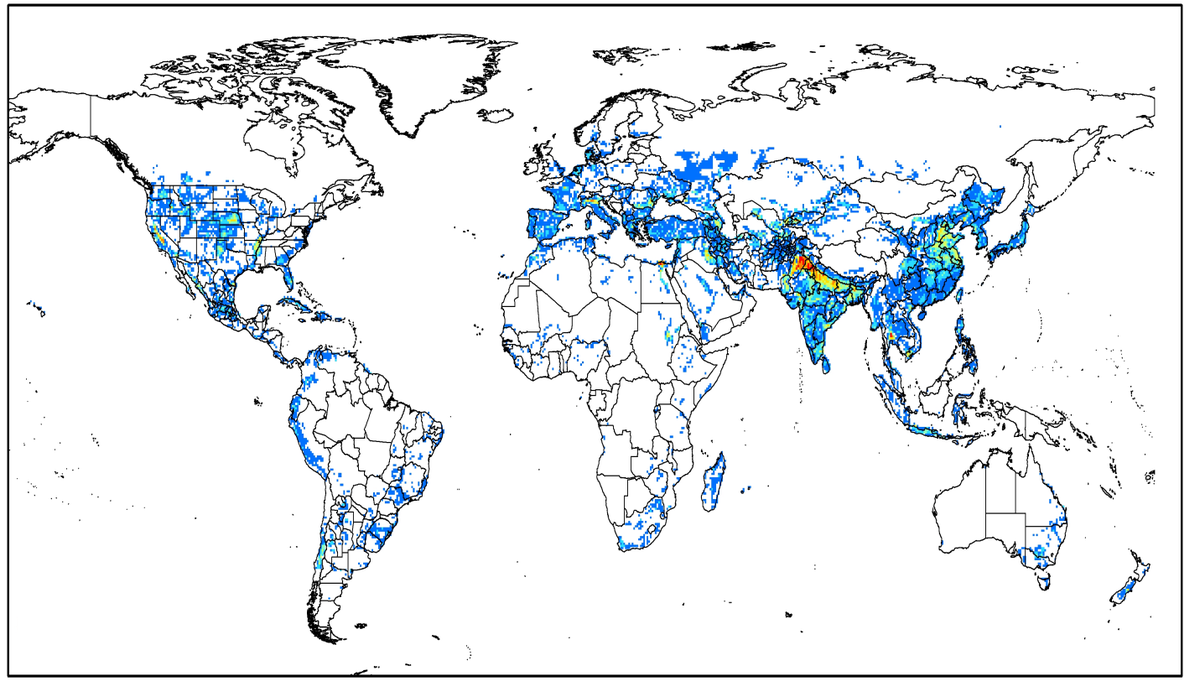
Version: WRF 3.8.1
Microphysics: Thompson
Radiation: RRTMG
PBL: MYNN
Land-Surface: NOAH
Horizontal Resolution: 4 km
Reanalysis data: ERA interim

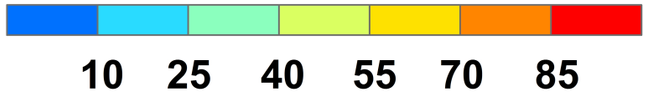
Simulation periods:
March 15 – Oct 31, 2011
March 15 – Oct 31, 2012

Irrigation Scheme and Input Data

(Qian et al., 2013)

Fraction of total area irrigated (%)





http://www.fao.org/nr/water/aquastat/irrigationmap/index.stm

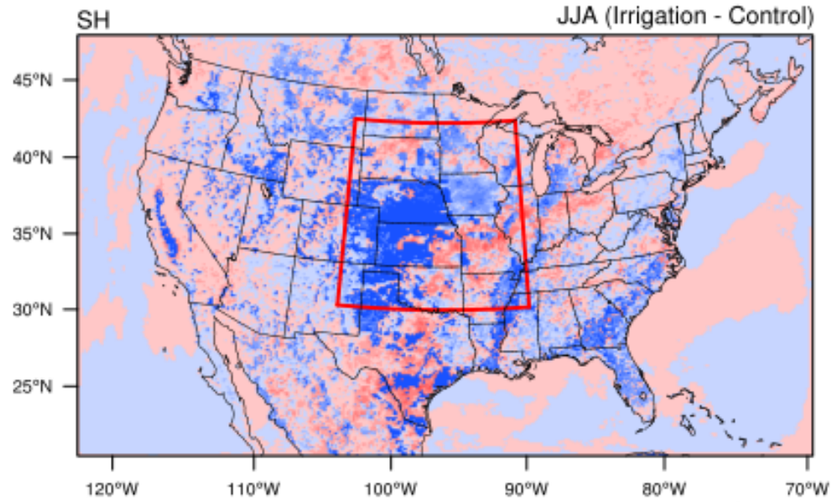
- ✓ Incorporated an irrigation scheme into the Noah land surface model as part of WRF.
- ✓ Integrated the FAO potential irrigation area data into the model.
- ✓ Irrigation is triggered when root-zone soil moisture availability (MA) is below a specific threshold (e.g. 50%) over croplands or pastures during the growing season (Apr – Sep) from LST 6am - noon.

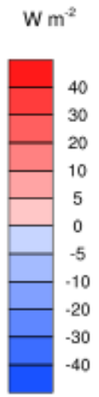
✓ $$MA = \frac{SM - SM_{WP}}{SM_{FC} - SM_{WP}}$$

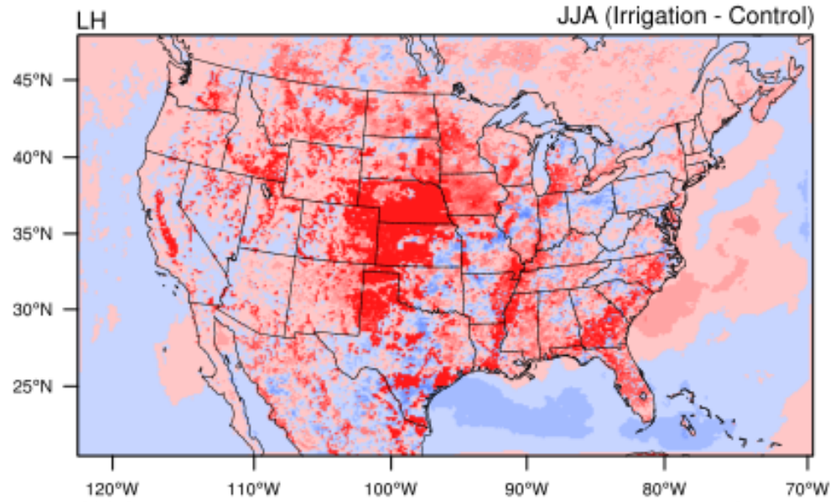
where SM is current root-zone soil moisture, SM_{WP} and SM_{FC} are soil wilting point and field capacity, respectively

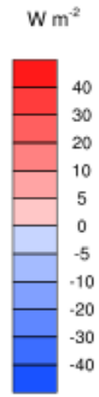
Irrigation-induced Surface Flux and Moisture Changes

SH



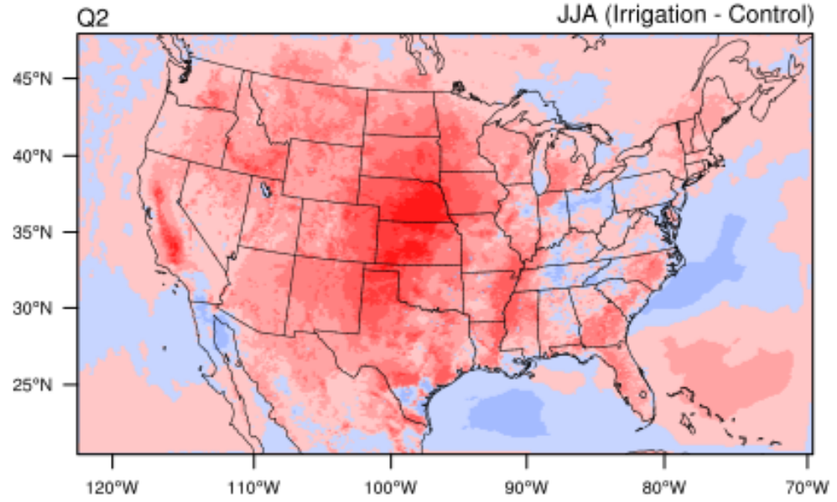


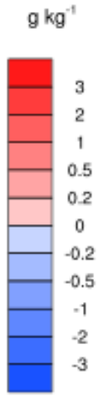


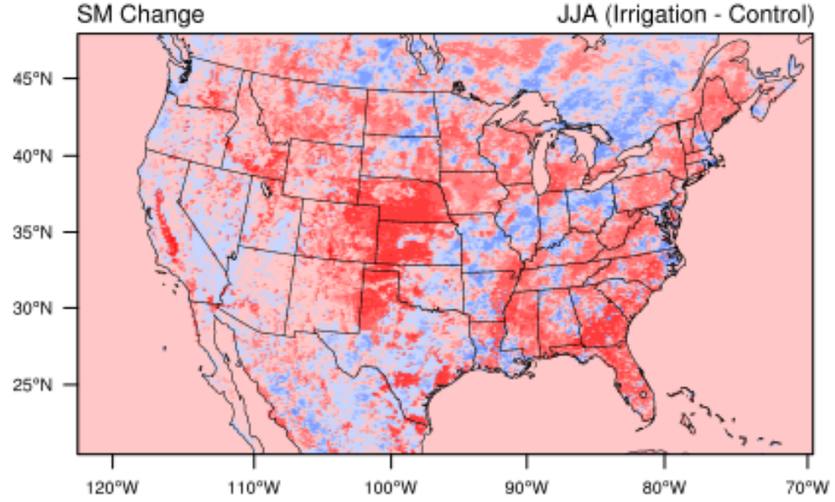


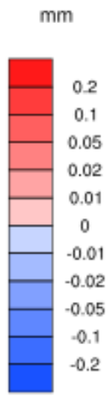
LH

Q2





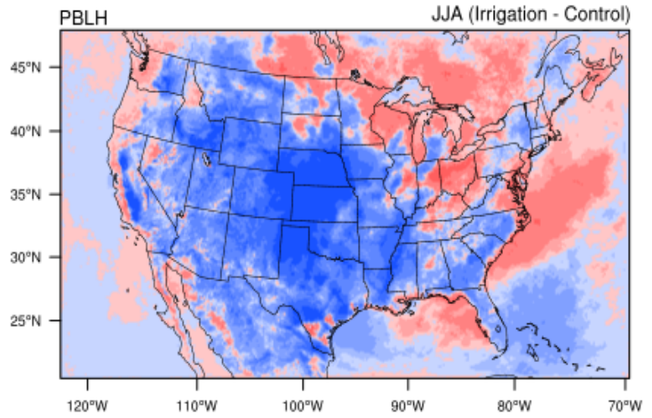




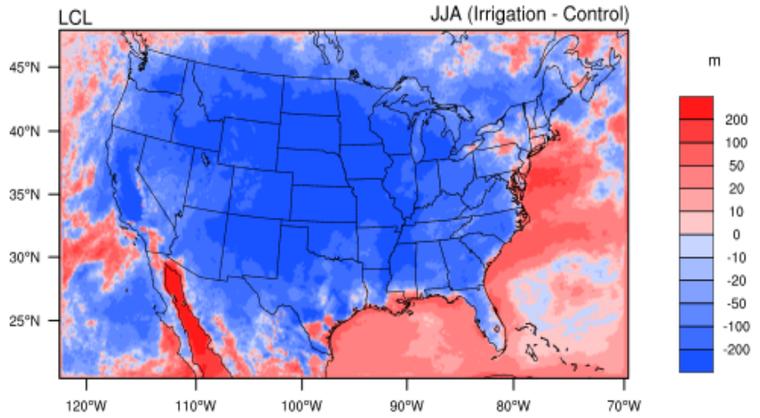
SM

Irrigation-induced Atmospheric Structure Change

PBLH



LCL



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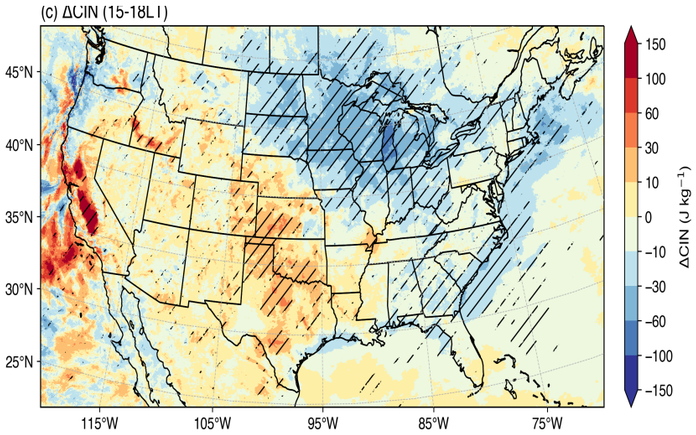
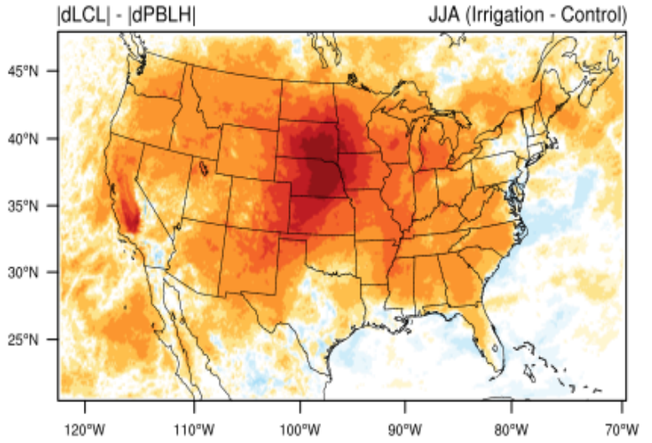
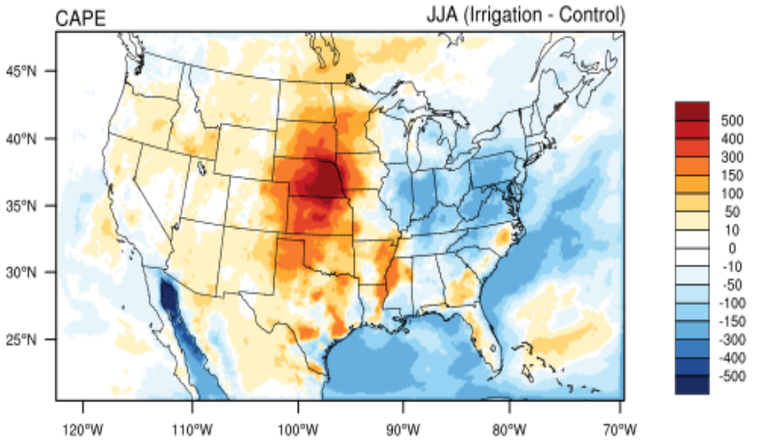


|dLCL|- |dPBL|



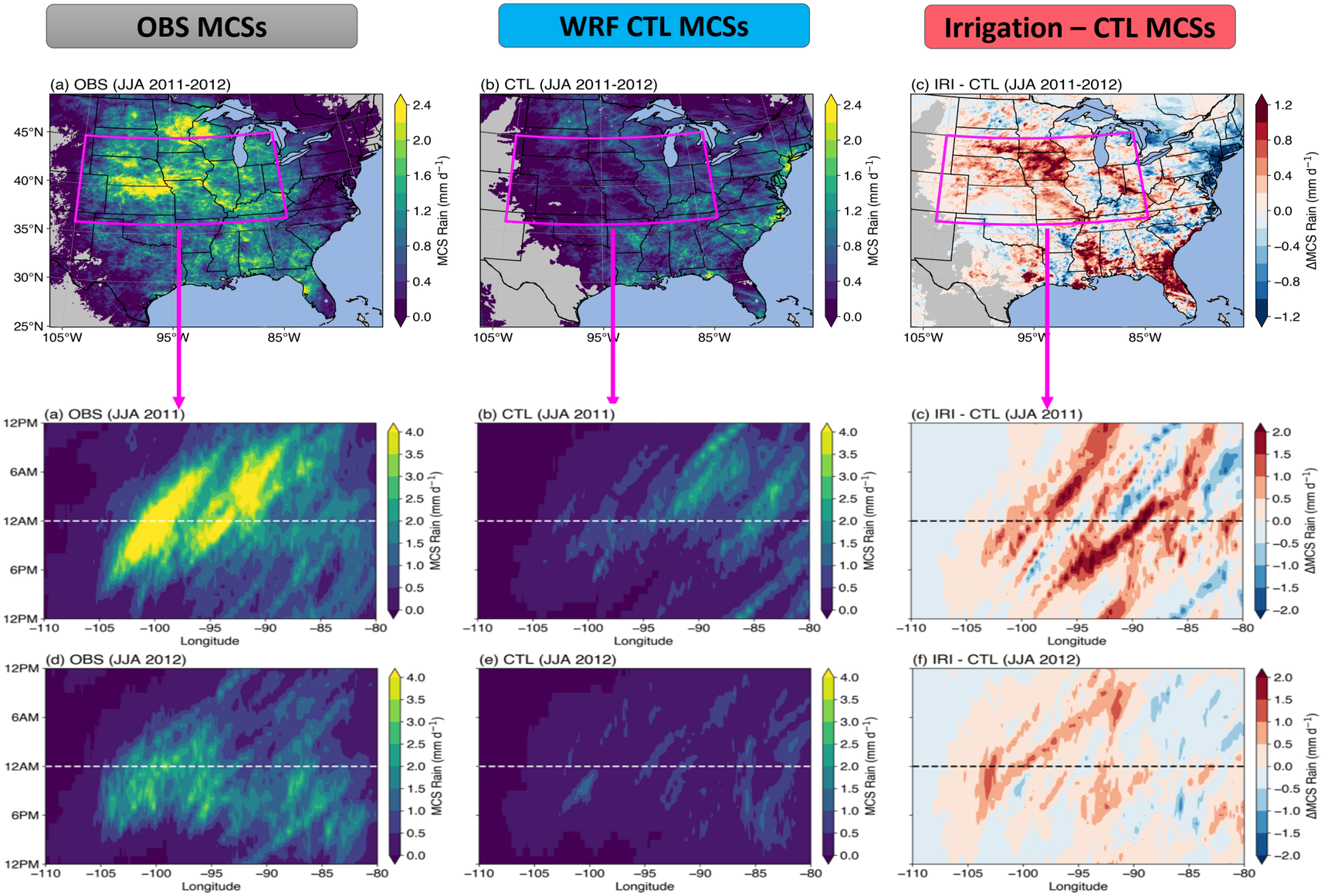
CAPE



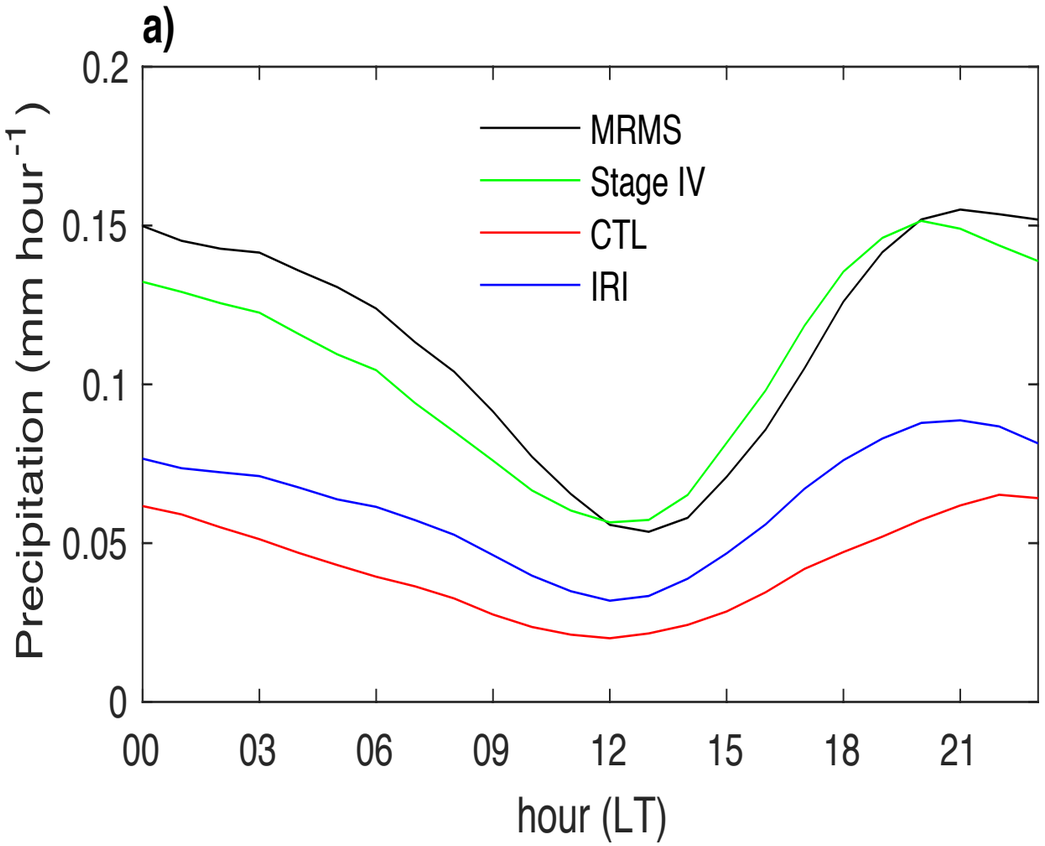
Irrigation-induced Changes in MCS Precipitation and Diurnal Cycle

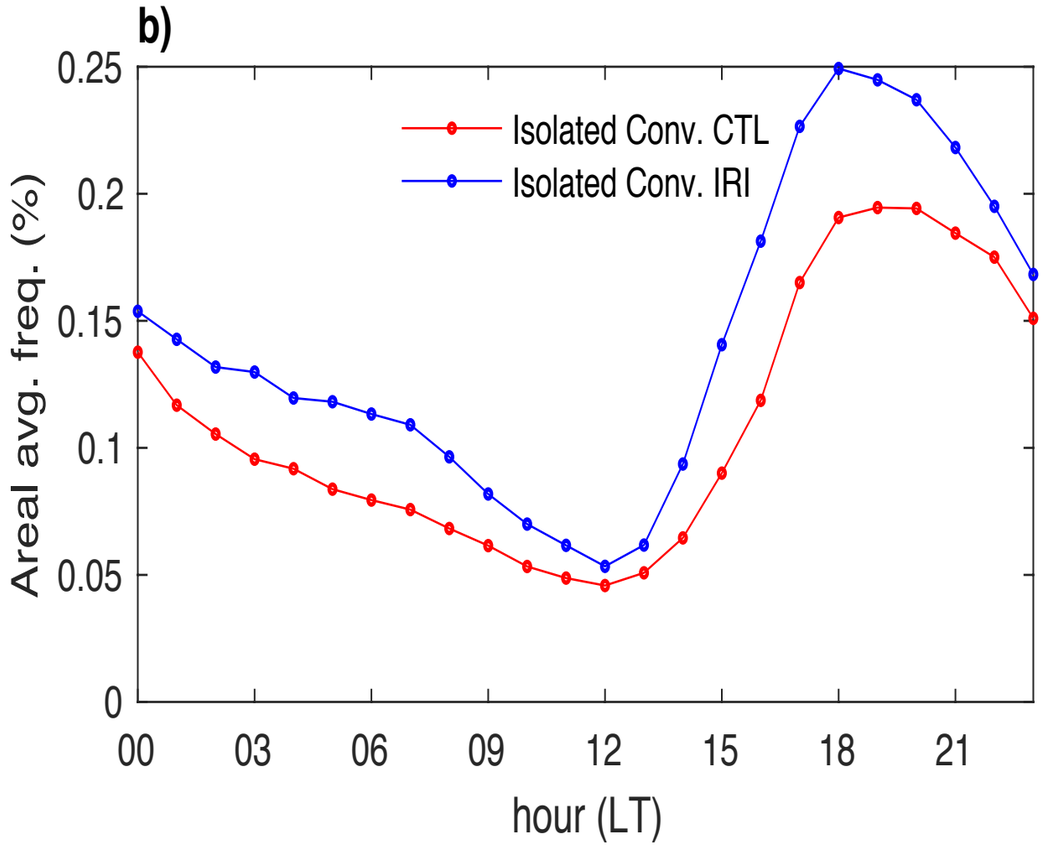
*MCSs are tracked using FLEXTRKR algorithm (Feng et al. 2018 *JAMES*): OLR+3D Radar Reflectivity

- Irrigation increases summer time MCS precipitation downwind of irrigated areas.
- Precipitation mainly increased during night time.



Total Precipitation Diurnal Cycle





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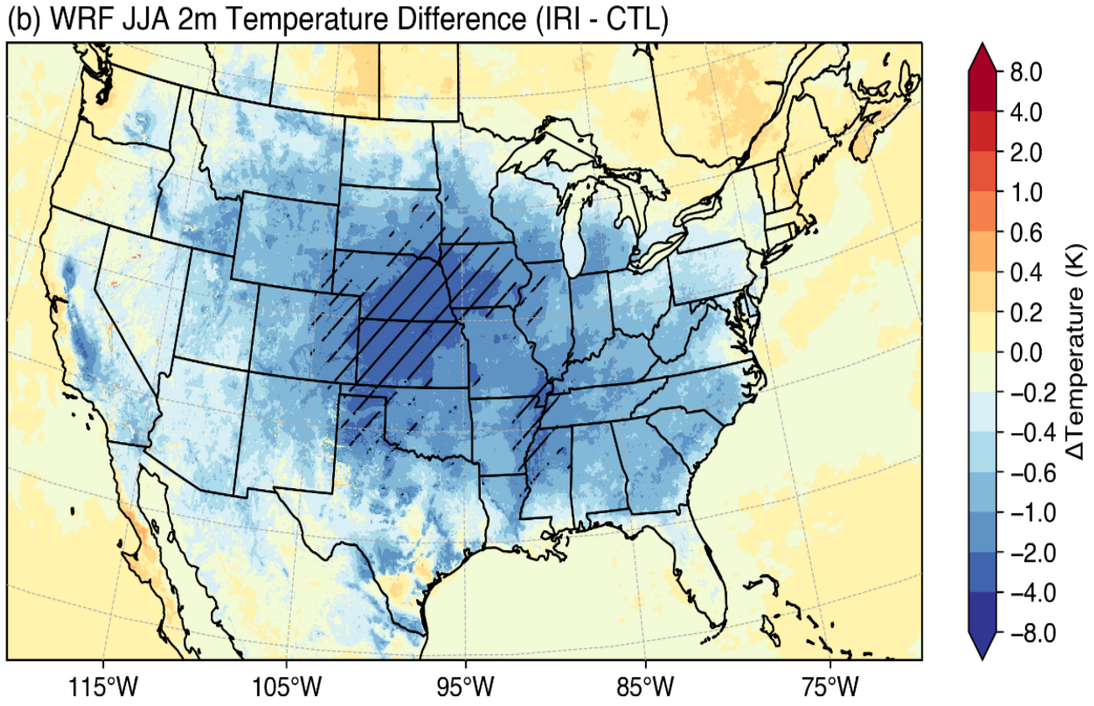
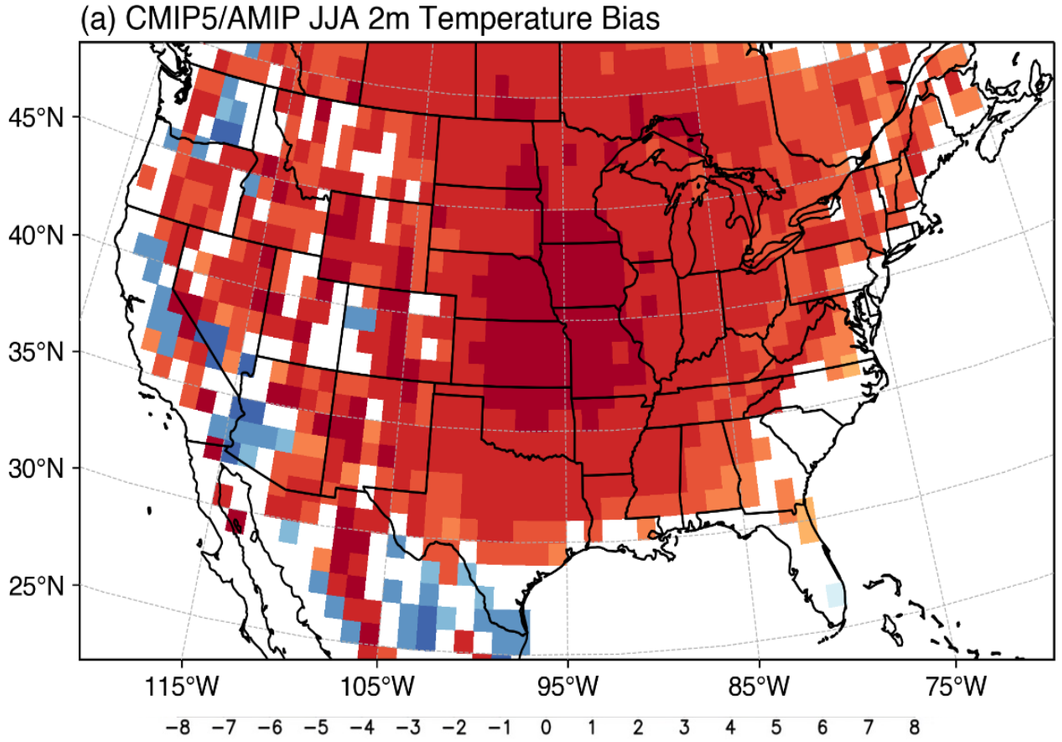
Irrigation Cooling Surface Air



Global climate model warm bias



Summary

- By using convection-permitting climate simulations over the contiguous U.S. coupled with an operational-like irrigation scheme, we show that irrigation increases surface evapotranspiration, decreases surface temperature by increasing evaporative fraction.
- By increasing mesoscale convective systems frequency, irrigation reduces model dry bias in summer and improves the simulated precipitation diurnal cycle over the Great Plains.
- The increased precipitation alleviates the warm bias, likely by damping the positive feedback between soil moisture and temperature.